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PREFACE

Every second year the Faculty of Mechanical Engineering of Szent István University together with the Committee of Agricultural and Biosystems Engineering of the Hungarian Academy of Sciences organise the International Conference on Engineering, Agriculture, Waste management, and Green Industry Innovation called "Synergy and Technical Development" at Gödöllő, the central place of the Hungarian agricultural scientific activity.

Focusing on technical and technological development, the conference discusses synergic trends between agriculture and industry, renewable energy production, education, fundamental and applied research. According to the main objective, the conference brings together experts from different geographic regions with similar scientific interdisciplinary interest, research activities and shares ideas and developments in the various fields of biosystems engineering.

During the sessions on the event that was organized during October 13-19, 2013 researchers, scientists, engineers, experts of institutions engaged in agricultural engineering development, gave summarizing presentations of their works. Overview of the best papers covering wide range of the conference main theme is published in this issue of the Hungarian Agricultural Engineering that celebrates the 25th anniversary this year.

All the papers have been selected by the editorial board and reviewed by prominent experts. We do hope that this unique publication can give good coverage of the conference's work and can inspire many of the Readers to take part on the next Synergy conference in 2015.

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THE AGRICULTIRAL CHARACTERISTICS EFFECTING THE INNOVATIVE PRODUCTION

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Abstract

It is an old truth and I also have written it down several times: agriculture is a never-ending struggle; a fight between people and the forces of nature. Farming is a success if men can win against the natural resources or can make them serve humans in long terms. To achieve this, men must know the characteristics - originated from natural conditions - that make the difference between this branch of national economy and the others.

When we plan the innovative projects we need to see clearly the characteristics of agriculture that must be taken into account for the success. Several experiences justify that if we want to persuade industrial analogies onto the agriculture, the hoped advantages may get injured due to the agricultural characteristics. There are such classic factors which dramatically influence the success and result of the agricultural developments. In this paper I give an overview on these but not trying to mention each one of them.

Keywords

agricultural innovation, key agricultural factors of innovation, innovative agricultural production, agricultural technical development

Introduction

It is evident that agriculture, in essence, is an industry characterized by strong regional „uniqueness," which is influenced by the natural and social environments of the region. Its industrial characteristics derive from its essence, that is, production activities comprising combined factors. Namely, the production activities are restricted by the natural conditions of each region (meteorological and geographical, as well as water conditions, etc.), which, along with the quality and quantity of natural resources (land, water sources, flora, etc.) are quite unique to each region. In addition, such regional characteristics are further amplified by its producers, that is, the localities and the societies around them. (Kawamura, 2012)

As we plan the innovative projects we need to see clearly the characteristics of agriculture that must be taken into account for the success. Several experiences justify that if we want to persuade industrial analogies onto the agriculture, the hoped advantages may get injured due to the agricultural characteristics. There are such classic factors which dramatically influence the success and result of the agricultural developments. In the followings I give an overview on these but not trying to mention each one of them. I will deal with:

- the natural conditions,
- some production's factors,
- the main elements of agricultural innovation flow and
- the basic elements of the technical development in the agricultural innovation.

Method

Based on my knowledge and former experiences I systemised the main characteristics which are affecting the success of innovation in the agricultural sector. I have produced some simplified models on agricultural innovation flow and the technical development. The results of these were completed with information from personnel connection with farmers.

Results and discussion

1. Natural conditions are **objective**; their effects cannot be changed to favourable ones for us by technical-technological developments, or just to a limited extent.

Natural conditions, including climate, soil conditions and natural geography influence primarily what farming can be carried out on a given field. In this sense, these factors have fundamental influence on the value of a given field (or territory). Therefore, the **basic element** of organizing farming and planning the developments in agriculture is the precise enumeration of natural conditions.

Among natural conditions the followings are the **determining**:

a/ climate, weather conditions,
b/ soil conditions,
c/ field conditions and
d/ water conditions.

ad a/. Climate conditions can be observed in the changes of weather. Weather has „two faces" from agricultural aspects: it carries the opportunities and conditions at the same time. It is not surprising why there are several sayings for the relationship of weather and agriculture.

From the *measurable effects* of weather the followings can be underlined:

- temperature (in the different seasons and year by year);
- the quantity and the distribution of the annual precipitation in the seasons;
- heat units;
- relative humidity of air;
- the intensity, frequency and direction of winds;
- the appearance of hail and fog.

The **effects of the factors listed above** can be traceable on:

- the crops,
- the quality and quantity of products,
- the fluctuation in the quality and quantity of production,
- the directions of animal breeding,
- the organization of production and
- the profitability of farming.

Since the weather is objective, it is important to know well the local weather conditions and to pay continuous attention to the data and information of forecast services. It is useful though to record our own experience and findings, since weather can „repeat itself" any times".

Reliable weather forecast has enormous importance in farming, since an unfavourable shift may baffle our original thoughts.

ad b/. Concerning the areas distribution of crops **soil** is one of the most determining factors. The „goodness" of soils primarily depends on its composition, nutrition-content and the characteristics of the „soil-life". To evaluate the soils we can rely on the findings of several mechanical, physical and chemical etc. investigations.

Linking the development level of production sources and the natural features of soils we can talk about the economic productiveness of the soil which is presented in the real volume of yield.

The productiveness of soil – like the capacity of other production appliances – is potential, i.e. it is just a possibility. Though the utilization of this possibility depends on several factors.

ad c/. Field conditions refer to the natural location of the soil; they show the location over sea-level and the quality of soil surface (flat, aslope, mountainous).

The soils' surface influences the way of cultivation, the applicable instruments and their performance. Due to our conditions crop production is dominant on the flat and aslope areas, while on the mountainous areas the role of pasture-based animal breeding is important.

The very surroundings can influence either favourably or unfavourably the value of that given field: the protecting chains of mountains, forests, larger rivers and lakes usually represent advantages for the given agricultural field.

ad d/. Water conditions refer to the water-absorption ability. This depends on the proximity of water flows, their runoff, the height of ground water etc.

These factors have influence on crop production, but at the same time the may have significant impact on e.g. the creation of animal breeding farms, since we all know that these have high demand of water.

From the facts mentioned above we can see that who wants to live on farming, it is good to know that **nature is the governing lord**, and he needs to count with the effects of natural factors.

Due to natural factors the followings can be considered „agricultural characteristics":

- Because of its dependence on nature, farming cannot be isolated from natural endowments and conditions.
- From the main activities of agriculture (crop production, animal breeding and horticulture) it is characteristic to mainly the crop production that the worker does its job in the open air, at the mercy of weather. (This exposure must be taken into account even if the modern appliances reduce it – let us think of e.g. the comfortable tractor box.) Weather sometimes tests the resistance and the tolerance ability of the farmer.
- In agriculture we work with live materials, live organisms, thus the works are limited to time. It means that every action has to be done in its own biological-agro-technical optimal period. It is highly recommended to take these periods, because if we do not do it, the chance for a successful farming reduces. Let us not forget that live materials behave similarly to humans. If he is hungry, he asks for meal, if he is thirsty, he asks for drink. If he is cold, he puts on warmer clothes, if he is hot, he takes off some clothes etc. One of the basic elements of successful farming: to understand the major features of life-cycles of live materials, organisms, and with human activity to facilitate their favourable improvement.
- Most of the agricultural works are territorially spreaded, and they often need the change of place. The harmonization of works on different fields and the necessary instruments and workforce is a significant organizational task. Special tasks are to meet the social needs of workers and – if it is necessary – to organize the transport of workers between the workplace and home. Big problem can be – and it is not indifferent from logistics point of view – the condition and usability of agricultural roads.
- While doing agricultural work there are peak- or campaign periods, when the working day is longer than usual. There are also other periods (mostly from autumn to spring) when there is less work. The rhythm of work is also influenced by the weather. It is very embarrassing when unfavourable weather or event (rain) interrupts the work whose time-demand is very limited (e.g. harvest).
- Special problem is the quality control of the agricultural work already carried out. It is often the case that after the end of an operation the quality of the work cannot be controlled or just in an unpunctual way. E.g. in the case of sowing or plant protection works the mistakes are uncovered only later, due to which it cannot be corrected.
- The differences between the major branches are significant. As for crop production and horticulture, the territorial demand, the dependence on weather conditions, and the periodical campaign-terms are determining. In the case of animal breeding repeated, daily routine is dominant, so in this field there are no Sundays or holidays.

Production factors

The agricultural production is going among the above mentioned conditions. To illustrate this here are some interesting data given by Pepó (2004) based on Landonin's article (1999) about the role of cultivation (or production) factors in wheat cultivation. (Table 1.)

Table 1. The role of the cultivation factors in the wheat cultivation

Extensive[1] technology	Cultivation factor	Intensive[2] technology
20 %	Year	15 %
40 %	Soil	10 %
5 %	Type	20 %
20 %	Cultivation	10 %
10 %	Fertilization	30 %
5 %	Plant protection	15 %
100 %	**Total**	**100 %**

Source: Pepó, 2004

(1: Farming of large areas, usually with low production for each unit of land farmed, usually without using chemicals. (Source: Longman Business English Dictionary) 2: An agricultural production system characterized by a low fallow ratio and the high use of inputs such as capital, labour, or heavy use of pesticides and chemical fertilizers relative to land area. (Source: BBC School fact sheet on intensive farming))

According to data in Table 1. it is conspicuous that on the lower level of technological development (typically in case of extensive technologies) the total ratio of soil, type and cultivation is 65% while in case of intensive technologies (where the technological development is of a higher level) this ratio is much lower, totally it is 40%.

It is conspicuous that the importance („role") of soil is 30% less in intensive case while the effect of type is 15% bigger than in case of extensive technologies.

In respect of the soil-plant relation the role of fertilization could also be important since in case of intensive technologies this factors weights the most, 30%. Knowing this, there is a risk that the use of chemicals in chemical fertilizers can grow to unlimited volumes. 'Fortunately' the economical considerations (above all the price of chemical fertilizers) hold rational farmers down. However there are some reasonable options that could reduce the use chemicals considering complexity.

Győrffy's remonstrance regarding this topic still seems to be actual. According to him in order to reduce the use of chemicals, the opportunities given by the force crop should be taken into consideration. Beside this, the areas of force crop should be ecologically optimized, plants collecting nitrogen should be grown in a bigger proportion and the use of the biomass should be more rational in order to improve the fertility of soil. (Győrffy, 1991.)

Pepó (2004) announced some data regarding the factors effecting the quality of wheat. According to him to reach the wished quality the weight of type should be 27% while that of soil should be 10%. (For completeness here are all the data: agronomy 41% direct factors – fertilization, plant protection 25%, indirect factors: force crop, seeding, harvest 16%. Ecological factors: 32% - weather: 22%, soil and other factors: 10%, type: 27%. Total 100%)

Since the agricultural characteristics cannot be separated from space and time, the list mentioned above can be expanded with several other aspects in the case of a specific enterprise. Therefore, during planning concrete development projects we need to take into consideration the things listed above space- and time-specifically.

3. Some elements of the agricultural production innovation

In the previous decades the Hungarian agriculture has proved several times that it is a favourable area for the innovation efforts.

We can say that innovation made the Hungarian agriculture known and recognized internationally. Between 1960 and 1980 the Hungarian agriculture significantly differed from the industrial sectors with its own values and system approach. This paradigm brought a dynamic development among countries within the same political systems.

Unfortunately the initial excellent results of the agricultural paradigm striving for priority were accompanied by the deteriorating economical conditions and expenditures exceeding the local optimum, then the Hungarian economy got into crisis blocking the development of the agriculture. However this does not decrease the value of the Hungarian agricultural innovation – leastwise in the mentioned period.

By the end of the 1980's the Hungarian agriculture's inability to develop was culminated by the problems in connection with the system change. These problems affected the system of innovation and its operation.

The cooperation between the parties interested in innovation is not that strong. The previous mechanisms are no longer, the new ones are not yet functioning. It is disconcerting that the imaginary actors of the agricultural innovation are busy with themselves and their money worries for a long time, and therefore has no energy to coordinate with the innovation partners.

It is sad that most of the times the inclination for coordination is missing as well. In my opinion this is a huge problem because the previously successful period of the Hungarian agriculture was due to the activities of the R+D sector as well as the work of the distributors and processing organizations.

I prepared and use a general model of agricultural innovation (Figure 1.). This model clearly demonstrates related and dependent works to be done. It shows that the innovation part-works can be systematized into two integrating umbrellas. These are marketing and knowledge. Marketing is important as the success of innovation is decided in the market. The whole innovation process should be guided by the endeavour for market success. Knowledge alloys earlier experience and recent information in the entire process.

The functional model is a proper instrument for:

- The review of the systematisation of the processes of agricultural innovation
- The introduction of the relation between the part processes
- The analysis of the status of the agricultural innovation
- Defining what to do in the area of development

We can say that the Hungarian agriculture was successful till the innovators could do their activities in a harmonized way as represented by the model. The situation has changed significantly by now. In theory the old practice would be successful, but the SME's do not have the necessary conditions to be able to follow the model. The other problem is that the conditions of a harmonized cooperation between the actors has changed.

The agricultural innovation, the agricultural research and the technical development should be set on new basis in order to improve the competency of the agriculture. It has to be decided which sector should enjoy priority in respect of the sector's competency. We are no longer able to develop every area since our current financial possibilities do not cover it.

4. Some elements of the complex technical development

The main source of the agricultural production development is the technological development. This system of activity is the aggregation of continuous, complex and consistent activities, that have an impact on the elements of the agricultural production (soil, labour and capital goods) causing quantity and quality changes. By this, the production reaches a higher level and in favourable cases it becomes more efficient. The technological development has a number of economical functions besides the modernization of production.

In order to help to understand the definition we have created the 'matrix model' of the agricultural technical development. The model in the matrix expresses the relationship between the basic elements of the agricultural production and the effective factors of technical development. (Figure 2.)

Based on the model an organization can specify its technical development tasks at a point where a given row meets a given column. The matrix model cannot be considered statically, it is easy to adjust it to the given external and internal circumstances and to the changes of these circumstances in two dimensions (time and space).

In connection with the agricultural technical development it is obvious that during the production development the ecological conditions (opportunities and givens) cannot be ignored. On one hand these can be the conditions of production development on the other hand these can restrict it as well. The agricultural technical development has to ensure that it makes the best of the ecological opportunities and that it avoids the disadvantageous effects. This question is complicated by the fact that part of the ecological factors (above all the climatic circumstances) can hardly or not at all be influenced by humans. That is why it is important to focus on those factors that can be positively influenced by human intervention.

From this list we can highlight the soil which we consider the essential element of production. It is known that Hungary's land features and the shape of their surfaces are different in respect of the agricultural production and its automatisation. The physical-chemical composition of land, its structure and the way it can be cultivated can differ in landscapes plants regardless of administrative, plant or natural borders. The same differences can arise in respect of the surface of the land. If we consider these as objective givens we can see that the effective factors of the technological development are partially applicable considering the ecological givens and opportunities. Based on our experience the features of land and its surface influence the applicable output of machines, the speed, the width of the work area etc. We can also see that the composition of soil has an effect on how the machine should be used and how safe the machine is, how long it can be used and the deterioration period.

In connection with the effective factors of technological development it is necessary to analyze the role and importance of complexity. Some practical examples prove that if the harmonization of development factors fails the expected advantages and ambitions cannot be realized. During the technical development, the effective factors need to be harmonized

otherwise as a result of the 'minimum law' the final result of development will be limited by a factor from the lowest level. One of the most important task of the technological development embedded in the innovation process is to provide an integration function between the factors mentioned above. Within the frameworks of this we have to ensure that the effective factors are optimised and that there is harmony between the development factors in time and space.

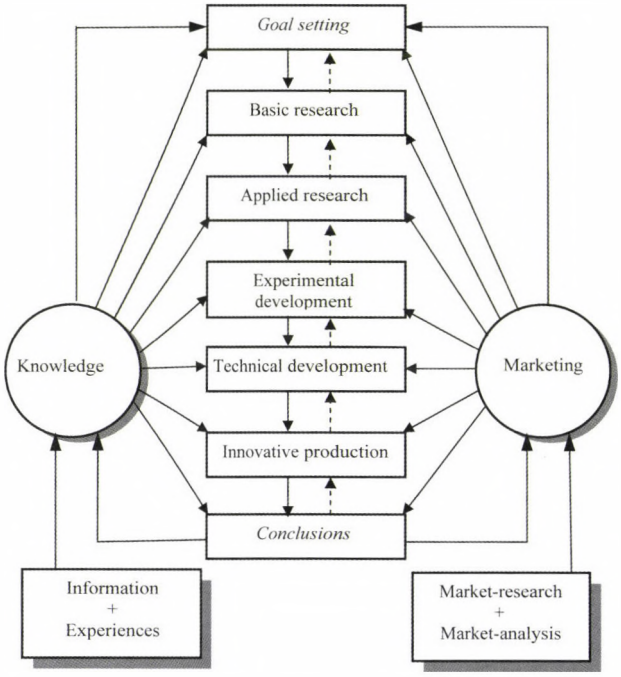

Figure 1. A general model of agricultural innovation
(Source: Husti, 2005)

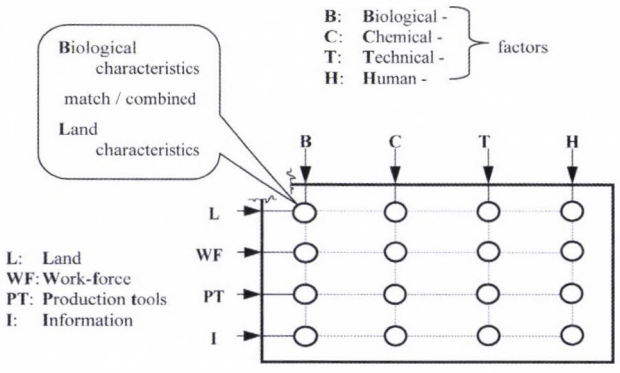

Figure 2. The simplified „combination-matrix-model" of the agricultural technical development
(Source: Husti, 2005)

The model about the substance of technical development (Figure 3.) shows that technical development serving agricultural production has got a particular bridging role between the production and the previous innovation phases by integrating several factors at the same time. It is important that the marked biological, chemical, human and ecological factors should be in harmony, because otherwise the balance breaks effective factor being in relative minimum as per the minimum-law.

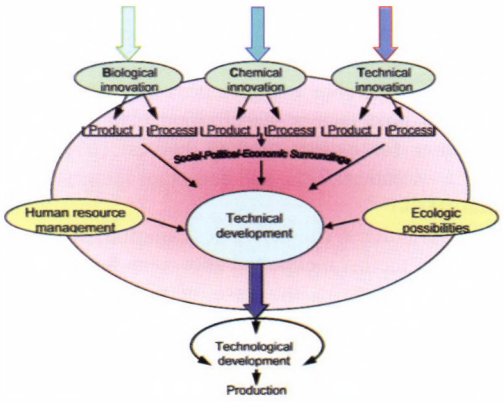

Figure 3. The substance of the agricultural technical development
(Source: Husti, 2005)

Conclusion

The engine of development is innovation even in the field of agriculture. If we want the innovation to be successful, we have to avoid forcing the industrial analogies in the agricultural relations. Namely there are a number of agricultural characteristics that need to be considered when dealing with an innovation related project. Out of these particularities, this paper analyzes the natural conditions, some elements of agricultural cultivation, the process model of agro-innovation and the main components of technical development as part of the agricultural innovation.

We can say that in case the above listed aspects get sufficient attention in relation to agricultural innovation, the probability for success will grow, that is to say that agro-innovation processes promote the renewal of agriculture's partial areas, products and technologies.

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EXAMINATION OF THE AGRICULTURAL MACHINE DISTRIBUTION IN HUNGARY

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Abstract

The Hungarian agricultural machine park went through the considerable modernization in last 13 years. With Hungary's European Union accession in the retail of the agricultural machine considerable market expansion and qualitative improvement can be experienced.

For the Hungarian market, a significant impact is the availability of grants for the purchase of machines, which intensifies the turnover. Year 2003 considered the first record, when the Hungarian farmers spent 456 millions of Euros to purchase machinery. In this last year - which preceded the accession to the European Union - the farmers were trying to seize the opportunity, in addition to its own funds and loans, to come to funds intended for government subsidies to its development plans. Repeated access to sources of grants, since 2007 has given new momentum to machinery turnover and created the possibility of mitigating the technical backwardness of Hungarian agriculture. Again, years 2007, 2008 and 2009 were outstanding with new record amounts of 402, 450 and 479 millions of Euros. The year 2010 was a catastrophic year for machinery dealer, but in last three years (2011-2013) there is a slightly increasing in the Hungarian agricultural machinery market. This rise in selling was success for dealers, because this realised mostly without state subventions. In 2013 the turnover of domestic agricultural machine market is above the last 13 year's average, which is a good promise for the traders.

Keywords

hungarian agricultural machine market, distribution of agricultural machines, value of sold machines

Introduction

The Hungarian agricultural machine park went through the considerable modernization in last years. During these periods, considerable market expansion and qualitative improvement can be experienced. Nevertheless, internal machinery park, its average age and its modernity still are staying behind the machinery parks of western European countries' in his totality. The technical-technological development was continuous in these Western European countries, the smallholders received a suitable support early already, that they utilized well, and that provides competitive advantage to them on more areas.

Results and discussion

Amount and value of the machinery purchased in Hungary

From the point of investment in agricultural machinery, after the year 2001-2003 the years 2007, 2008 and 2009, can be considered most advantageous (Fig. 1, Table 1). In the Hungarian agriculture, in those years, the total value of realized investments in machinery surpass the amount of 1293 millions of Euros, which was supported with a profit of production from previous years, as well as with market expectations in the first half of 2008-is still a year positive. Agricultural enterprises are intended to expand and modernize its machinery parks and were trying to use more funds from the approved amount of support. (Hajdú-Magó 2008)

After a good 2008 year, turnover has declined substantially in the early 2009's year. A number of external, unfavourable conditions also reduced the desire for investment, which was already otherwise have been undermined by the inflow end of support. State tender-Forint, weakened significantly, which led to a significant rise in prices and market prices of products were already in collapse, and global economic environment did not show an encouraging vision for the future.

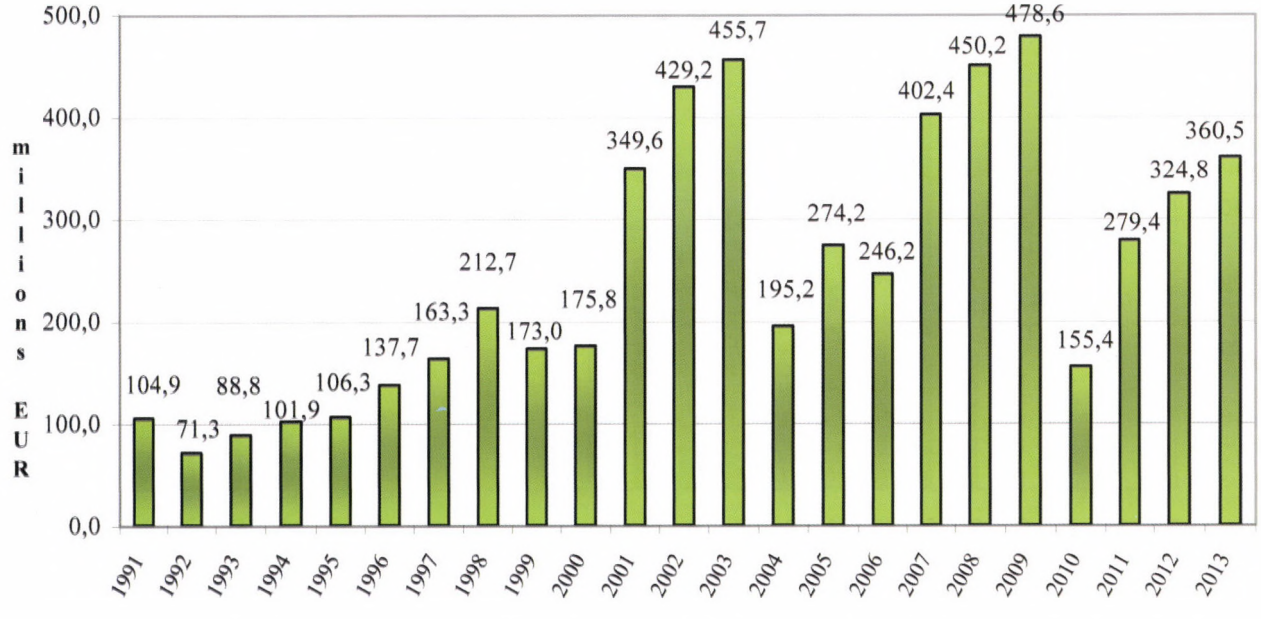

Figure 1. Investment in agricultural machines from year 1991 to year 2013 in Hungary

Farmers in the summer of year 2009 could again, after a year and a half, to apply for grant funds intended for purchase of machinery. The total amount of grants to fund amounted to about 107 million Euros. This amount and intensity of the grants at a rate of 25-35% induced trade of machinery of about 479 millions of Euros in year 2009.

The growth on the tractor and harvesting equipment markets was particularly high (Fig. 2.-3.).

Table 1. The number of a sold agricultural machines in Hungary (2007-2013 III quart) (Bojtárné et al 2013, Vágó 2013)

Machine	Year 2007 (pieces)	Year 2008 (pieces)	Year 2009 (pieces)	Year 2010 (pieces)	Year 2011 (pieces)	Year 2012 (pieces)	Year 2013 III quart (pieces)
Tractors	3244	3261	3045	990	1917	1995	1256
Wheat harvesters	442	412	503	69	176	239	217
Harvesting machinery adapters	650	744	773	185	316	427	372
Balers	387	484	396	192	303	286	308
Fodder harvesters	1421	1517	1215	833	805	777	1040
Self propelled loaders	290	434	425	139	265	222	241
Basic soil tillage machinery	4196	4108	4014	2060	3726	4090	2569
Seeders and planters	1101	1155	1028	354	664	867	789
Fertilizing machinery	1015	1006	828	504	726	918	668
Machinery for plants protection	1464	1518	1529	815	1077	1087	1215
Agricultural transport trailers	544	691	557	215	273	395	327

(New agricultural machinery trade only)

Economic recession in years 2009-2010 affects the agricultural sector too

The majority of Hungary's farms are small and familiar. There is, however, a growing tendency towards larger structures. The average farm size is currently about 9 hectares. Agricultural production is mainly concentrated on maize, followed by grain and sugar beet as well as rapeseed, sunflowers, meat and milk.

The income situation of the farms improved clearly last two years. Following a relatively poor harvest in 2010, agricultural production value increased by 25% in 2011. In addition, government subsidies increased by about 15%. Hungarian imports of agricultural machinery increased by 80-110% compared to 2010, reaching 280-325 million EUR. Remarkable that damage caused by winterkill and dry weather had a negative effect on the harvest income of farmers in 2012, but the Hungarian agricultural machinery market rises by 15 % in relation to 2011 (Wiesendorfer et al 2012). There was an 11 % increase in machinery investments in year 2013 too (Fig. 1).

There was no government aid worth mentioning for investments in agricultural machinery last years, only investments in a few product fields such as gardening and landscaping equipment are likely to be supported. (Magó-Oljača 2012)

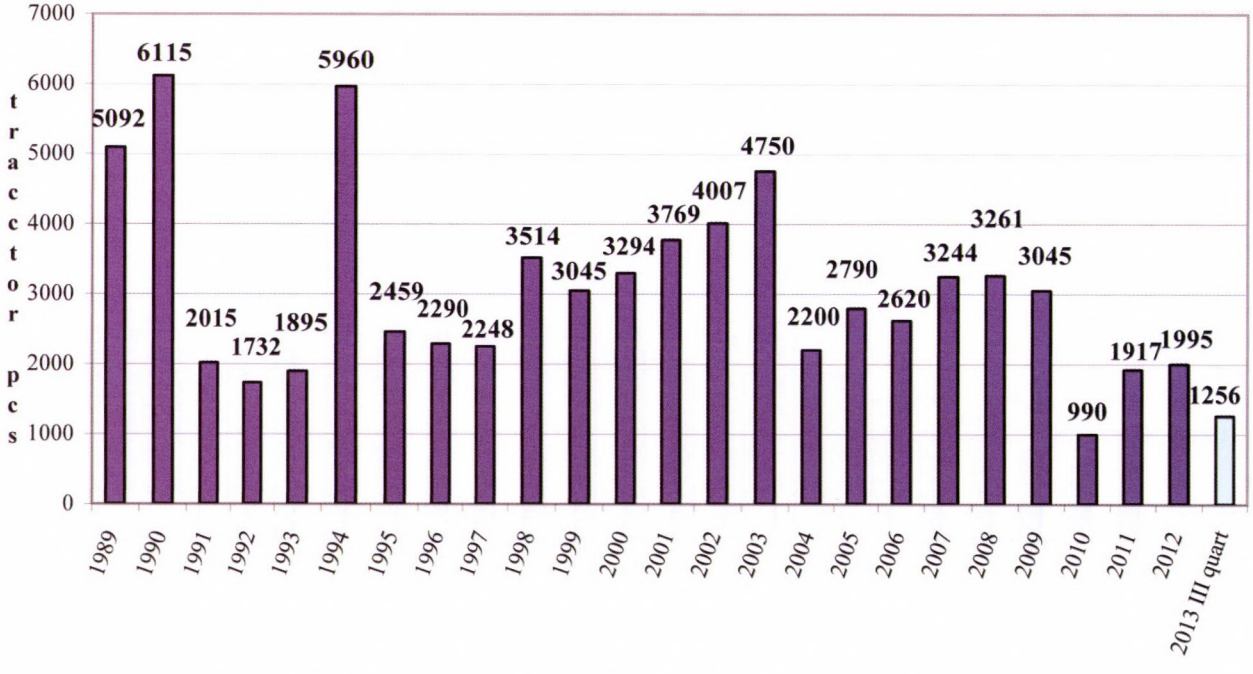

Figure 2. Number of tractors sold in Hungary from year 1989 to year 2013 III quart.

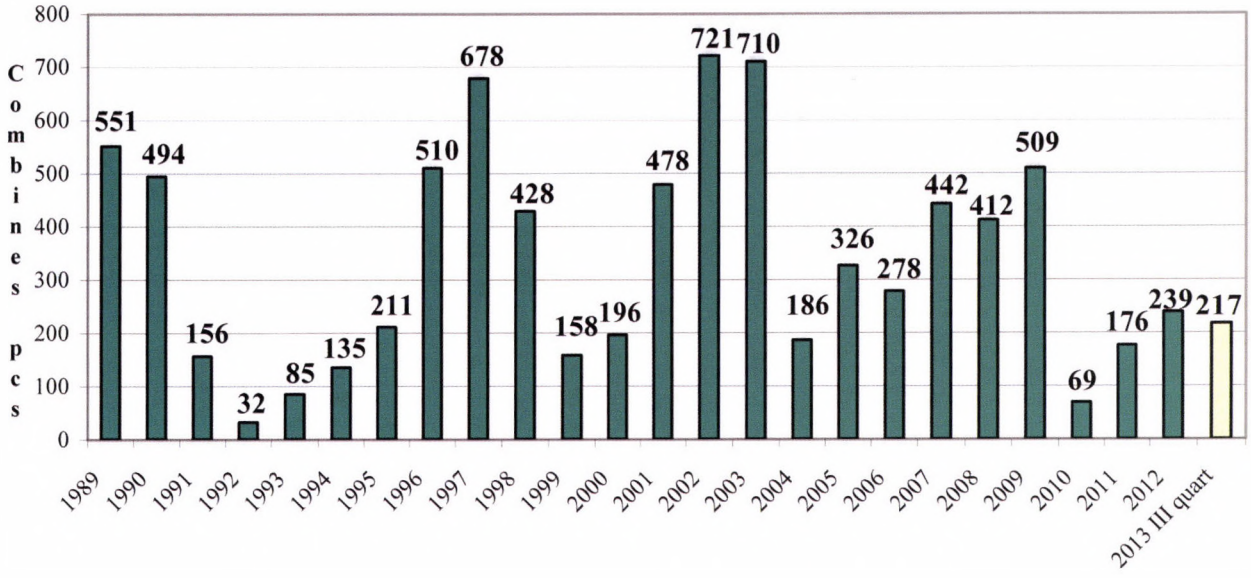

Figure 3. Number of harvesters sold in Hungary from year 1989 to year 2013 III quart.

Hungarian traders, market actors

Among the actors in the Hungarian market traders of machinery amounted to more than one thousand of them, in terms of turnover, only one tenth can be considered significant. Their maximum annual turnover amounts to approximately 535 millions of Euros, of which turnover of machinery and equipment comprises nearly 465 millions of Euros and sales of spare parts reach 65 – 75 millions. Circle of dealers is unusually heterogeneous, and the following are present: the individual contractors, vendors, resellers own production company - organized in trade network – as well as dominant agribusiness actors - while operating as a department store – relying on a larger number of polygonal sales bases. High degree of concentration is characteristic for the Hungarian machinery market. Nearly 90% of total turnover – which is implemented with the ultimate agricultural users – conducted around 20 companies. Most important sellers of agricultural machinery: AXIAL Kft, KITE Zrt, and Invest Kft. (and former the IKR Zrt.) are realizing almost two thirds of the total machinery turnover in Hungary (Magó 2011a). Domestic importers of agricultural machinery are representing the world's leading manufacturers of agricultural machinery - American and European global companies - and their machines. The three major competitive firms are specialized in trade between the different brands and for some brands have the authorization of exclusivity. (Hajdú 2009)

The annual number of buyers of agricultural machinery from the circle of agricultural entrepreneurs – who make the purchasing side of the market – shows a decreasing tendency. The established range of customers comes from the ranks of trade actors with higher incomes. The growing competitiveness of agricultural producers directed toward cost effectiveness and supply of highly productive machines. (Magó 2011b)

In the past thirteen years, agricultural producers were buying new machinery (mainly tractors) in the amount of nearly 4 billion of Euros. Half of the total agricultural investments are focused to the purchase of tractors. 3700 types and standard variants of tractors, that come from sixty manufacturers, are present in the market. Fifty percent comes from the expensive, technologically highly developed Western European countries and from the United States and Canada. Cheaper tractors, Eastern European and Turkish, account for about 34 percent, while the tractors of Far Eastern producers, also with relatively lower prices, account for about 16 percent. This proportion was other in the ninety fold years. The majority of the tractors arrived from the Eastern Countries (Hajdú-Magó 2003). That is why there are a big number of tractors but low invested sum in the diagrams. (Fig. 2 vs. Fig. 1)

Offer of Hungarian machinery market

Realized annual turnover of the Hungarian market of agricultural machinery, during the last 13 years, was around 340 millions of Euros, representing about 1.2% of European turnover (Fig. 1). Nevertheless, Hungarian market is not negligible for the machine manufacturers. Actually, on the Hungarian market are present all the major manufacturers and traders of agricultural machinery and road. The market is open and characterized by very tough competitiveness. (Magó 2013)

Hungary offer of agricultural machinery in recent years steadily expanded. In 2002 machinery selection could have been made from 54 thousands of different machines, while in last years more than 130 thousand types and standard variants, as registered in the dealers catalogs. The total share offer „Eastern Route" (Eastern-Europe and the Far-East) accounted for only 7%, but in some industries e.g. tractors share in Korean, Chinese, Indian and Turkish products can be considered significant. Besides those, in Hungary offer are permanently present and traditional (Belarus, Russian, Polish, Romanian, etc.) importers. Offer of domestic manufacturers of agricultural machinery is characterized by a decreasing tendency. Currently, the share of Hungarian machine is 13.3%, while in some product groups (e.g. machinery for primary soil tillage) was significantly higher than the average. Agricultural machinery industry in Hungary specialized in certain areas. There is a significant innovation activity in the area of mechanization of vegetable machine technology in the production of multifunctional transport vehicles, as well as in the segment of soil tillage machinery production – more than 30% stake in the Hungarian market belong to domestic producers. Altogether, approximately 87% of the agricultural machinery used in Hungary is imported. (Bojtárné et al 2009)

According to previously mentioned, the Hungarian market of agricultural machinery is characterized by a wide variety of machines. Hungarian machines offer is greater even than that of many developed European countries. (Magó 2006) Considering that in these markets products of Hungarian factories are not represented, the eastern offer is significantly narrowed (due to higher demands of the market actors.

Conclusions

For the Hungarian market, a significant impact is the availability of grants for the purchase of machines, which intensifies the turnover: if the grants are available, machinery turnover is increasing, and in case of lack of subsidies decline in purchases becomes evident, as it was in the year 2004 and 2010. Machinery Dealers notice an increase in demand for used machines in the absence of grants for the purchase of new machinery. The Hungarian market extreme oscillations are evident.

First in the years between 2001 and 2003 was recorded dynamic growth of investments in machinery. Year 2003. considered the record, when the Hungarian farmers spent 456 millions of Euros to purchase machinery. In this last year - which preceded the accession to the European Union – the farmers were trying to seize the opportunity, in addition to its own funds and loans, to come to funds intended for government subsidies to its development plans. The role of direct subsidies – finishing with membership in the European Union – could not take much less resources allocated by tenders.

In 2004 was recorded significant, more than 50% decrease in the procurement of agricultural mechanization. By re-activating the grants in 2005, the volume of investments started to increase again. In the year 2005, grant applications did not take place, which reduced the number of machinery investments. Reduction of investments was significantly related to decrement of funds of the central support and the expectations of new grants for 2007-2013.

Repeated access to sources of grants, since 2007 has given new momentum to machinery turnover and created the possibility of mitigating the technical backwardness of Hungarian agriculture. Again, years 2007, 2008. and 2009. were outstanding with new record amounts of 402, 450 and 479 millions of Euros. As we mentioned before the 2010 was a catastrophic year for machinery dealer, but in last three years (2011-2013) there is a slightly increasing in the Hungarian agricultural machinery market. This growth in sales is realised mostly without state subventions. Finally, in 2013 the turnover of domestic agricultural machine market is above the last 13 year's average, which is a good promise for the traders.

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RENEWABLE ENERGY ASSISTED AIR CONDITIONING SYSTEM INSTRUMENTATION

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Abstract

Optimal control of heating and cooling of a big building with different heat sources e.g. conventional gas, electric power completed with renewable energy sources e.g. ground heat, air heat, wind and solar energy, waste heat and biomass energy is very difficult job. Last years a big, approx. 10.000 m^2 campus building was rebuilt and enlarged at our university. The old heating system was exchanged totally, and a new cooling system was built in. This new system got bivalent as the conventional system was completed with 10 pcs separate 100 m deep U-type-tube bore-hole ground heat exchanger altogether with 60 kW heat peak power heat pump, 280 kW electric power air-source air – water heat pump, and heat exchanger in the air handling system of a 350 seating capacity lecture-hall. Additionally, with educational purposes, a small wind generator on the roof belongs to the system, and in the future low power solar photovoltaic cells will be built. We are making a complex measuring system first of all for educational purposes, but the wide spread data collecting gives the possibility of improving and optimizing the control system and estimating an optimal energy storage unit. Examples of temperature change of some measuring points during a random chosen summer day are presented.

Keywords

renewable energy, bivalent system, measuring system

Introduction

The single-floor Museum of Agricultural Machinery is situated in the Campus of St. István University and belongs to the Faculty of Mechanical Engineering. It was built in 1968. In the beginning of the first decade of 2000's the need of renovation of the building arose. By a lucky chance the Faculty of Mechanical Engineering had the possibility not only for the renovation, but for extending the building with an additional floor, too. The renewed building's name is Integrated Engineering Information Technology Training Center (IEITTC). The project was finished in 2012. Now the IEITTC with 10.000 m^2 superficial area kept the original farm machinery museum function, and gave new locations for the education of mechanical engineering. The general plan of location can be seen on the Fig. 1.

Heating-cooling system

The old heating system was changed totally, and a new cooling system was built in. This new system got bivalent as the conventional gas heating system was completed with 10 pcs separate 100 m deep U-type-tube bore-hole ground heat exchanger altogether with 60 kW heat peak power, 80 kW electric power air-source air – water heat pump, and heat exchanger in the air handling system of a 350 seating capacity lecture-hall.

In the building there are three kinds of heating and two kinds if cooling system. Radiator heating is in corridors and in serving rooms. Fan-coil heating-cooling systems are in small laboratories and big lecture-halls. Radiators are not involved in cooling. Air handling system provides for proper and economical air handling in big lecture-halls and in small laboratories.

2 pcs 100 kW and 1 pc 80 kW condensation gas boilers, actuating valves, safety apparatus, air-bleed valves, expansion tanks, manual controlled valves, closing valves, circulation pumps, heat pump and control system are located in boiler house. Gas boilers supplied by the normal public gas service. 10 pcs and 100 deep each borehole ground sounds locate under the east wing of the building. They provide heating or cooling of the heat pump. The sounds together with heat pump system are filled with glycol to avoid freezing. The secondary side of the heat pump and the other parts of the heating/cooling system are filled with water. Heat production units provide 42°C water and consuming circuits take out the desired water income with inverter driven circulation pumps.

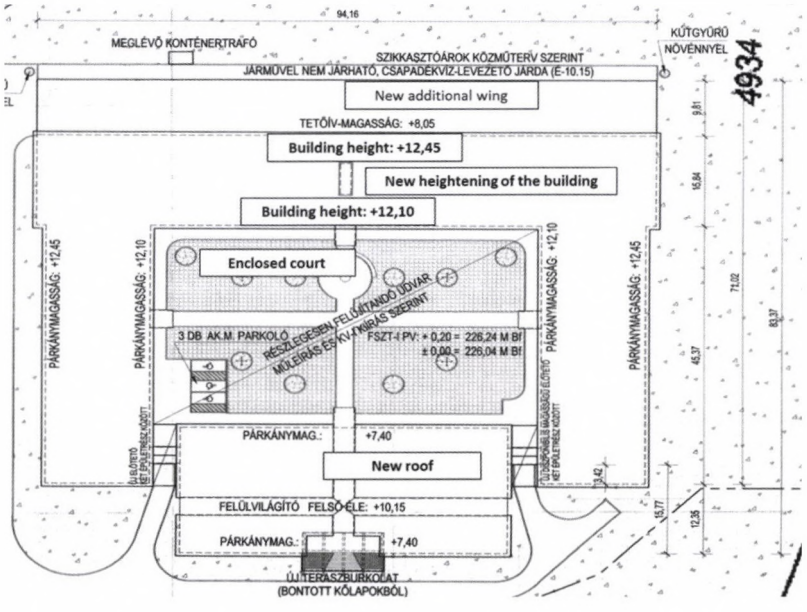

Figure 1. General plan of location

Cooling is provided by heat pump and in case of cooling peak load an air-water heat pump can help, which is located on the roof. Both of them can provide 7/12°C cooling water and they work together with puffer tank located in boiler house. The consuming circuits take out the required cooling liquid with inverter driven circulation pumps for fan-coils and air handling system. Fan-coils in rooms can be controlled by thermostats.

The whole system is controlled by Elcon DIGINET programmable building equipment controller. Main operating modes are heating and cooling. The controller set the proper actuator valves automatically according to operating mode. The reference signal of the controller is function of outer air in a given temperature range.

Measuring system

Unfortunately because of the shortage of the project budget, only the operating sensors were built in the whole system. Just after finishing the project, the St. István University won a research project TÁMOP-4.2.1.B-11/2/KMR-2011-0003 with title: "Increase of the level of the education and research" together with subproject in the Faculty of Mechanical Engineering: „Energy production based on renewable energy sources". As the rebuilt IEITTC in its heating-cooling system has renewable energy sources, and the new project can sponsor the instrumentation we decided to install a new, independent measuring system. Unfortunately this task is very difficult, because a subsequent instrumentation in case of operating building equipment sometimes almost impossible. Based on our experiments [1] and our existing instruments and sensors we decided to instrument the building and complete it with training solar panel, training low power wind turbine and training photovoltaic cell, too. This instrumentation gives us a good possibility to demonstrate for our students a complex, conventional and renewable energy flow system in use. We can research the improve the dynamical behavior of the controlled system, optimal control of the system according to settling times, summarized CO_2 emission, costs, etc…

The simplified block diagram of the measuring system can be seen on the Fig. 2. We want to measure the main parameters: gas flow, electric powers of heat pumps, heat flow in main units (fan-coil units, radiator units, heat puffer, …) the ambient air temperature and humidity, the wind speed, small (training) solar panel power, small (training) wind turbine power and small (training) photovoltaic cell power, on-off states of circulation pumps, etc…

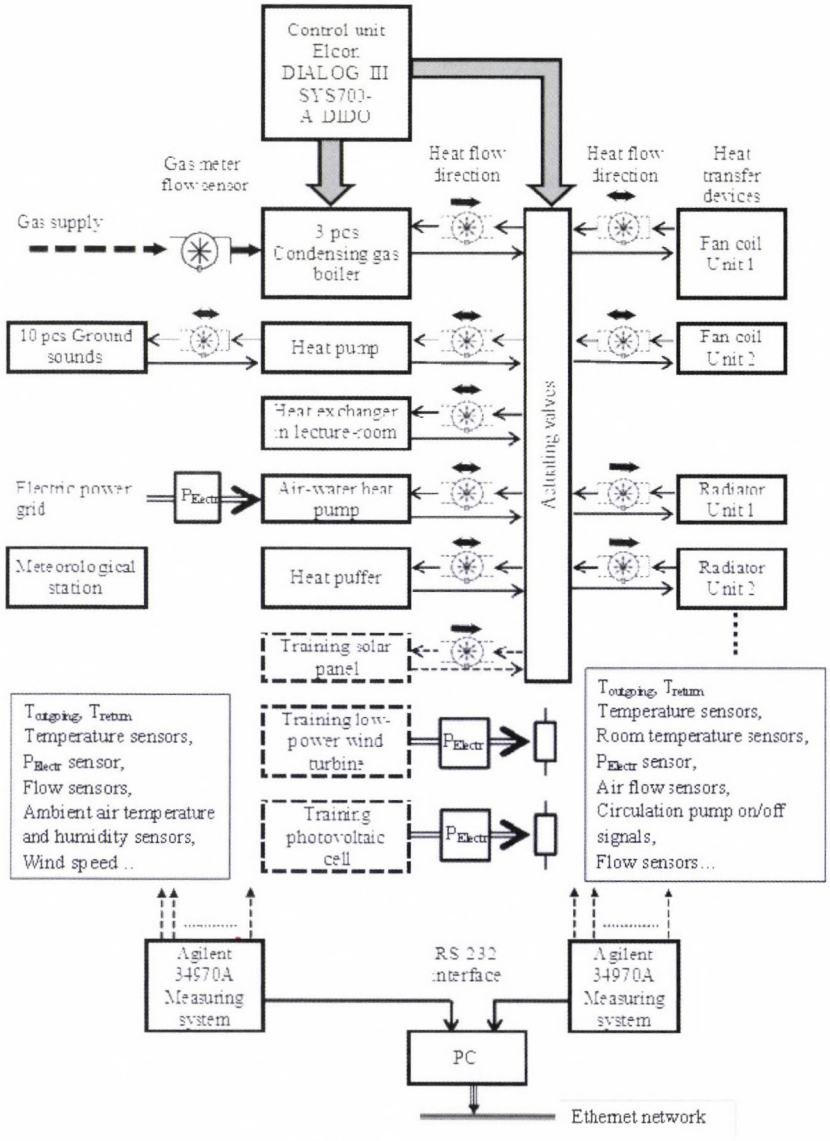

Figure 2. Simplified block diagram of the system

We measure the temperature mainly with Pt100 RTDs, in some cases with thermocouples. Unfortunately we can clamp the sensors only onto the surface of the pipe below the heat isolation. The most difficult task is the measuring of the flow of water or glycol. There is no possibility to plumb into the pipes, because the whole system is ready. There are inverter driven circulating pumps in water circuits, and we can suppose, that the flow is approximately constant during operation. We can measure the flow with snap-on ultrasonic flow sensor, this measurements can be repeated regularly for checking purposes, and after that, we can record only the on-off state of the circulating pump, instead of application of built in flow sensor.

We use two pieces Agilent 34970A measuring system together with a PC. The whole measuring process can be followed through Ethernet network.

Results

We could install only the measuring cables for 40 channels from the boiler house to the measuring room. This post-install process was very difficult because of architectural reasons and building-up the fire barriers.

We want to show 3 examples with short explanations.

Example 1. On the Fig. 3 heat transfer of fan-coils are optimal with approx. 5°C (ΔF) temperature difference, but at the same time the heat transfer of the soil sounds are unfavorable, because the temperature difference is only approx. 2°C (ΔG). This kind of overrunning can get poor in case of no time for regeneration.

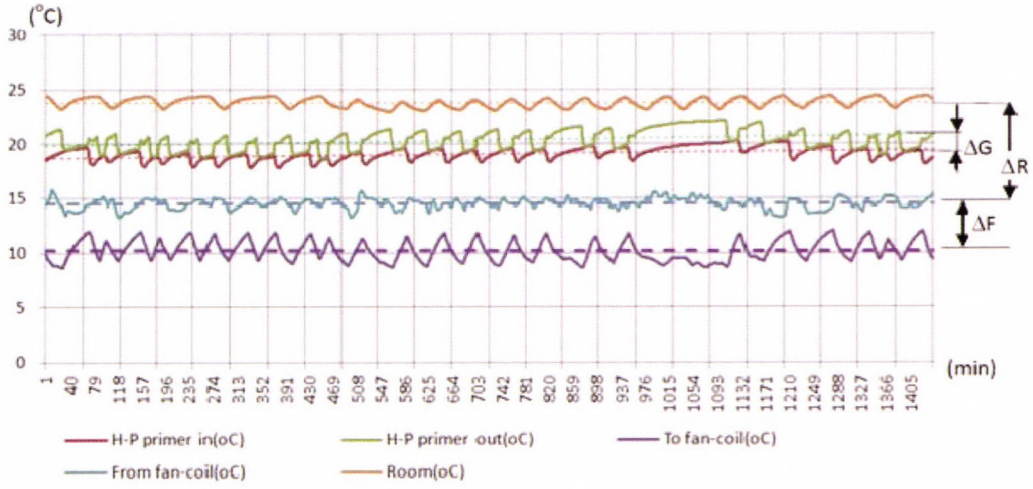

Figure 3. Example of fan-coils and ground sounds heat transfer

Example 2. On the Fig. 4. the heat transfer of fan-coils is acceptable with temperature difference of approx. 4°C (ΔS), but the ΔHLB temperature difference signs a high heat loss.

Example 3. Because of the increased load the heat intake temperature of the soil increased, and during this period ΔT (ΔP-S) didn't decrease. After the saturation the ambient temperature decreased, so the load moderated as well, and the soil could receive the heat at a lower temperature at the same time, there was enough time for the regeneration and the pump could operate with a lower power. Because of the effective operation of the system, the knowledge of this process is very important. Heat storage capacity is necessary to "survive" the peak load periods. The other possibility is to involve into the system the air-liquid heat exchanger on the roof during night. During this time the soil heat exchangers can regenerate.

The investigations are very important to make an optimal system with heat pump soil sound, in winter condensing gas boiler and air heat pump located on the roof.

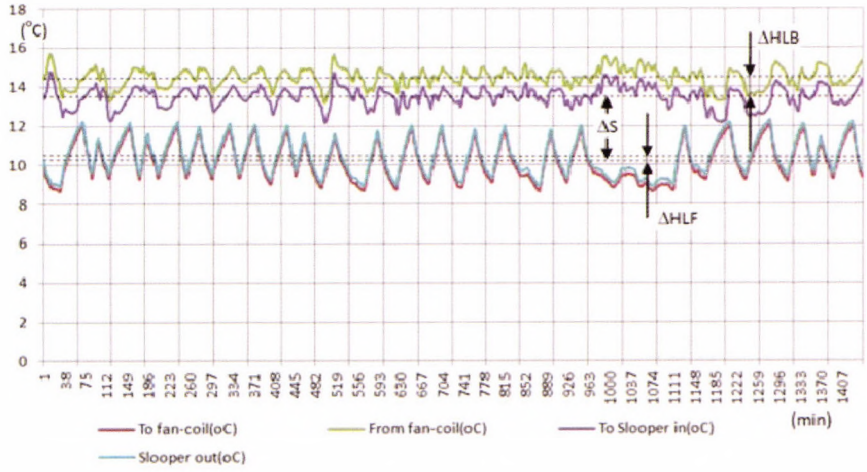

Figure 4. Example of fan-coils heat transfer and return pipe heat loss

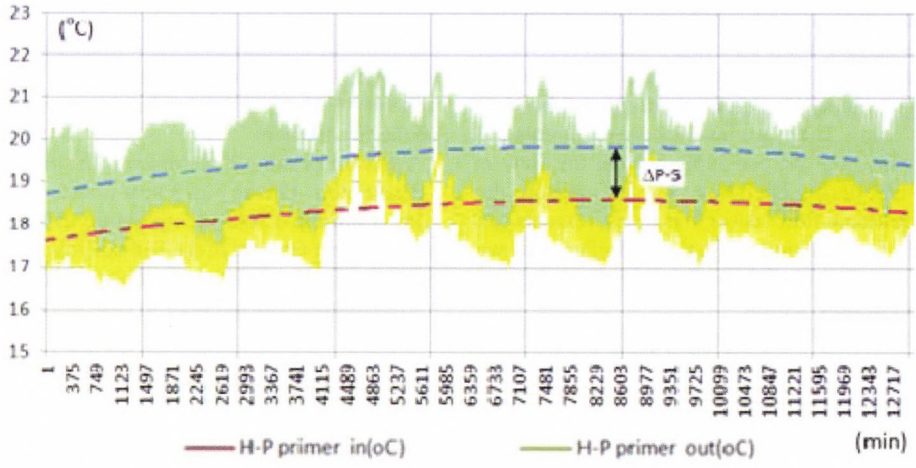

Figure 5. The distributing pipe's temperature of heat pump primary side during 3,5 days. The average ambient temperature increased from 22°C to 24,5 °C.

Acknowledgements

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MEASUREMENT OPTIMALIZATION BY INFORMATION ENTROPY

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Abstract

Stochastic processes are always changing. Measuring the process parameters never gives us a stable end value. In our institute we develop a statistical surface metrology method. To calculate the optimal length of measurement we use information entropy. The entropy is a saturating function. By exponential regression we are able to forecast the optimal length of measurement.

Keywords

soil surface, roughness, entropy, optimization, mobile robot

Introduction

In our institute we developed a new method for soil surface monitoring (Blahunka, Faust, Bártfai, & Lefénti, 2011) (Blahunka, Bártfai, & Lefánti, 2012). A mobile robot is moving over the field. The mobile robot has and 6 DOF IMU device (Bose, 2009). The IMU measures the acceleration (all three dimensions, 3 DOF) and angle speed (all three dimensions, 3 DOF). At the beginning we used the vertical acceleration. There are many issues with this acceleration. The IMU measures the sum of gravity and kinetically acceleration. The vertical axle changes by the mobile robot body. Finally we are calculating the height different between the axles by the angel speed.

The method give us a distribution which specific to the field. The classification based on agricultural needs, the site of the clots.

Like every stochastic process monitoring, we had a question: how long should it take? To answer this question we used information entropy.

Entropy

The entropy shows how much new information we get. Shannon defines it at 1949 (Shannon & Weaver, 1949).

$$H = -\sum p_i \log_2 p_i \qquad 1$$

Equation 1 shows the entropy for discrete events. p_i–s are the probabilities of events. Because of $\log_2$ the entropy is calculated by binary bits.

How can the entropy changing (increasing, decreasing). To calculate the entropy we need a distribution (probabilities for all events). The entropy depends on the number of the events, probabilities. With the same number of events the entropy is higher when the probabilities are the same. Let's see two examples: coin, dice.

Coin

The coin has two events. At first we use normal coin, both side has the same probably. Calculating the entropy for this case gives 1. Throwing a (normal) coin gives us 1 bit new information.

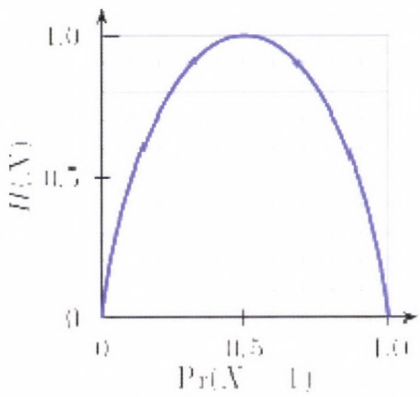

Figure 1. Entropy for two events (coin), source: (Wikipedia contributors, 2012)

However if we cheat, the probabilities are not the same. One side has a bigger probability. This way the entropy is smaller. Worst case the coin fallen always at one side. At this case the entropy is 0. We know the result, there is no new information by the measurement.

Dice

The dice has 6 sides. All sides have the same probability. This way the entropy is equal log26.

Big question of dice? How many times should we throw to get the 1/6 probabilities. For example 1000. 1000 is not divisible by 6, it means not all events will be 1/6. Every throwing makes a new distribution and new entropy. The entropy has a limit, the theoretical value log26. We can get this value when all events have the same probability. If we are lucky it can be after 6 throwing. But for 7th throwing the entropy will deceasing.

We use this experience to define the optimal length of (stochastic) measurement.

Method

Our measurement result is a histogram. The soil surface is classified by clot size and a distance between clots. This histogram gives a distribution which is specific for the surface. We calculate the entropy after every clot.

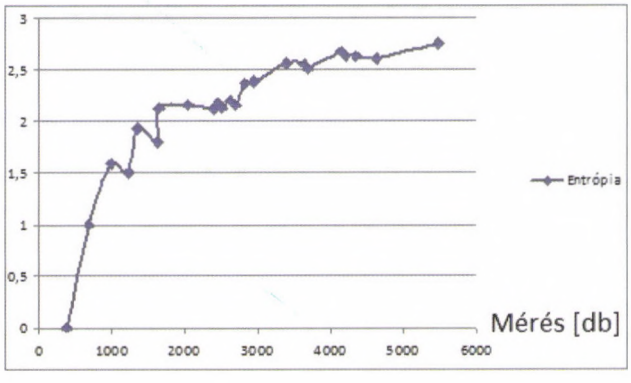

Figure 2. Entropy by distance

The entropy shows a saturating function. Why should it be a saturating function?

At the beginning there are new columns in the histogram. More events make higher entropy. That's way at the beginning it raising fast.

When all events appear the value of entropy depend on the final distribution. As we measure more the final distribution stabilizing. Of course every clot makes a small change on the distribution but the main concept doesn't change. That's why the ending section approximate the theoretical limit of the entropy.

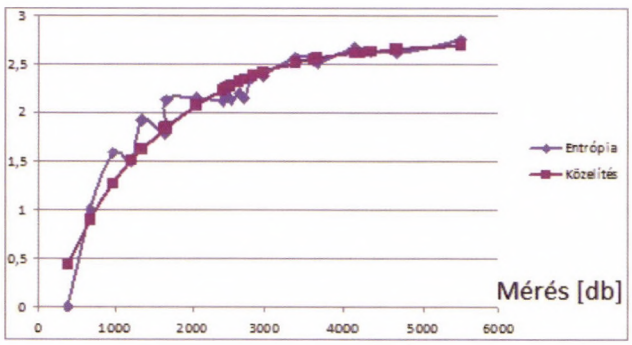

Figure 3. Exponential regression

Figure 3 shows the measured entropy and the result of the exponential regression (Seber & Wild, 2005). The regression find the parameters for the following equation:

$$H = H_{\infty} - e^{(ax+b)} \qquad 2$$

Where, H_{∞} is the theoretical limit of entropy. Parameter a shows, how fast the saturation.

Results

In our method every clot changes the histogram. After histogram changing we calculate the entropy. Based on the entropy function we calculate the regression.

$$H = 2{,}75 - e^{(-0{,}000745x+1{,}127849)} \qquad 3$$

Equation 3 approximate the entropy by r^2=0,93.

Using these parameters we are able to define the optimal measurement length based on the accuracy.

$$H = 2{,}75 - e^{(-0{,}000745x+1{,}127849)} \qquad 4$$

Table 1. Optimal measure length

Accuracy [%]	Length [sample]
10	3244
5	4174
1	6333

Table 1 shows the optimal length of measurement by accuracy. Figure 3 shows these points. For example: to know the surface by 10% accuracy, we should take 3244 samples.

Conclusions

To know a stochastic process is an endless measurement. A process, surface is changing continuously. Also if we know that this is a homogeny surface, the statistical parameters became nearly constant.

Our method big advantage is, that we are able to forecast the optimal length of a stochastically measurement. Using exponential regression we get the parameters of entropy function. With a given accuracy we are able to calculate the optimal length of measurement. After this point we will have more value about surface but our knowledge won't be more.

Nomenclature

DOF Degree-of-freedom
IMU Inertial Measurement Unit

Acknowledgements

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ARMFIELD HT31 TUBULAR HEAT EXCHANGER IN THE EDUCATION

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Abstract

At numerous areas tubular heat exchangers were replaced by plate heat exchangers, because of their smaller place demand and better heat transfer. But easier structure, easier cleaning and new technical solutions turned the attention once again to tubular heat exchangers. They are widely used in food industry, in chemical industry, in pool technology and in building engineering.

At the Institute of Process Engineering (Szent István University, Faculty of Mechanical Engineering) the tuition of heat exchangers (their structure and sizing) is important. Till now at Szent István University the tuition of heat exchangers was about teaching theoretical knowledge, because there was no appropriate tooling. During the last year in the Knowledge Transfer Centre Project the university purchased an Armfield HT30XC heat exchanger and different heat exchanger accessories. At first, we made measures on the HT31 tubular heat exchanger with which we defined the operating interval of the equipment. At different adjustments we progressively changed the mass flow and temperature of hot and cold water. The collected data base can be used for teaching of heat exchanger processes. To show the processes we made diagrams. With these diagrams we help students to understand the steps of sizing and operating of heat exchangers.

With the collected data base, measurement documentation and diagrams the tuition of heat exchangers is complete and the practical teaching of students can be done on a higher level.

Keywords

heat exchanger, tubular heat exchanger, Armfield

Introduction

The role of heat exchangers is very important in practice. Extending of their application and modeling is needed in industry. Modeling of heat exchanger systems is a great responsibility, because the incidental failures occur increasingly. Our Armfiled HT31 tubular heat exchanger is applicable for the modeling of heat technical problems. Now, after theoretical studies there is a available equipment for tuition at Szent István University. At the Institute of Process Engineering (Szent István University, Faculty of Mechanical Engineering) the tuition of heat exchangers (their structure and sizing) is important.

We gradually changed cold and hot water mass flows and hot water temperature in our study. The set up data base is a good tool to demonstrate the heat transfer processes in heat exchangers.

Description of armfield ht30xc heat exchanger unit

In this experiment we used an Armfield HT30XC heat exchanger unit with HT31 Tubular Heat Exchanger. The Armfield range of small scale heat exchangers comprises several units which represent the common types of heat exchangers found in industry. They demonstrate different techniques for indirect transfer of heat from one fluid stream to another. Their small size produces a fast system response to changes in variables such as water flow rate and temperature, so that training exercises can be carried out in a relatively short space of time.

The interchangeable heat exchangers are individually mounted on a service unit (HT30XC) which provides the required services and sensor output displays.

The units can be quickly changed without the need for tools, and the service unit also allows students to evaluate experimental heat exchangers of their own construction. Once a heat exchanger has been installed on the service unit and the unit is switched on, the entire assembly can be operated remotely from a computer. The supplied Armfield control software also includes a full set of training exercises and allows data logging and display of results in tabular and graphical format.

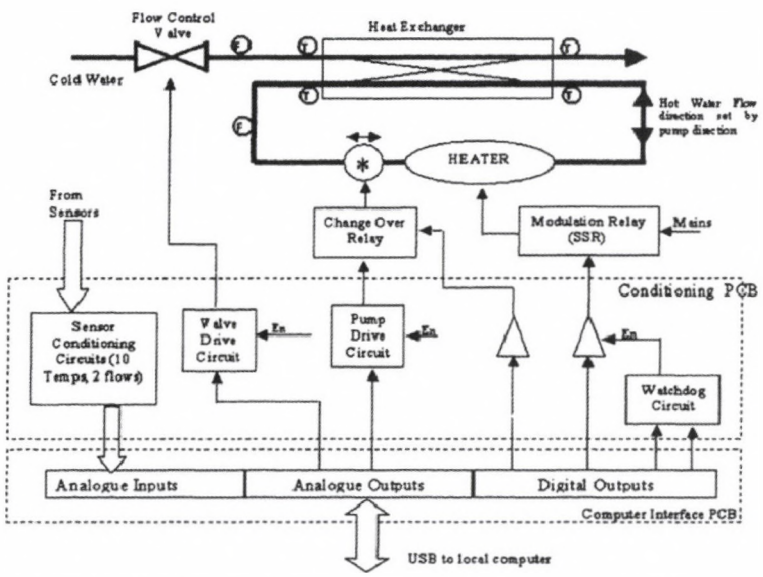

Figure 1. Simplified Block Schematic Diagram of the HT30XC Service Unit (Rubaiyat Amin Khan, 2000)

On Fig.1 the simplified block diagram of the Armfield HT30XC heat exchanger unit can be seen. The cold water circle, hot water circle and the measurement points (T-temperature measurement, F-mass flow measurement). The territory marked with broken lines traces the digital inputs and outputs.

Cold water flow (the process flow) for the heat exchanger is derived from the local mains water supply, with the equipment protected by a pressure regulator and integral filter and the flow controlled by a proportioning solenoid valve. Flow meters measure the hot and cold flow rates, and thermocouple sensors measure the temperature at key points throughout the heat exchanger. Once a heat exchanger is connected, the unit can be entirely operated via a computer and all sensor outputs can be logged. The hot water flow rate can be controlled from the computer software by varying the rotational speed of the re-circulation pump. Again this can be set from 0% to 100%, with the actual flow rate being measured by a flow meter and displayed in L/min on the computer screen.

The tubular heat exchanger is the simplest form of heat exchanger and consists of two concentric (coaxial) tubes carrying the hot and cold fluids. Heat is transferred to/from one fluid in the inner tube from/to the other fluid in the outer annulus via the metal wall which separates the two fluids. In the HT31 version two separate concentric tubes are arranged in series in the form of a U to reduce the overall length and allow the temperature mid way along both fluid streams to be measured. This arrangement minimises heat loss from the exchanger without the need for additional insulation and allows the construction of the exchanger to be viewed.

Figure 2. Armfield HT30XC heat exchanger unit (www.armfield.co.uk/ht30xc)

The six - type K - thermocouple temperature sensors are labelled T_1 to T_6 for identification and each lead is terminated with a miniature thermocouple plug for connection to the appropriate socket of the console on the service unit. Thermocouples are installed at the following locations (when operated counter current):

T_1 – Hot water inlet [°C]
T_2 – Hot water mid-position [°C]
T_3 – Hot water outlet [°C]
F_{hot} – Hot water flow rate [l/min]
T_4 – Cold water inlet [°C]
T_5 – Cold water mid-position [°C]
T_6 – Cold water outlet [°C]
F_{cold} – Cold water flow rate [l/min]

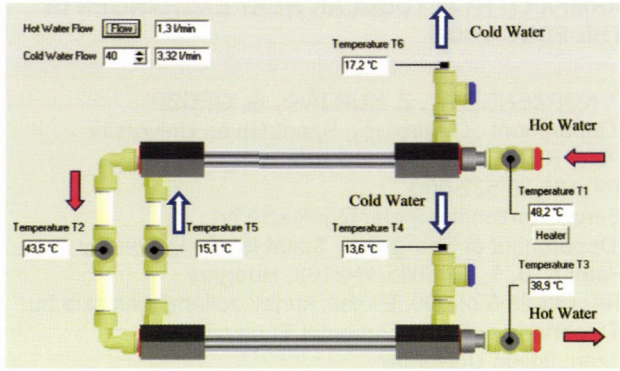

Figure 3. Armfield HT31 Tubular Heat Exchanger (www.armfield.co.uk/ht30xc)

Technical details of HT31 Tubular Heat Exchanger are as follows:

- Each inner tube is constructed from stainless steel tube, 9.5mm outlet diameter, 0.6mm wall thickness.
- Each outer tube is constructed from clear acrylic tube, 12mm inlet diameter, 3.0 mm wall thickness.
- Each heat transfer section is 330 mm long giving a combined heat transfer area of approximately 20000 mm^2.

Measurement setup

Two modes are available for controlling the hot water temperature, a manual control mode to provide constant heater power and an auto temperature control mode. Both modes are accessed via the software. In this experiment we used the auto control mode. In auto mode, the power to the heaters is modulated in accordance with a PID algorithm to achieve a stable temperature at one of the sensors (usually the hot water inlet to the heat exchanger).

During the measurements we modified the hot water temperature, hot and cold water flowrate, but only one of the main parameters was changed at the same time.

Each measurement series was repeated four times, the results were averaged and temperature curves were created.

We made our measurements with 6 different hot water ($Q_{hotwater}$) and 6 different cold water mass flow ($Q_{coldwater}$) values. We parallel modified inlet hot water values (T_1=30, 40, 50 ,60°C-ra). We modified only one parameter at once. With a constant cold water temperature (T_4) we adjusted the needed hot water temperature (T_1). We checked at given hot water mass flow (Q_{hot}) the temperature increase of the hot water side ($D_{Thot}=T_1-T_3$) with the increase of cold water mass flow (Q_{cold}).

On Fig.4 the results of five adjustments can be seen. With the increase of cold water mass flow the temperature difference of hot water inlet and outlet side increased.

Conclusions

In the following we introduce the application limits of the Armfield HT31 Tubular Heat Exchanger equipment.

We show at constant inlet hot water temperature (T_1=50°C) and at constant inlet cold water (T_4=12°C) the measured temperature at adjusted hot water and cold water mass flows (T_3 - hot water out, T_6 – cold water out).

With the increasing of hot water mass flow the outlet hot water temperature caused less temperature difference (compared to constant inlet 50°C hot water temperature).

With the increasing of cold water mass flow, and at constant hot water mass flow the outlet cold water temperature is

decreasing, so heat transfer is decreasing as well. Due to the effect of great cold water and hot water mass flow the values cannot be interpret in the grey parts of the table.

The Armfield HT31 Tubular Heat Exchanger is applicable for measurements on the adjusted 50°C inlet hot water temperature and 12°C cold water temperature at 4.4l/min mass flow.

At increased 9.9 l/min mass flows the equipment in not applicable for modeling.

Acknowledgements

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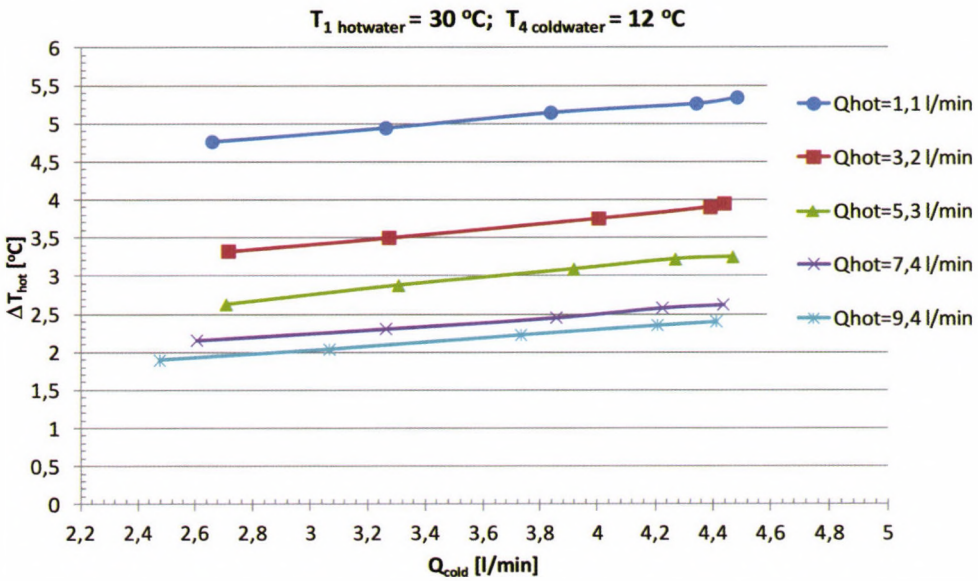

Figure 4. Hot water temperature change in the function of cold water mass flow (at 30°C-o inlet hot water and 12°C inlet cold water)

$T_{1\ hot\ water\ in}$ = 50 [°C]
$T_{4\ cold\ water\ in}$ = 12 [°C]

Q hot water [l/min]

T_3 - hot water out
T_6 - cold water out

Q cold water [l/min]

liter/min	1,2 ± 0,1	3,4 ± 0,2	5,7 ± 0,3	8,0 ± 0,4	9,9 ± 0,5
2,6 ± 0,1	39,9	43,9	45,7	46,5	46,9
	17	19,3	20,9	21,7	21,9
3,3 ± 0,1	39,3	43,3	44,9	45,5	45,5
	16,2	18,6	19,9	20,8	20,9
3,7 ± 0,1	38,8	42,8	43,8	43,9	43,5
	15,8	18,1	19,3	19,8	19,9
4,2 ± 0,1	38,5	42,5	42,3	-	-
	15,6	17,8	18,7	-	-
4,4 ± 0,1	38,3	42,3	41,3	-	-
	15,5	17,7	18,3	-	-

Figure 5. Limits of Armfield HT31 Tubular Heat Exchanger

DESIGN OF PRUNING DEVICE TO SUPPORT THE ALTERNATIVE LAID FLAT PLANTING TECHNOLOGY

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Abstract

Many procedures exist for the propagation and plantation of woody-stemmed plant in the national and international practice of the forestry and agricultural areas. One of such methods is the planting of which multiple versions are applied. Currently on the market available planting machines for planting of cuttings or rooted seedlings can be used only with a number of technology trade-offs. All planting machines are capable of vertically implanting the plants. Lay down propagation technology is not available currently on the market. Therefore our goal is to develop such mechanization technology which will able to improve the energetic plant propagation. The technology to be developed will be better than traditional methods because of the higher field performance therefore the lower overhead expenses.

Keywords

lay flat plantation, propagation material, pruning, cutting technology

Introduction

In the recent years the machine developments for woody energy plant production are more and more important to increase the working quality and working speed. The experts of the Hungarian Institute of Agricultural Engineering are participating continuously in different agricultural machine developments.

A new technology development was launched by the Silvanus Group Ltd. This technology will be based on the laid down plantation of the planting material. In this case some steps of the preparations of the planting material and field, structure of the planting and the subsequent plantation management jobs are the same like in case of previous vertical planting version.

For production the required material for cutting and planting it is necessary to satisfy the special needs of the lay down planting system. To support the requirements of this alternative technology our aim is to develop the mechanized laid down plant propagation technology. For this many technical researches are required to develop new multipurpose machines. By the mechanization of the new system the field performance, operational reliability and working speed of pruning, harvesting and planting can be significantly increased.

Based on the results of the former developments and investigations we started to develop as a first step, the pruning machine for the propagation material for the lay down planting technology. Such a machine which is able to pruning propagation material does not exist yet. The pruning of the propagation material had been carried out by hand work which is quite slow and expensive.

The first step in the technology development is to find solutions for the technical problems, which arise in connection with the production and planting of cuttings. The raw materials' non-destructive clearance from lateral branches can be done on standing sprout on nurseries or as the first step of the processing after the harvest. Both procedures require the appropriate development of mechanization while the location and other circumstances are also taken into consideration. In case of pruning of standing plants an easy, single hand tool is required which can substitute the current procedure which is carried out with pruning shear. This used procedure has high time-consuming and living labour demand.

The aim of recent study is to submits the preliminary concepts and results of a new pruning machine development, which properly serves the quality propagation material production for the new lay flat planting system.

Alternative planting technique for planting energy plantations

In case of woody energy plant production, unlike from the conventional arable plants one of the most different specificities are the form of propagation material and the system of planting. This alternative planting technique also has some differences what are described in this section.

Production of the propagation material used in the system of 'lay-flat' planting

The planting rods are produced in special stool beds. The rods are made of one year old shoots harvested from the trees of the stool bed. The planting rod is an intermediate stage of the cutting production. Cuttings can be produced by cut the planting rods. During the cutting production the workers must give attention to the location of the buds on the planting rod. The incisions must be placed next to a bud on the upper part of the cutting, so after planting the sprouts can erupt from these buds immediately. During the production of planting rods it is unnecessary to deal with these problems, the workers may only watch the prescribed diameters and length of the planting rod.

To produce as much planting rods as possible, which comply with the quality and size requirements, producers need suitable stool beds. The spacing and the formation of the stool bed is highly depends on the tree species and varieties. In some cases it means, that the stool bed consists low trees, which are cut back every year. This method is mainly the characteristic of poplar stool beds. In other cases the trees/shoots are cut back every year on the lowest level near to the soil surface, mainly used in willow stool beds.

Another thing is the characteristic of the one year old shots of the tree species. They can grow straight without strong branches. It is the easier to process these rods. In case of each tree species, like white willow, the shoots grow with strong branches on them. In case of these species the proper scaling of the stool bed has a very high importance. Willow is a fast growing tree species and the bred varieties grow faster than the original initial species. The optimal scaling of the white willow stool beds makes high density with low row distances. By these conditions the shoots will grow upwards and won't grow strong branches, because the available sunlight of the shoots is limited.

Harvesting of the planting rods, preparing them for planting

Rods are taken from one-year-old material that is harvested between December and March when the plants are dormant. Each species can be harvested later, too, but only in appropriate case. The main phases of the cutting production process are: the harvesting of the rods, the removal of the branches if necessary and the cutting to size. The sizes depend on the planting technique

and on the species. During the process it is important to pay attention to the storage of the rods on low temperature. It is recommended to store the rods between -2, -4 °C where cuttings remain viable for up to 3 months. They should only be taken from cold store and delivered to the planting site on the morning of planting. If rods/cuttings are left in temperatures above 0°C a break in their dormancy will occur, adventitious roots will develop and the buds may burst. This will lead to a reduction in water and nutrient content and consequently reduced viability.

The average length of the rods is 2 m, the diameter moves between 3 cm to 0.5 cm. The thinner part of the rod has more bud on it, but it's nutrient-poor. It is not necessary to cut the thinner part, but during the planting these parts have to overlap each other. Thus the sprouts will be strong enough and the density of the shoots will meet the requirements of a high-yield plantation.

Plantation for the machine tests

To design the woody energy plant propagation material harvester is not an easy task because of the lack of literature and previous developments.

For the design of the concepts we could use some results and analyses from agricultural and forestry machines field tests where we investigated working quality and energetic parameters as well. We also have to determine before the start of the design the agro-technical requirements and the propagation material parameters and standards. On the field of the Institute some planting tests we carried out this spring to investigate lay down plantations of different material and to prepare a universal test area for testing the machine prototypes. The preparation of the field and the current plantation can be seen in Fig. 1.a and b.

Figure 1.a. Plantation for the machine tests

Figure 1.b. Plantation for the machine tests

Requirements for the designed pruning machine

The basic aim of the pruning machine is that it should be hand operated because of the seasonal usage and the sizes of the propagation material fields. Also important point of view is to design a light version that could be easily handled and operated.

The pruning machine must non-destructively cut the lateral branches from the propagation materials. By this machine in a single pass will be possible to remove the substantial part of the lateral branches. The remaining parts of the lateral branches from the plants can be removed after harvesting. After the prototype version we will further develop the machine to better remove the side pruning from the propagation material.

Design and modeling of the concepts

During the development of a hand pruning device for propagation of material production of energy wood we introduce those solutions what was investigated for the design. The following figures demonstrate the possible operational variations and their brief characterizations.

Concerning the above solution, a commercially available 55 mm in diameter circular saw blade has been used (Fig. 2.a.). The construction provides an easy solution to remove twigs, however successful drive can operate efficiently in case of individual motors (e.g. model electric motor). Additional problem is the variable size of chunks which remain after the twigs because the smaller diameter is responsible for more residual surplus. Over and above, a very strict maximum diameter at butt end should be considered.

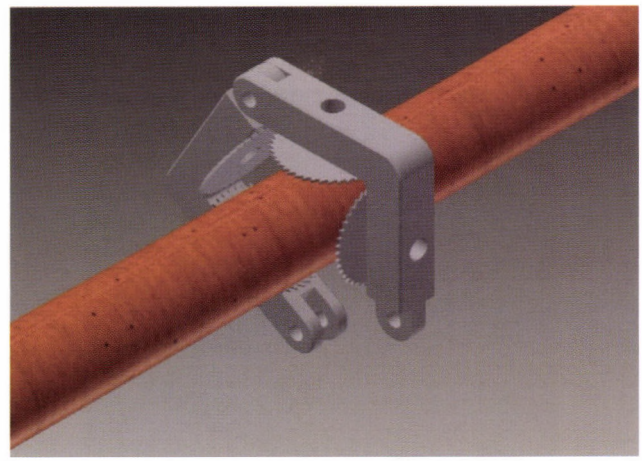


Figure 2.a. Circular Saw Blade Solution

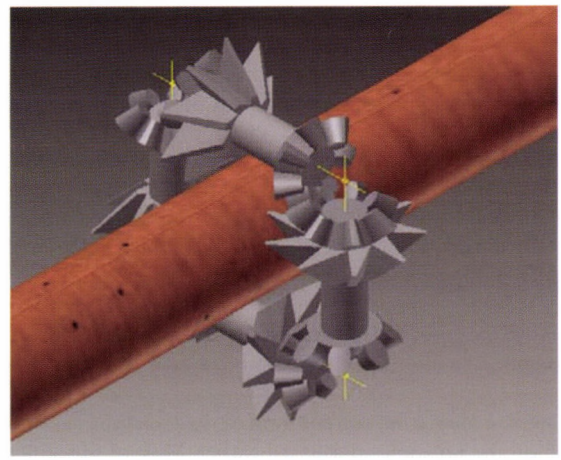


Figure 2.b. Cutter head with angular gear drive

The second solution is the cutter head with angular gear drive (Fig. 2.b.), provides a good example for how to solve the problem in the easiest way with available component in bulk. A forestry fine machining cutter head is presented in figure which has been installed onto motion model of the structure (Béda Gy. 2010). The drive installation is sufficient concerning one cone. In other cases, power transmission is carried out by the angular gears.

In this shaped cutter cylinder configuration (Fig. 3.a.), the simplest possible design was the goal. The moving parts have been minimized whereby number of function has been changed, e.g. opening of the structure. In the present situation the machine has to tilt, against opening, as long as the plant does not fit into the interior of the structure. The drawback of the design is that the semicircular shaped cutter cylinder makes the construction expensive. Nevertheless it does not provide a perfect encompassment because if we go up on the plant, the diameter will reduce.

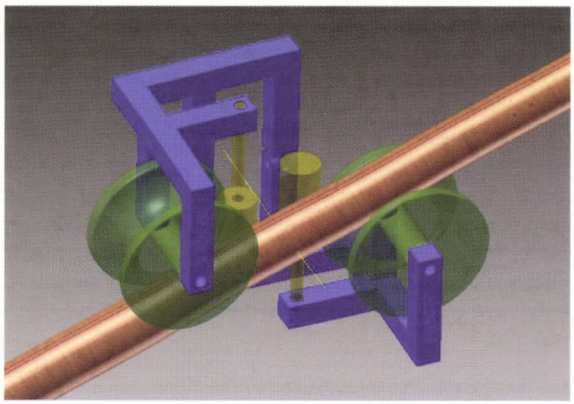


Figure 3.a. Shaped cutter cylinder

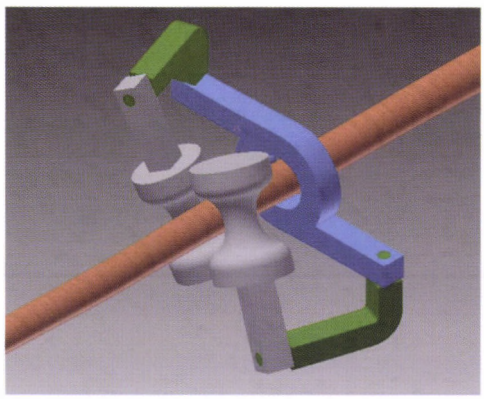


Figure 3.b.Multi-degrees of freedom cutter cylinder

Primary aspect is the most accurate pitching and the far better twigs removal in respect of the shown multi-degrees of freedom cutter cylinder configuration in Figure 3.b. The essence of the configuration is the ellipse shape cutter which can be moved by the multi-degree of freedom arm system. As a result of this solution, the stick can be almost entirely (2-3 mm) encompassed with the tool. However, it is a very expensive method, due to the specially designed tool and the formation of the regulation of the complex motion arm system.

The developed concept for the internal structure of the prototype

In Figure. 4. above the current form of the prototype can be seen based on the principles discussed earlier. Most of the structural characteristics have been taken over from the second and third concept. Only the forestry taper cutter head was kept, which was equipped with individual bearings. The drive comes from external resource, which could be electrical or internal-combustion as well. It is the criterion that the connecting shaft between the machine and the resource should be flexible (Béda Gy. 2010). This construction was designed to reduce weight.

The above-mentioned tilt process and not the moving parts, enables the locking of the structure. This solution would greatly simplify the structure. The adequate spacing is provided by taper roller pair which can be found below the cutter cone. Thanks to this the milling cutter does not catch into the plant.

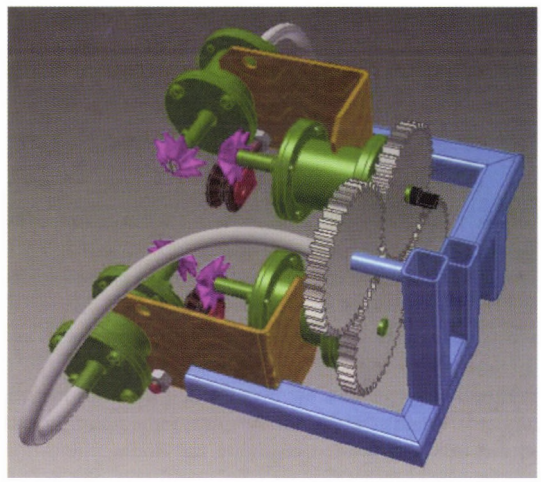
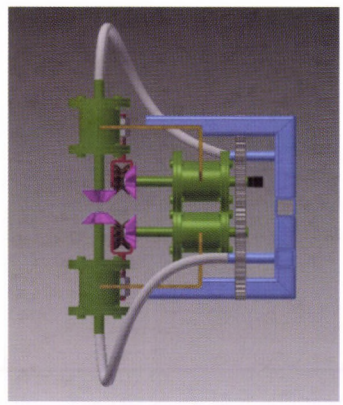


Figure 4. Internal structure for mechanical drive, first concept



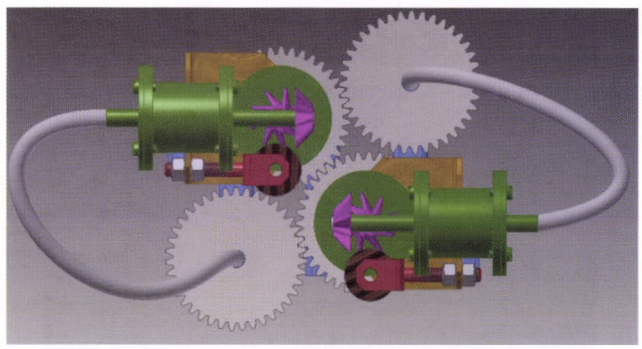


Figure 5. Internal structure for mechanical drive, second concept

Due to the hard drive intermediate component in the above described prototype (Fig. 5.), the structure was pretty heavy. Therefore, several hours handwork would be exacting. Furthermore, neither the flexible drive of the shaping is easy,

especially inside the machine (Tóth et.al. 2011, Simon et al, 2011). Owing to this problem a second version has been created which cannot be found an individually embedded in the shaft of the cutter cone. But high-speed engine model motors are placed in an adequate shaped casing individually each milling cutter (Fig. 6.). This design is shown in the figure below.

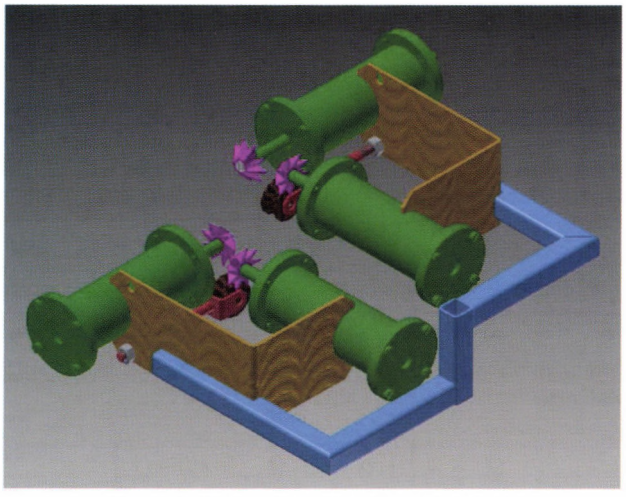


Figure 6. Internal structure for electric drive

The structure of the design is much easier, although it makes the system much larger. The effectiveness of the two designs can be evaluated after construction and testing.

Conclusions

Based on the results of the developments and investigations we started to design pruning machine conceptions for the propagation material of lay down planting system as one of the first steps to develop a whole technology. Such a machine which is able to non-destructively clear the lateral branches on standing sprout propagation material does not exist yet.

We carried out investigations for lay down plantations of different materials and to prepare a universal test area for testing the machine prototypes on the field of the Institute.

By satisfying the requirements of the propagation material treatments many different pruning possibilities had been investigated and finally from four suitable possibilities two pruning machines with two different driving options had been designed for further examinations. In both cases the basic requirements were satisfied different ways.

The next steps will be the modeling and analyses of the concepts, strength and vibration control, finite element analysis of the structure and total deformation analyses. According to the preliminary results the next step of the further work will be to carry out the modeling of the material movement in the machine, start manufacturing the prototype machine and carry out some field tests to measure the features of the prototype and determine the working quality and energetic parameters of the machine.

Acknowledgements

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PERFORMANCE COMPARISON OF HYBRID- AND FLAT PLATE SOLAR COLLECTORS

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Keywords

Thermal efficiency, electrical efficiency, performance of PV/T collector, analysis, factors affecting

Introduction

This paper introduced the advances and disadvantages of hybrid photovoltaic collector. After explain about detailed efficiency analysis, the further section is focused on performance differences of hybrid- and flat plate collector. Initially the solar system which was installed in the Department of Physics and Process Control, Szent István University is presented. The aim of this work is to study the behaviour of hybrid collector under different load test. The most important measured parameters and settings of the experiments are introduced. Preliminary standards and evaluation of performance reviewed.

At the Department of Physics and Process Control, Szent István University, Gödöllő various solar applications were installed for educational, demonstrational and research purposes, such as PV and solar thermal units, transparent wall insulation and solar dryer unit. The term PV/T refers to solar thermal collectors that use PV cells as an integral part of the absorber plate (Zondag, 2008). The PV/T system can be segregated into two parts, the thermal solar technology what converted the solar energy into heat, and the photovoltaic technology which derived from solar cell technology and convert the solar radiation into electricity. The hybrid collector can reduce the main problem of photovoltaic systems, the high temperature of the solar cell effects reduction in the efficiency. In order to solve that problem and get more efficiently system it is necessary to cool the PV cell and decrease its temperature.

Calculation method

The PV/T, combining PVs into the solar thermal module, indicates a new direction for renewable energy utilizing. The examination of PV/T (installed in 2011) is performed in this paper. The solar energy technology has many advantages and disadvantages comparing to the conventional energy. The PV/T module can collect solar energy at different brands of the spectrum and lead to energy and exergy efficiency (Zondag et al., 1999). Sum of the collector's thermal efficiency (η_{th}) and the PVs' electrical efficiency (η_e) gives the overall efficiency (Eq. 1). Hybrid collector efficiency is defined as the ratios of useful system heat gain and electricity gain to the incident solar irradiation on the collector's absorbing surface (Chow et al., 2009) and is written as follow:

$$\eta_o = \eta_{th} + \eta_e \qquad 1$$

Efficiency of PV/T collector

Efficiency of hybrid collector is given by a thermal and an electrical part in this period the separate theory of efficiency determined.

Thermal efficiency

The steady state thermal efficiency of a traditional flat plate solar collector is calculated by:

$$\eta_{th} = \frac{Q_u}{I} \qquad 2$$

By calculating the specific heat (Q_u) the useful collected heat from solar radiation could be determined as the multiplied by mass flow rate (m), capacity of flowing medium (C_p) and temperature differences of working fluid (T_i – inlet and T_o – outlet temperature of working fluid).

$$\dot{Q}_u = \dot{m} C_p (T_o - T_i) \qquad 3$$

The difference between the heat losses and the useful solar radiation:

$$Q_u = A_c \left[I(\tau\alpha) - U_L (t_{p,m} - t_a) - Q_e \right] \qquad 4$$

In Eq. 4 a more complex determination of specific heat can be seen where A_c is the surface of the collector,$\tau\alpha$ is the transmittance-absorption effort of glazing cover, U_L is the overall thermal loss coefficient, Q_e electrical energy generated from the PVs, $t_{p,m}$ is the absorber plate temperature. Hottel and Willer developed the equation of flat plate collector (Hottel et al, 1958). Because it is hard to measure or calculate the temperature of absorber plate as it is a complicated function of incident solar radiation, different collector geometry and attribution of working fluid. It is important to notice that the equations are correlated to the solar collector formation (as cylinder or rectangular shape). Some geometrical parameters in the equations could vary correspondingly if the collector shape is changed meanwhile the basic work principle of the collector remains the same.

$$Q_u = F_R A_c \left[I(\tau\alpha) - U_L (t_i - t_a) - Q_e \right] \qquad 5$$

The unknown parameters are in the Eq. 5 can be determined as: FR is the heat-removal factor, ta is the ambient temperature.

Electrical efficiency

The ratio of incident solar radiation to measured output power (P_o) gives the electrical efficiency (η_e) of a PV module is.

$$\eta_e = \frac{P_0}{I A_c} \qquad 6$$

As it is mentioned the cells' temperature is influenced the electrical efficiency of the PV module, it is decreasing and this dependence can usually be written as (Duffie et al., 1991):

$$\eta_e = \eta_{rc} \left[1 - \beta_{PV} (t_{PV} - t_{rc}) \right] \qquad 7$$

Where the ηrc is the initial electrical efficiency at reference temperature, βPV is the cell efficiency temperature coefficient, the tpv is the PV cell temperature and trc is the reference temperature of PV cell.

$$T_c = T_{amb} + C_f\left(218 + 823\overline{K}_t\right)\frac{NOCT - 20}{800} \quad (8)$$

The generated electrical energy can be calculated as follows:

$$Q_e = P_0 = \eta_e I A_c \quad (9)$$

Results and discussion

Performance of solar equipment is depending on the environmental factors, the design of the collector or PV module, materials used in it, etc. The main factors which are impact on the lower thermal efficiency of a hybrid collector when compared with a thermal collector were identified (R. M. da Silva et al., 2010). Among others due to the imperfect adhesive between additional thermal resistance and the encapsulation, the high reflection losses still appeared, energy is transmitted to the electrical production, the lower quality of absorber plate. The lower electrical efficiency when compared to a photovoltaic collector is due to the optical losses in the glass cover. A sensitivity analysis were carried out it can be seen on Fig. 1. The graph shows that the emittance of the solar cells is the most important factor in heat losses. It was verified that the angular dependence of optical properties related to the components of the radiation must be taken into account. Otherwise there can be an overestimation on electrical and thermal efficiencies in the order of 2%.

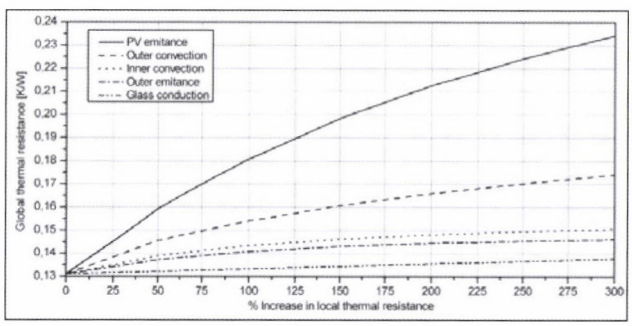

Figure 1. Sensitivity analysis on PV/T
(R. M. da Silva et al., 2010)

Many factors have effect on performance of a solar equipment installation, such as: shading, corroded parts, contaminations, accessories failure, objects on solar panels, cell density, duct depth, length of collector, inlet temperature of working fluid, flow rate etc. Based on observations of experiment and literature it can be concluded that the liquid based photovoltaic thermal collector systems has better indexes in performance than air based systems (Daghigh et al., 2011). During the experiment the hybrid module was let to warm up to about 50°C, and in between the electrical output was measured (voltage and current) on a load. Meanwhile the test hybrid collector worked on a separate liquid circle, where the water was cool down by a special cooling system to around 10°C. By this way PV/T module temperature was dropped and the power change were measured. It can be seen from the following diagram (Fig. 2), that the about 10°C of drop in the module temperature caused about 1 percent of efficiency increase. It is important to notice, the PV module was not operated at its MPP during the measurement.

$$P_{thermal} = c\,m\,\frac{dT}{dt} = c\,\rho\,\frac{dV}{dt}\,\frac{dT}{dt} \quad (10)$$

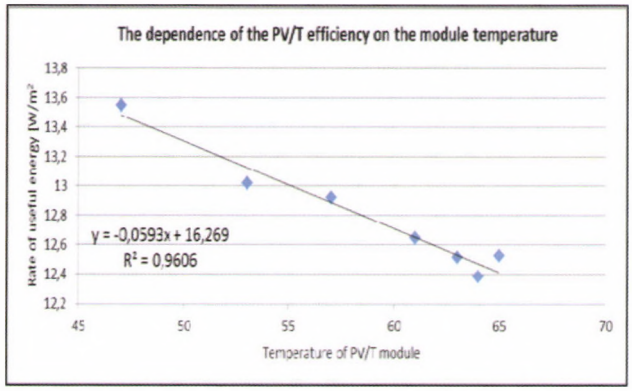

Figure 2. Rate of the module temperature and useful solar energy of a PV/T collector

By the equation above (Eq. 10) specified thermal performance determined with a comparison of the incident radiation power efficiency. However that value changing when the operating parameters are changing also, but it is characterized the operation of the device. Based on measurements calculation results can be seen on Fig. 3.

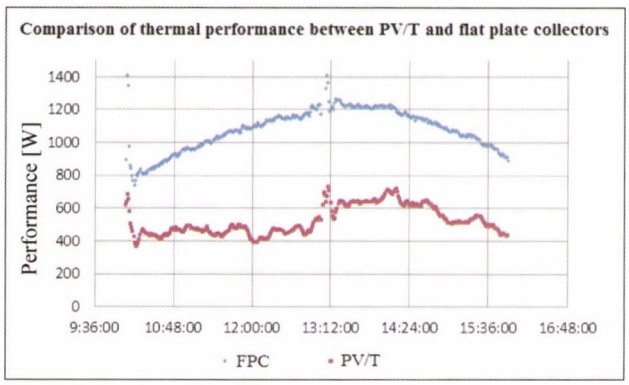

Figure 3. Thermal performance of hybrid and flat plate collectors

A comparison of thermal performance made between the hybrid and flat plate collector. Graph above show that the hybrid collector thermal performance much lower than the other one. However, it should be take into account that the hybrid collector is not specifically designed for domestic hot water. On the oder hand electrical performance of the PV/T collector was compared to a polycrytalline PV module (Fig. 4).

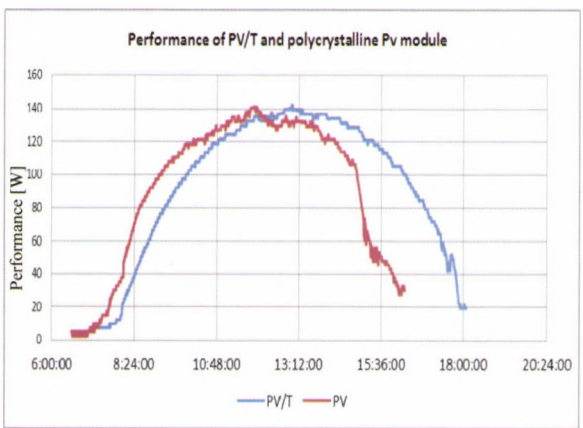

Figure 4. Electrical performance of hybrid and polycrystalline

Conclusions

In this paper, the performance assessment of a PV/T collector was carried out. A detailed performance analysis was carried out to get a complete view of the utilized solar power of hybrid solar collectors, thermal and electrical parameters, and efficiency of different parts of PV/T collectors. From the investigation it can be concluded, that the thermal characteristic of the adhesive and working fluid flow rate has a considerable impact on the overall efficiency. In the frame work it can be concluded that the hybrid flat plate collector can be used to overcome the overheat problem of the PV system. From our examination on hybrid collector, based on measurement data it can be concluded that about 10°C temperature drops on the collector cause one percent efficiency increase.

Acknowledgement

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SOME DEVELOPMENTS ON MOLECULAR BEAM EPITAXY TECHNOLOGY FOR SOLAR CELL PREPARATION

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Abstract

This work presents the electronical and mechanical control system of a molecular beam regulation connected to molecular beam epitaxy (MBE) technology in the view-point of solar cell preparation. It is more of them about to create a regulated vacuum technical out-heating. For the free path and small residual impurity in the MBE, 10^{-10}-10^{-11} mbar vacuum should be attained. The strict, according to plan dosage of molecular beam has an important role in the programming layer-growth. It happens with the heating of the current source (Knudsen cell), then conducting the leaving molecules through a cryogenic pipe section. The mechanical control is realized with the help of a DC electro engine through a transmission, which moves the shutters over the sources. The control happens with PLC (Programmable logic controller) technique. The operator surface completion is made with the help of WinCC flexible computer program. The MBE system is equipment for crystal growth, which machine opens the door to preparation of low-dimensional systems under controlled circumstance.

Keywords

control, layer grow, nanostructures, ultra-high vacuum, semiconductors.

Introduction

The solar cells have increasing importance in the area of renewable energy resources (Farkas, 2011). The molecular beam epitaxy (MBE) is the most sophisticated method for producing nano-structures. The experimental setup described here is the only one presently in whole Hungary. The growth of the nano-structures is achieved with the help of molecular beam in ultra high vacuum. The use of the nano-structures revolutionized inter alia material science and electronics, for instance solar cells (PV modules). MBE is the most versatile technique for preparing clean and well-defined surfaces, interfaces, layers and nano-structures of different semiconductors. The most usable systems are for III-V semiconductors like GaAs. The GaAs based solar cells can reach high efficiency by using nano-structures (Réti and Ürmös, 2012). MBE allows a controlled growth of films with sharp doping profiles and different composition.

The condition of the materialization of the GaAs-based solar cell structures is the grow of controlled semiconductor crystal-layers and nano-structures. The application of nano-structures revolutionised industry, including electronics industry. Such few atom-line layers and other nano-sized objects can be materialized particularly with MBE (Herman and Sitter, 1989). The fabrication of semiconductor nano-structures used in electric devices is possible with various epitaxial techniques, the most sophisticated technique and device being MBE, where nano-structures are grown with the help of molecular beams in ultra-high-vacuum (UHV) (Hanlon, 1989). One of the classical methods to prepare thin films with clean surface is the evaporation in ultra-high-vacuum. Fig. 1 shows the UHV system with facilities for MBE.

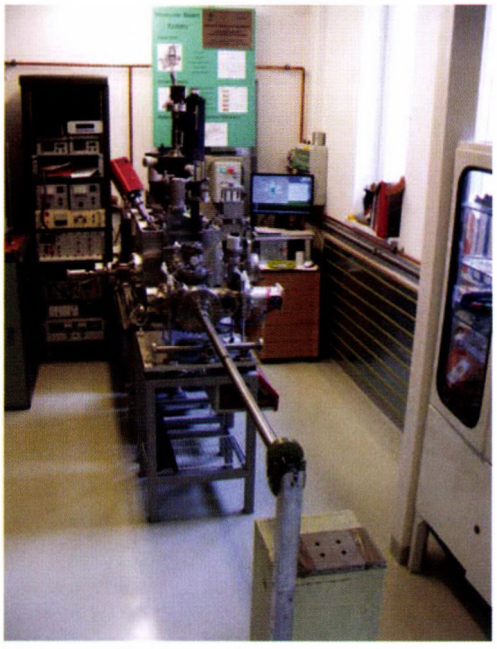

Figure 1. View of the molecular-beam epitaxial laboratory equipment

In the laboratory scale experimental setup consists of three chambers. One of them is the reactor for sample preparation. Another one is the loading chamber, while the third one is an additional chamber for vacuum pumps. Vacuum valves are between the chambers. Knudsen-type crucibles are used as effusion cells for the evaporation. In our case, the molecular sources are As, Ga, In and Al. The regulation of such four molecular sources of the cells is carried out partly mechanically and partly electronically. For the packing of the very complicated developed vacuum chamber, for the producing the emission of several components and introspection windows, a full computational documentation has to be created. The temperature measurement is done with the observance of the background's partial pressure. The mechanical control of these molecular sources and the regulated vacuum technical out-heating control are happen with PLC. The operator surface completion is made with the help of WinCC flexible computer program.

The purpose of the work is to present a non-traditional evaporator procedure. Special nanostructures can be produced with the precise, computer-controlled process, while the mechanism of self-organization becomes observable.

Technical background

Crystal growing takes place in the main chamber (Fig. 1). The MBE growth needs very high requirements with the equipment. So we have to use a reliable and precise control (Réti, 2011). From the view-point of electronics, the control is slow. The growth rate ranges between 0.1–1 ML/sec (mono layer, ML). In reticent case, the UHV condition means 10-10–10-11 mbar pressure. After the closing of the system, it is need the out-heating of the chambers in order to achieve this vacuum level. The out-heating needs slow control without overshoot. In the case of the shutter movement, a slower control is required, because the

shutter has to close before the next ML begins to grow. The heating of the effusion cells and the sample holder are also relatively slow processes because a process free from overshoot is required. Because of the reliability, PLC system for the control of the MBE is required.

Before the crystal growing procedure starts the equipment needs to be heated out, following a specific temperature characteristics to evaporate different contaminating materials and clean the vacuum chamber. The temperature is measured at 6 different points and 6 heating wires are controlled (Fig. 2).

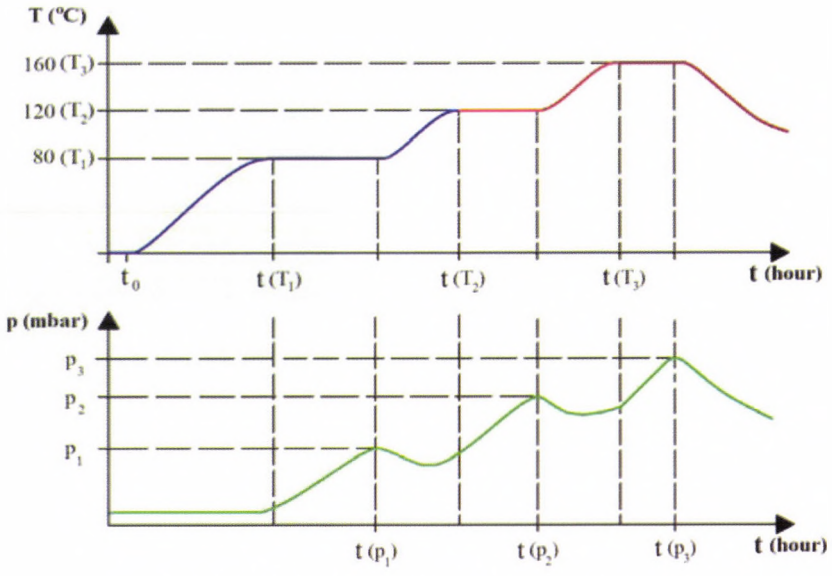

Figure 2. Temporal course of the out-hating process

The temperature levels, as it can be seen on Fig. 2, are essential in order to avoid the congestion during the thermal independent movement happened detachment of molecules attached to the wall of the chamber and must be given the time interval required for removal. The time interval can be determined by pressure-monitoring in the chamber. The closed loop heat control is performed by the Simatic type PLC.

The outheating system

Heating cables had to be placed on the chamber evenly. The stainless steel chamber walls must not be welded nor holes drilled into it, thus a special solution for a looser fixture became necessary. The fixing elements were folded from aluminium and are presented in Fig. 3.

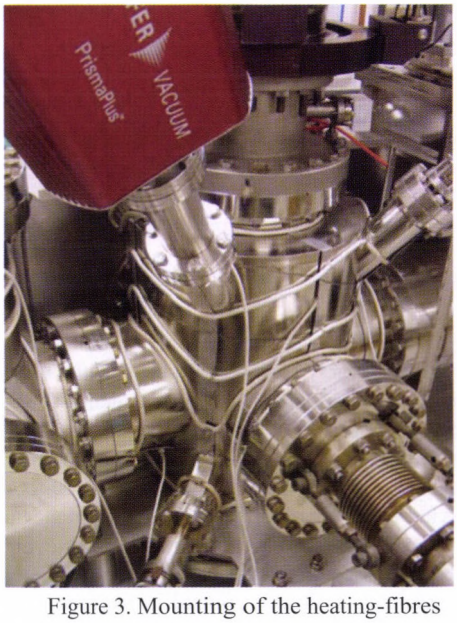

Figure 3. Mounting of the heating-fibres

In positioning the heating cables it has to take into consideration that parts of the system must not be heated above 200°C, such as the chamber window or the manipulator. The number and distribution of the Isopad heating cables for each chamber were determined according to the weight and surface area of the modules.

The first task was to develop the temperature control of the external steel housing. The requirements of the technology were the following: the steel housing could be heated evenly; the three chambers could be heated separately; heating has to be slow, at a maximum rate of 50°C/hour; accuracy of control has to be under ±0.1°C, with no overheating; heating process has to take place according to a predefined heating profile.

The heating process consists of three steps (Fig. 2). First, the chambers are heated up to

80°C. Simultaneously, contaminants peel off from the chamber walls, increasing system pressure, thus it is important to operate the vacuum pumps during this step. After reaching

T_1=80°C, the temperature is kept as constant. This is necessary as contaminants take time to detach from the walls. Rapid heating up of the system could cause contamination to burn to the walls, preventing reaching required vacuum pressure. The second step of the heating profile starts after reaching $3x10^{-6}$ mbar system pressure. Maximum temperature in this step is T_2=120°C. Further desorption of contaminants from the walls will increase vacuum pressure again, thus at the end of this step another constant temperature heating period takes place, until system pressure returns to $3x10^{-6}$ mbar. The third step consists of heating the system up to T_3 = 160°C and keeping this temperature. This step can last for days, depending on how long the chambers had been vented. Program controlled gradually heating of the system is of great significance, as a sudden rise in temperature could result in contamination burning to the chamber walls, which in return could prevent the system from reaching the required chamber pressure.

The mechanic and the electronics of the shutter-moving

According to plan dosage of molecular beam the strict has an important role in the programming layer-grow. It happens with the heating of the current source (Knudsen cell) (Fig. 1), then conducting the leaving molecules through a cryogenic pipe section. This pipe (like a cannon-conduit) points to the wafer.

With the opening and cover of this cannon-conduits mouth it can be handled the amount of the molecules that come to the model. It means that we fixed a cover-disc to the end of a stick which enters to a vacuum-space that parallels with cannon-conduits. It turns to the wanted direction through a transcription by a DC electro engine (Réti at. al., 2011). Earlier time the turning-mechanisms were manual controlled and build-in not to restrict each other moving. Because of this, according to a normal base area, we had to turn four different directional and length stick, that ends are thickened. This problem can be solved by putting the four actuation motor to the common base area and each turns a fork. The cogs can be fixed, which are running to the forks, to the mechanisms that turns the blende. Hereby, even the angle difference of the motor and blende-axis, it managed to materialize the motor turn with a minimal backlash. We restrained the slew of the forks turning with the common base area switch, to let the blendes do their allowed moving.

Figure 4. Realization of shutter-mover of the MBE

Thus the motor-driven moving of the aperture has come true, the possibility of programmable electrical control has been provided. For starting point a blanket statement of the Knudsen cells has been chosen. The algorithm does this with each motor in every inrush and only after this marks back its control capability. Thus the engine works under 12 V DC we solved the rotation direction problem with polarity change. The micro-switches fixed to the last-state got two functions (Fig. 4).

On one hand they a signal is given if the rotator of the motor switches them to opened or closed state, and on the other hand their (switching) on/off states is a signal for a motor-observer, which ensures the safety from random overloads. So if either driver-motor stops running for some reason, it only gets current for 4 seconds at most. Two relays for controlling every motor are used.

The control of the outheating and the shutter-moving

The outheating needs slow control without overshoot. In the case of the shutter movement, slower control is required, because the shutter has to close before the next ML begins to grow. The heating of the effusion cells and the sample holder are also relatively slow processes because the processes should be free from overshoot. Because of the reliability, a PLC system for the control of MBE is used.

A PLC is an industrial computer used in automation of wide range of processes. PLCs are used in many industries and machines. Unlike general-purpose computers, the PLC is designed for multiple inputs and outputs (I/O) arrangements, extended temperature ranges, immunity to electrical noise and has very reliable hardware structure. Programs to control machine operation are typically stored in non-volatile memory. A PLC is an example of a real time system since output must be produced in response to input conditions within a bounded time, otherwise unintended operation will result. The main difference from other computers is that PLCs are armoured for severe conditions, and have the facility for extensive I/O arrangement. These connect the PLC to sensors and actuators.

As it was mentioned, the PLC gives reliable control therefore we use it in the control of the MBE equipment. The type of the used system is Siemens Simatic S7-300. The system consists of the central rack with the CPU, 24V power supply and the I/O modules. In the same cabinet the protecting equipments, fuses and the relays are placed. The supervision of the system is possible by using an operator computer which is in this case a touch display with function keys.

The operator surface completion for control of the heating and of the shutter-moving is made with the help of WinCC flexible computer program and is shown in Fig. 5.

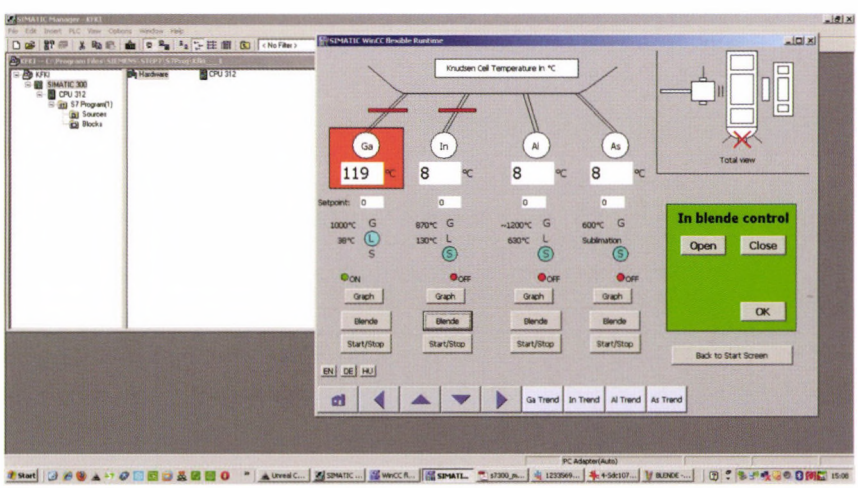

Figure 5. Operator surface of the MBE facility

The all-time status of the Knudsen cells from a perspicuous window of the control program can be followed. Here we can see the momentary temperature and the open or close status of the cells.

Conclusions

The automated MBE technology, compared to conventional vaporization procedures, enables the reproduction of ordered zero-, one- and two-dimensional nano-structures. By ensuring the accurate and calculable increase of molecules and evaluating the sub phases, the mechanism of self-organisation can be acquainted. Knowing the mechanism of self-organisation enables the production of high efficiency solar panels with quantum valleys and quantum dots.

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EXPERIENCES WITH MICROWAVE PRE-TREATMENTS OF SWEET WHEY PRIOR TO MESOPHILIC ANAEROBIC DIGESTION

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Abstract

In our work we focused on the examination of the applicability of microwave pre-treatments of sweet whey prior to anaerobic digestion. To quantify the structural change of organic matters of sweet whey biochemical oxygen demand (BOD), chemical oxygen demand (COD) and biogas yield were used as control parameters. Our results show that microwave pre-treatments are suitable to enhance the biodegradability of sweet whey. It was proved that the flow rate and ate specific power intensity has also effect on the biodegradability and biogas production of whey. Increased intensity and decreased flow rate has led to decreased solubility of organic matters of whey.

Keywords

microwave, sweet whey, biodegradability, anaerobic digestion

Introduction

The world is facing an energy crisis due to increasing concern related to fossil use, i.e. environmental impact, climate change, finite availability and security of supply. Rapidly rising motor fuel prices and the enhanced needs for them has stressed to increase the biofuel production. Biofuels are liquid or gaseous fuels made from plants and residues such as agricultural crops, municipal wastes and agricultural or forestry by-products.

Professionals in food industry companies face the high disposal costs of bio-wastes and the rising price of energy sources. Nowadays the renewable energy generation can be often connected to waste management technologies. For example since an effective utilization of food industrial biomass waste has desired, the establishment and optimization of an efficient biogas production process from these waste materials is very important from perspectives of both energy and environmental issues.

Food industry generates a huge amount of liquid and solid organic waste and by-products. Beside the considerable environmental risk of waste, it has a good potential to indirect bio-energy production for example in anaerobic digestion (AD) process. Biofuel production from agri-food wastes can also contribute to make waste management more socially acceptable, sustainable and cost effective (Nagy and Farkas, 2013). The anaerobic fermentation is a complex biological process developed in the absence of oxygen and in the presence of methanogenic bacteria, that transforms the organic substance into biogas (or biological gaseous mix), composed mainly from methane and carbon-dioxide (Kalmár et al., 2010).

Digestion is the oldest technology for waste stabilization and however less final waste sludge production can be achieved by controlled anaerobic decomposition. It is verified, that the biological degradability of organic matter of processed raw materials – such as solid wastes, sludge, lignocelluloses contained by-products- has effect on the rate of digestion. Because of non-biodegradable components and large molecules (proteins, polysaccharides) of raw materials different kind of pre-treatments are required to achieve an appropriate and economic ethanol and biogas yield.

Whey is an important by-product of the dairy industry, in the case of conventional cheese technology the final volume of whey is about 85-90% of the volume of processed milk. Two main whey types are produces in dairy technologies, acid whey and sweet whey (or cheese whey) depend on the procedure of casein precipitation. The principal components of whey are lactose, proteins and mineral salts. Approximately 150 million tons of whey disposed in the environment world-wide every year mainly in developing region (Leite et al., 2000, Saddoud et al., 2007). It represents a large-scale loss of resources and causes a strong environmental load because of the high organic matter content of whey and whey contained dairy wastewater.

The conventional waste treatment process is itself not suitable for producing stabilized whey waste for direct disposal (Siso, 1996). The technology of ethanol fermentation from whey is developed in several countries. For instance several distillers producing ethanol from whey are in commercial operation in Ireland, the USA and New Zealand, where about 50% of cheese whey is used to ethanol production (Mawson, 1994; Siso, 1996). In most cases, the bio-ethanol producing from non-concentrated whey can be unprofitable, because of the low ethanol concentration in fermentation broth the distillation process demands a lot of energy and it is uneconomical.

In Hungary the utilization of whey and membrane separated fractions of acid whey is used in whey based food industrial product. The whey is also could be appropriate as raw material for anaerobic digestion or animal feeding. Whey can be characterized by high chemical oxygen demand (COD) and biochemical oxygen demand (BOD) and more than 90% of 5 days BOD is caused by lactose content (Kisaalita et al., 1990). In the case of cheese whey the average fat content is less than in the acid whey and therefore the specific biogas and methane product is less.

Despite the many theoretical advantages, the anaerobic digestion is not widespread in the practice of dairy industry due to low dry matter content of whey, rapid acidification and the problems of slow reaction, which causes a longer hydraulic retention time in a continuous bio-system (Malaspina et al., 1996). Whey digestion process usually is carried out two major stage, the first involves the conversion of complex compounds to simple materials (for instance lactose into volatile acids, or polymers into monomers), in the second stage the end-products of fermentation process are transformed into mainly methane and carbon-dioxide by methanogenic bacteria (Göblös et al., 2008; Cohen et al., 1994).

Some pre-treatments assist or accelerate the hydrolysis of macromolecules or enhanced volatilization. The most commonly used process is the mechanical and combined (thermal and acidic or alkalic) methods as pre-treatments of biogas and bio-ethanol technologies, but there are some experimental lab-scale and pilot scale intensive system (assisted by microwave and ultrasound) to rapid digestion. Among pre-treatments, microwave irradiation alone or combined it with other thermal and chemical methods is considered as an intensive process with short process time and good ability to accelerate the hydrolysis stage of AD process and to enhance the specific biogas production.

The major advantage of MW heating over conventional thermal methods is the volumetric heating, which leads to faster heat and mass transfer and shorter process time. Application of MW irradiation combining with the oxidation process, such as

ozonation, can also be considered to be promising technology as pre-treatment before AD of high organic matter containing but less degradable sludge (Beszédes et al., 2009). Energy transfer carried by microwave irradiation affect the biodegradability of materials in two ways. Thermal effect is expressed in the increase of internal pressure of intracellular liquor caused by internal heating and rapid evaporation, which altogether can lead to cell wall disruption (Géczi et al., 2013). The non-thermal effect of high frequency electromagnetic field contributes to alter the structure of macromolecules with polarization of side chains and breaking of hydrogen bounds (Park et al., 2004; Lakatos et al., 2005).High efficiency of MW treatments in the biomaterial processing and also on the rate of chemical reactions is often explained by the non-thermal effects of microwaves due to the direct interaction of electromagnetic field with molecules (Leonelli and Mason, 2010). MW irradiation has been successfully adopted as pre-treatment method via the high energy dissipation of polar compounds of sludge.

There are several studies concluding that the MW method has advantages over the pre-treatment process operating by conventional heating (Toreci et al., 2009). Increasing effect of MW irradiation on anaerobic digestion of organic solid waste was found, considering the substrate to bring 78% improvement was achieved after MW pre-treatment (Shahriari et al., 2012). Zheng et al. (2009) reported that microwave heating of primary municipal sludge resulted in 2.5 fold increases in soluble organic matter content related to the control at a pre-treatment temperature of 90 °C.

Thermal and a-thermal effects of the microwave (MW) irradiation play role in the "hot-spot" overheating phenomena, and the different dielectric parameter of cell components led to selective heating manifested in the different thermal stress, which contributes in the intensive degradation of cell wall components such as cellulose and pectin (Banik et al., 2003). MW pre-treatment solely has verified positive effects on cell wall destruction and releasing of organic matter into the soluble phase, but combining of it with addition of chemicals such as alkali, acid and oxidizer agents cause synergetic mechanism to accelerate the decomposition under aerobic and anaerobic condition., as well (Cheng et al., 2011).

Materials and methods

Sweet whey was used for the measurements, which is originated from a dairy works (Sole-Mizo Ltd., Szeged, Hungary). For the microwave (MW) pre-treatments concentrated whey fractions obtained from membrane separation process were also used to test the efficiency of MW process on whey with higher organic matter content. The membrane separation was carried out by 10 kDa ultrafiltration (UF) membrane made from polyethersulfone (PES). Components of samples were analyzed by Bentley 150 type infrared photometric milk analyzator. Main characteristic of processed samples are given in Table 1.

Table 1. Main characteristic of whey and concentrated whey

	Protein [w%]	Lactose [w%]	Fat [w%]	Total solids [w%]
Whey	0.47±0.13	2.61±0.04	0.18±0.01	3.24±0.07
Concentrated whey	0.73±0.16	3.59±0.09	0.34±0.08	5.36±0.24

MW pre-treatments were performed in a tailor-made microwave system; containing a continuously irradiating magnetron with changeable power in the range of 110 W to 700 W operating at a frequency of 2450 MHz. Power of the continuously irradiating microwave magnetron is adjustable by varying of anode voltage through a transformer with variable voltage. Experiments were carried out in continuously flow system; volumetric flow rate was varied by the speed of peristaltic pump.

The chemical oxygen demand of sample was measured triplicated using colorimetric standard method (APHA, 2005). COD in supernatant was determined after separation by centrifugation (12,000 rpm for 10 minutes) and prefiltration (0.45 μm Millipore disc filter). The biochemical oxygen demand (BOD5) measurements were carried out in a respirometric BOD meter (BOD Oxidirect, Lovibond, Germany), at 20 °C for 5 days. Total organic carbon (TOC) content of sample was analyzed by Teledyn Tekmar Apollo 9000 type TOC analyzer using 750 °C furnace temperature.

Batch mesophilic biogas production tests were carried out triplicate in continuously stirred reactors equipped by Oxitop-C measuring head applied pressure operating mode (WTW GmbH, Germany). Bottles had a total volume of 500 mL with a free headspace of 350 mL for gas production. For each anaerobic digestion (AD) tests fresh mesophilic anaerobic seed sludge was used supplied from an anaerobic digester of the local municipal wastewater treatment plant (Szeged, Hungary). pH of the mixed sludge was adjusted to 7.6. Reactors were purged with nitrogen gas to remove oxygen from the bottles. AD reactors were placed in an incubator at 37±0.2°C in dark. Biogas volume produced in AD tests was calculated from the pressure increment of head space of sealed bottles

Results and discussion

In our experiments the effect of volumetric flow rate, microwave power intensity and the number of treatment were examined on the chemical oxygen demand (COD), biochemical oxygen demand (BOD) and the ratio of BOD to COD parameters. The BOD/COD shows the percentage ratio of biodegradable part of total organic matter content of processed whey.

Our results shown, that the concentrate fraction of membrane separated whey had lower biodegradability than the non separated whey; although the COD has increased during the membrane filtration. These results can be explained by the relative higher concentration of proteins and other macromolecules in the concentrate phase which enhance the total organic matter content and therefore the oxygen demand of chemical digestion but these types of components era known as heavier degradable by microorganisms.

The experimental results have verified that the microwave pre-treatments are suitable to enhance the biodegradability of organic matter contents of whey what manifested in higher BOD_5 and increased BOD_5/COD values. Microwave irradiation has effect on the structure of macromolecules of whey therefore the solubility and the ability of microbial decomposition was enhanced, as well. Similar tendency in BOD and BOD_5/COD values have been experienced after the microwave treatments of the concentrated whey.

Table 2. BOD_5 and COD of microwaved samples

Sample	q_V [Lh^{-1}]	MW power [W]	Number of treatment	COD [kgm^{-3}]	BOD_5 [kgm^{-3}]	BOD_5/COD [%]
Whey	-	-	-	89.0	24.8	27.87
Whey conc.	-	-	-	100.0	22.1	22.09
Whey	6	290	1	102.1	41.1	40.26
Whey conc.	25	290	1	92.4	34.1	36.92
Whey conc.	6	700	1	91.9	44.8	48.73
Whey	25	700	5	100.2	43.6	43.55
Whey conc.	6	290	5	88.3	44.1	49.94
Whey	25	290	5	99.3	39.0	39.28
Whey	6	700	1	103.8	50.1	48.27
Whey conc.	25	700	5	93.5	44.1	43.86
Whey	15.5	490	3	103.5	45.2	43.66
Whey	15.5	490	3	101.2	44.9	44.38
Whey	15.5	490	3	98.7	42.8	43.39

The most effective MW pre-treatment procedure produces 2-fold and 120% increment in biodegradability characterized by the BOD_5/COD parameter for whey and concentrated whey, respectively (Table 2).On the other hand, taking into consideration the increment of BOD_5/COD values, membrane separation as pre-treatment before MW operations was not beneficial. It was concluded, that the decreased volumetric flow rate due to the increased exposure time to MW irradiation resulted higher biodegradability by processing of whey and also concentrated whey. It was also experienced, that higher biodegradability was occurred after MW treatment with higher power intensity.

Beside the biodegradability obtained from aerobic degradation process the biodegradability in anaerobic bio-transformation process was also investigated. Efficiency of anaerobic digestion (AD) was characterized by the specific biogas yield, expressed in biogas production per total solid (TS) content of digested whey; and the generated biogas volume per total organic carbon (TOC) consumption during the AD process. Latter parameter gives information about the organic matter utilization during the biogas transformation and suitable to characterize the biodegradability under anaerobic condition.

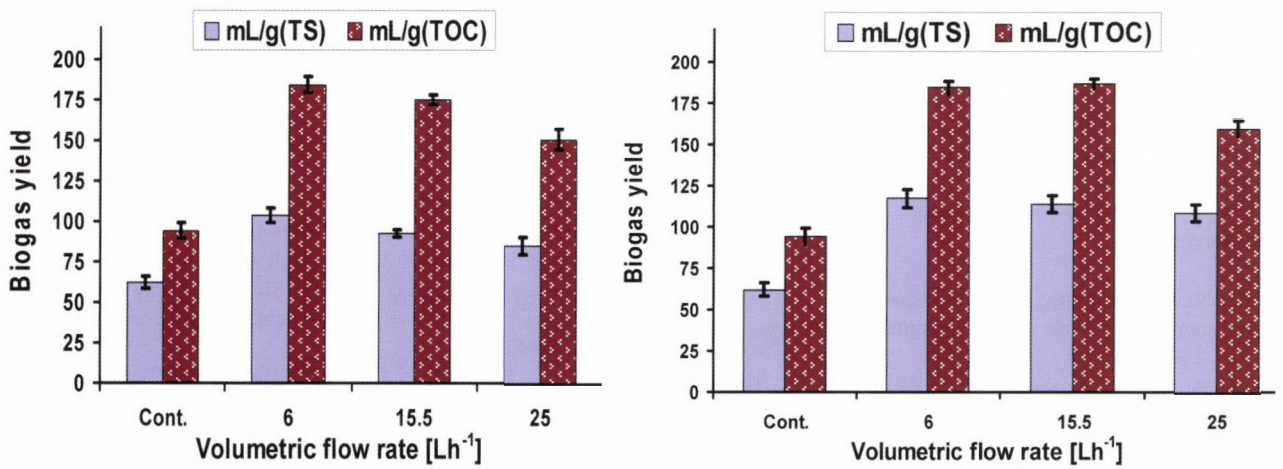

Figure 1.B Biogas yield of MW pre-treated whey samples by 280W (a) and 700W (b) MW power

Related to the control (non pre-treated) sample MW pre-treatments increased the biogas yield from whey. Specific biogas production of untreated sample (62 mL/gTS) could be enhanced to 100 mL/gTS applying 280W MW pre-treatment with flow rate of 6 L/h, and to above 120 mL/gTS after 700W microwave power with 6 and 15.5 L/h flow rates, respectively. Differences between the biogas yield obtained from MW pre-treated samples with different flow rates were higher using the lower – 280W- intensity than that of experienced after pre-treatment with the highest -700 W- power intensity.

Different tendency was observed between the effects of MW pre-treatment on values of the TS based and the TOC consumption based biogas yields, respectively (Fig. 1). There was not significant difference between the TS based biogas production of MW pre-treated samples applying different flow rates at MW power of 700W, but biogas production related to TOC consumption show that decreasing the flow rate (and therefore

increasing the residence time in MW cavity resonator) had advantageous effect on the organic matter transformation to biogas, therefore the overall efficiency of AD process was higher.

Conclusion

In our work we focused on the investigation of MW pre-treatments on the aerobic and anaerobic biodegradability of whey co-digested by sewage sludge. Our results show that microwave pre-treatments are suitable to enhance the biodegradability of sweet whey due to the increased ratio of BOD to COD. It was proved that the flow rate and ate specific power intensity has also effect on the biodegradability and biogas production of whey. Increased intensity and decreased flow rate has led to decreased solubility of organic matters of whey.

Considering the specific biogas production was concluded, that MW pre-treatments increased the biogas yield of processed whey and membrane separated concentration of it by approximately 66%, and 42%, respectively. Data obtained from whey co-digestion with sewage sludge have revealed a 60% reduction in the lag-phase of AD process using high intensity MW pre-treatment (700W) with low (6 Lh-1) flow rate. Taking into consideration of the degree of anaerobic decomposition characterized by the ratio of produced biogas volume to the consumed organic matter (given as TOC) during the AD process can be concluded that the MW pre-treatments with optimized process parameters did not decrease the efficiency of the process.

Therefore, beside the sufficient organic matter removal efficiency, the biogas production could be increased with accelerated biotransformation what indicate a higher capacity for an industrial scale continuously fed digester

Acknowledgement

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WIND ENERGY POTENTIAL ESTIMATION IN HUNGARY

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Summary

In Hungary, wind energy capacity increased in the years between 2006 and 2010. At the end of this period the quota was fulfilled, and since then there are no new investments, although there is a big demand for new projects.

The current Hungarian wind energy capacity is 329.6MW, which produces 620-730GWh/year with a capacity factor of 21-23%. With this we save approx. 220 million m^3 /year natural gas whilst we avoid ~400 000 tons of CO_2 emission.

It is a fact that wind power plants (after the return of investment -9-10 years-) produce cheap energy. From financial side wind power plant utilization is one of the most perspective investments. Our analysis points out that the ambitious plan of Hungary for 2020 (the increasing of renewable energy utilization) is unlikely to be met without wind energy utilization.

Key words

Wind Power Plant, Wind Energy Capacity in Hungary, Cost of Wind Energy

Overview of hungarian wind energy development

In the period of 1980-90 energetic wind measurements proved (made on measurement towers) that at bigger heights (100-120 m) at certain areas of Hungary there are right circumstances for wind energy utilization. The installation of the first wind power plant was in 2002 at Kulcs in Middle Hungary, the wind power plant is an Enercon plant with 600 kW performance (it was partly supported by E-ON). Due to the positive results of this first plant, there is no doubt that Hungary is is an economically proven good place for wind energy utilization.

Main steps of Hungarian development:

I. 1977¬ – 1986 – wind mills used for pumping water
II. 1980 – 1997 energetic purpose wind measurements (wind towers, electrical network towers)
V. 1997 – energetic purpose wind measurement on special towers
VI. 1999 – energetic purpose wind measurements for wind farm planning
VII. 2001-2005 Installation of individual plants
VIII. 2006-2010 Installation of wind farms

In 2005 the new law on electricity stated that the government subsides in the frames of the KÁT subsidy. This subsidy helped the investments to return in 9-11 years. After this a so called wind tender was announced for Hungarian companies. The approx. 330 MW was installed in Hungary (Fig.1). The tower height of Hungarian power plants is between 90-120 m.

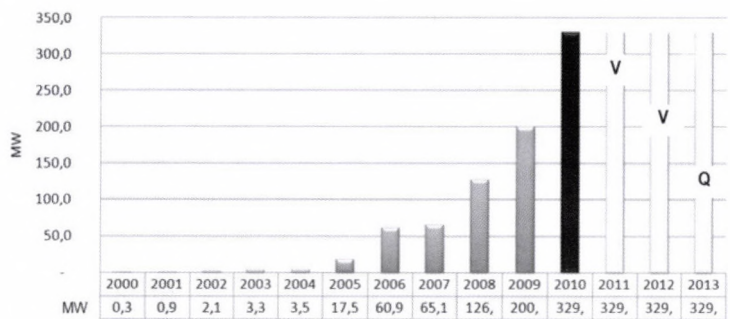


Figure 1. Hungarian wind energy capacity (until 2010) (V = unvaried, Q = announced tender)

The production of the current capacity is according to the plans 630-700 GWh/year. The utilization factor is ~21-24 %. At some parks 23-25 % value can be measures. With these data it can be proved the estimations were correct.

The current wind energy capacity is equal to the energy of ~200 million m3 natural gas, whilst ~400 000 tons of CO_2 emission can be avoided.

Development in europe and in the word

The big energy content winds are on 80-200 m, so the tower height is very important.

Capacity depend on rotor diameter as well, nowadays D>100m is typical.

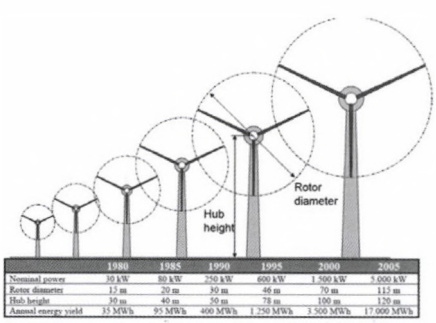


Figure 1. Hungarian wind energy capacity (until 2010) (V = unvaried, Q = announced tender)

Expected biggest capacity (can be Wp as well):

$$P_{max} = \frac{16}{27} \cdot \frac{1}{2} \cdot \rho \cdot A \cdot v_{\infty}^{3} \quad \text{(kW)} \qquad 1$$

where:

ρ – air density $[kg/m^3]$,

A – examined surface $(D2\pi/4)$ $[m^2]$,

v_{∞} – wind speed until control $[m/s]$.

Wind speed is important, see v^3. Before wind power plant installation these parameters must be defined.

The 16/27 value in the equation is the Betz maximum. In reality only smaller performance can be realized. Wind power plant producers give the P-v, c_p-v diagrams. On the c_p-v diagram at the biggest c_p value the P_n = nominal performance can be found. On the basis of the measured yearly energy production (kWh/year) and nominal performance the utilization number can be calculated (KF).

The importance of wind speed can be defined because of v^3. Because of this wind measurements are important before wind power plant installation. The value of v is increasing until the border height (which is 250-400 m). The wind values can be defined from two measured data (measured in every direction). From two measurements the Hellmann coefficient (α = in Hungary 0.2-0.4) can be defined, which is the index of the height function. At the nacelle height wind speed is (vg):

$$v_g = v_r \left(h_g | h_r\right)^{\alpha} \qquad 2$$

With the measured α data more punctual wind maps can be made (Fig.3).

$$K_F = \cdot \frac{E}{8760 \cdot P_n} \qquad 3$$

A KF *8760 (hours in a year) gives the nominal utilization hours, which is hn/year (pl. 8760 x 0.23 = 2014.8 h/year on P_n performance). According to Hungarian calculations the working of a wind power plant is economically efficient on 2000hn/year nominal performance (P_n), the investments return in 9-10 years with KÁT subsidy.

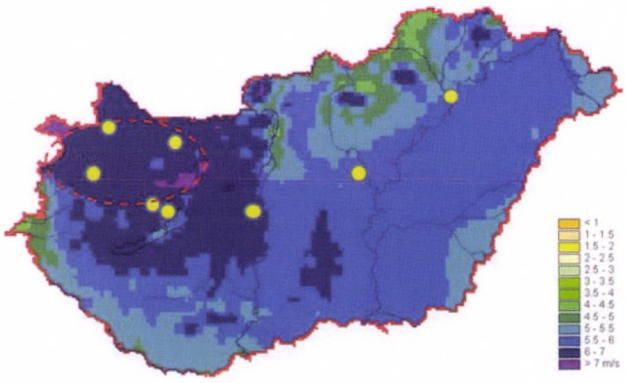


Figure 3. Hungary's wind speed map at 125 m height (Hungarian wind power plants and wind farms are marked)

Capacity development in the world

Wind power plant production is the most dynamically developing branch of industry. (Fig.4) According to WWEA report, in 2012 the capacity was 218 052 MW. The estimation for 2016 is 500 000 MW, and for 2020 1 000 000 MW.

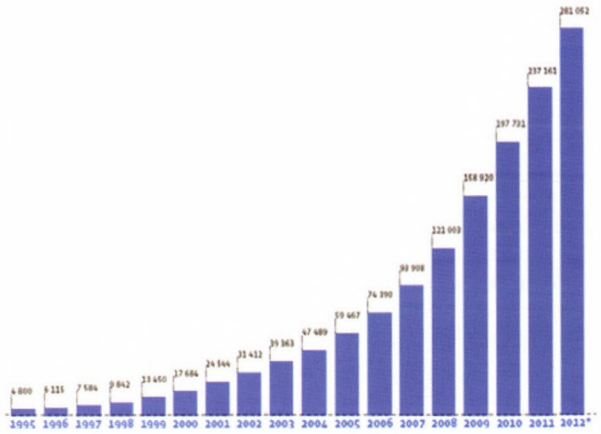


Figure 4. Trend of development (MW) until2012 in the world

Fig.5 shows yearly built capacity.

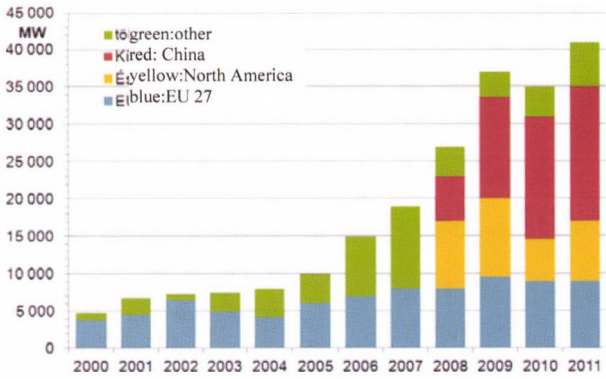


Figure 5. Yearly development trend (MW/year) until nowadays in the world (until 2008) data source: Mind Power Barometer – EUROBSERV'ER – February, 2013

In the last years China made the biggest development (Fig.5). Until 2006 Europe had the leading role in Europe. In 2008 the USA and in 2009 China took over Europe. In 2011 China invested more in development than Europe and the US altogether.

Until 2007 Europe had the leading role in Europe. In 2008 the USA and in 2009 China took over Europe. In 2011 China invested more in development than Europe and the US altogether.Fig.6 shows the European capacity at the end of 2012.

In 2011, 676 TW/h electricity was produced from renewables, which is the second biggest amount after water energy (Fig.7)

According to the National Action Plan of the EU 27 countries the capacity in 2020 will be three times bigger than in 2010. The trend of nowadays proves this (Fig.8).

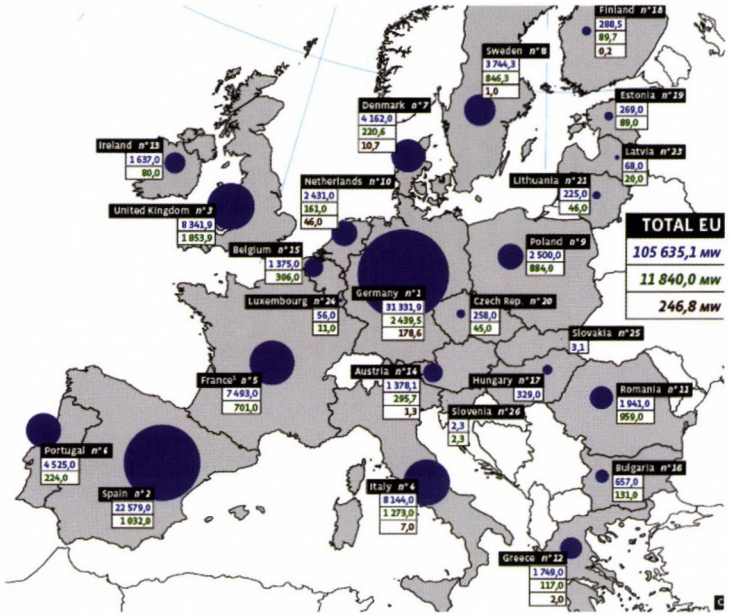


Figure 6. European wind energy capacity at the end of 2012 and capacities built in 2012

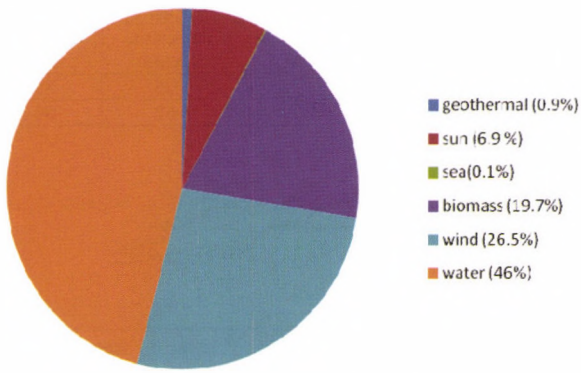


Figure 7. Renewables in the EU electricity supplies
Proportion of final gross renewable utilization for electricity production (2011)

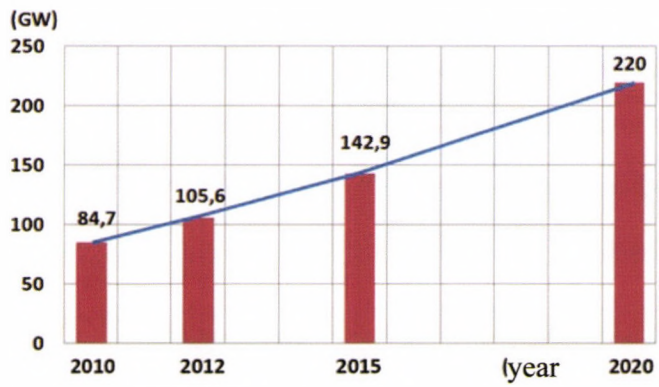


Figure 8. Wind energy capacity change according to EU27 National Action Plans
data source: Wind Power Barometer – EUROBSERV'ER – February,2013

Production costs

The production costs of the wind power plants have to be given with their utilization level since 2000. The Hungarian wind power plants are modern and they are chosen for the wind conditions of Hungary. Unfortunately we are not in leading position at the wind energy, we are at the 24th place (produced energy per capita).

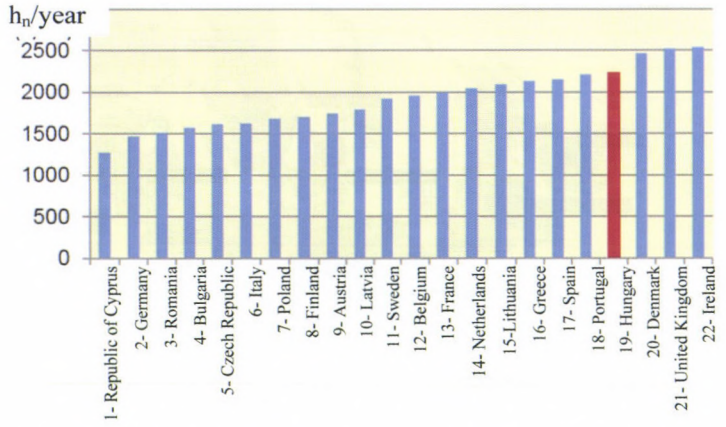
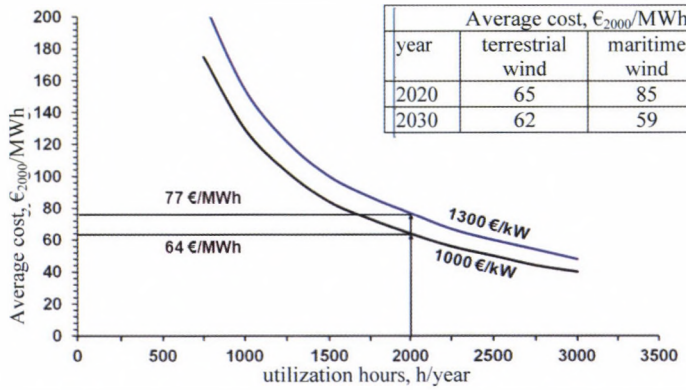


Figure 9. Utilization wind power plants (hn/year) in EU 27 countries
source: Wind Power Barometer – EUROBSERV'ER – February, 2013.

Energy production costs and costs of investments

On Fig.8 the curve represents the production cost per utilization level. The upper curve shows the data of maritime plants, and the other the lower the terrestrial plants. The maritime and the terrestrial plants differ in their material and in their construction. The terrestrial types have high towers and big diameter rotors, but the blade angle change (pitch control) is happening faster.



Average cost, €2000/MWh			
year	terrestrial wind	maritime wind	PV
2020	65	85	137
2030	62	59	113

Figure 10. Energy production costs and the utilization time (hour)
source: Wind Power Barometer – EUROBSERVER – February, 2013.

Costs

For an example we check the costs in long-term. Such example can be seen on Fig11. After installation of the plant the cost return and loan costs are typical (KÁT interval). The maintenance, repair another costs does not reach the 25-30 % of overall costs, but they are 15-20% bigger the market price of electricity (PA). At the internal of return the wind power plan gains subsidy (min8-10 years). TA+PA realizes price from. The energy production costs are 25-30% smaller at ŐK1 and at ŐK2 it rises because of higher maintenance costs, etc. At T the difference between average wind energy price and costs is bigger than the subsidies. *At governmental investments the profit is as well governmental.* In Germany the price of wind energy price will be lower than market electricity price in 2015-2016. The power plants which were built before 2006 returned.

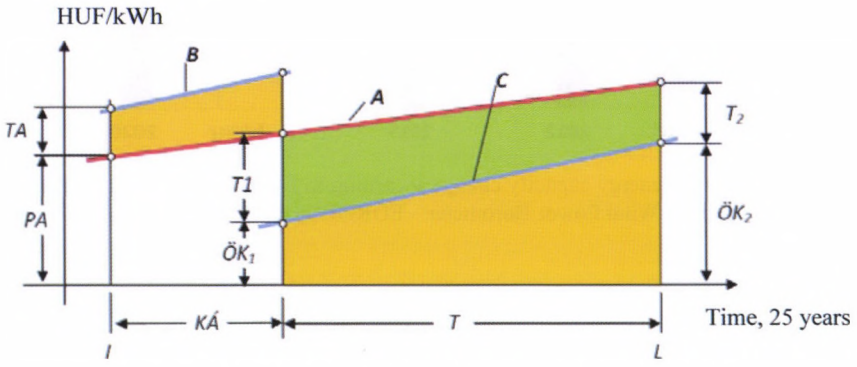


Figure 11. Costs of electricity during wind power plant lifetime

Abbreviations:

- PA = market price of electricity
- TA = governmental subsidy (KÁT, or METÁR)
- A = trend of electricity price
- B = trend of subsidies
- I-L = lifetime of equipments = KÁ + T
- KÁ = subsided interval
- T =interval after the payback of loan and subsidy
- $ÖK_1$ = costs of wind energy production (utilization, repair, control costs) after KÁT
- T_1 = the difference of electricity price and wind energy production costs after KÁT
- C = trend of electricity production (increasing utilization, repair and maintenance cost)
- $ÖK_2$ = costs of wind energy production (at de-installation of the plant).
- T_2 = costs of wind energy production (utilization, repair, control costs) a at de-installation of the plant

T_1, T_2, A and C area = gaining of the society (min. 3-4KÁT investment)

Hungarian situation

According to the NCST in the 14.65 % renewable program until 2020: out of 1530 MW renewable based electricity 750 MW should be derived from wind energy (so additionally 410 MW should be built to the current 330 MW)

In 2009 tenders were announced for the installation of 410 MW capacity. (There were competers for 1100 MW.) The quotas were not distributed, because of tender discrepancies. In the case of a new tender, the first installations can be done the earliest in 2015 (because of machine delivery deadlines).

According to other renewable trends, the Hungarian plans can only be fulfilled with a bigger investment in wind power. (See the justification in the [2] article.)

The wind power plant investments did not gain subsidies. The mood for investment is good; three years ago 1000-1200 MW additional capacity could have been built. If we would like to reach the capacity defined in the NCST, than we need to build additional 900-1000 MW. With this at the end of 2020 1300 MW would operate. Of course, the investors the only invest if they see their investment to return.

The return of investments depends on two major factors:

a) The governmental guaranteed overtaking of electricity, min. in the investment period of the equipment;
b) Subsidies of the overtaken electricity (similar to the European practice) should result in a 8-10 years long return period. (For bank acceptance.)

In Hungary the government does not invest direct stock in the wind energy installation only KÁT subsidy. The KÁT subsidy returns in short term. With the usage of wind energy the fossil fuel addiction of the country is decreasing and income rises from selling CO_2.

The lifetime of the modern wind power plants is 20 years, but with care it can be 25 years. In the future the energy produced by wind power plants will be cheaper than the energy produced by carbon plants or gas plants.

The technological increase and the increasing value of fuel prices cannot be neglected.

To be concrete if the investment returns than (approx. 10 years with subsidies) the price of electricity decreases to 8-10 HUF/kWh. There is no cheaper energy source, and the plants produce it for additional 10 years (it can be 20 years).

Loading to the electricity network

Wind energy, as other weather dependant renewables need network equation. The wind power plant owners would take these additional costs.

The equation of the network is not impossible even if it is about bigger capacities, because the reserved capacity is already in the system. The remaining performance is significant. The utilization ratio of the CCGT plants is low. The CCGT plant at Gönyű reached 60% utilization level at only one month (Fig.11) The Hungarian power plant capacity is 9000-10000 MW, the max. consumption is ~6000-6500MW , whilst we use 1000-1500 MW import each day. This means that the 330 MW wind power plant capacity, or even 3-4 times bigger would cause no problem for network equation. The installation of an equation 500-600 MW SZET power plant would be a great advantage, and even a common interest of electricity producers.

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SEASONAL HEAT STORAGE

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Abstract

Solar district heating systems require large seasonal storage capacity.

The objective of seasonal heat storage is to store summer energy for winter use. The volume of storage unit increases roughly as the cube of the characteristic dimension, and its area for heat loss increases as the square, so increasing the size reduces the loss-to-capacity ratio.

Keywords

seasonal heat storage, hot-water heat storage, gravel-water heat storage, duct heat storage, aquifer heat storage

Many projects are being launched in order to utilize solar energy for heating or cooling. Solar district heating systems require large storage facilities. In most case these stores are in the ground, as there is no other feasible way to gain the necessary capacity. In the large-scale storages the summer energy is stored for winter. They may, depending on their size, meet as much as 40–70% of the annual heating needs of a residential estate. The volume of storage unit increases roughly as the cube of the characteristic dimension, and its area for heat loss increases as the square, so increasing the size reduces the loss-to-capacity ratio.

Several ground storage methods have been developed and used. The following types of heat stores have been explored. The main types are the hot-water, gravel-water, duct and aquifer heat storage.

The choice of the type of seasonal storage is mainly depends on the local conditions and primarily, on the geological and hydrogeological situation in the ground.

The hot-water heat storage has the widest range of utilization possibilities. (See Fig.1.)

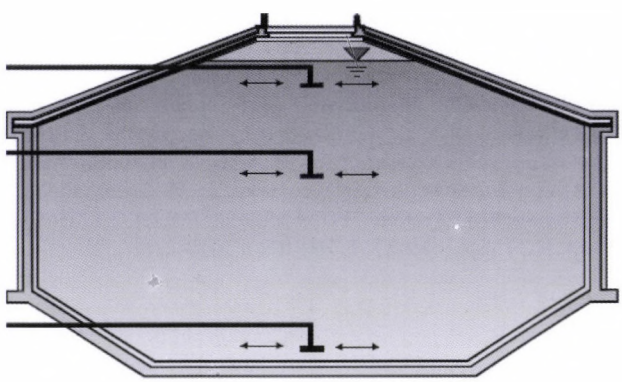

Figure 1. Hot-water heat store

Energy is added to or removed from the large underground water storage tanks or caverns or water filled pits in the ground that are roofed over by pumping water into or out of the storage unit. The hot-water heat store is made of usually reinforced concrete and is partly embedded into the ground. It can be built almost independently from geological conditions. The storage has heat insulation at least in the roof area and on the vertical walls.

A hot-water heat store made of a new high-density concrete material was built for the first time in Hannover. This material has a low vapour permeability so that an additional liner is not necessary. There are developments, for example an additional charging and discharging device with a variable height was fixed in the middle of the storage volume. Because of this development, the temperature stratification in the store can be improved and simultaneous charging and discharging becomes possible. This plant is in operation since June 2000.

The gravel–water heat store has a watertight plastic liner and filled with a gravel–water mixture forming the storage material. (See Fig. 2.)

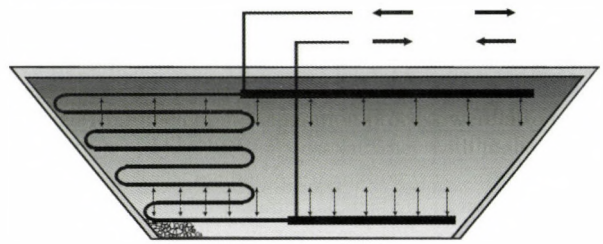

Figure 2. Gravel-water heat store

There is heat insulation at the side walls and on the top. Heat is charged into and discharged out of the store either by direct water exchange or by plastic pipes installed in different layers inside the store. The gravel–water mixture has lower specific heat capacity of, so that the volume of this type of stores has to be approximately 50% higher compared to a hot-water heat store to obtain the same heat capacity for the whole store. Gravel–water heat stores are in operation at the University of Stuttgart (ITW, 1050 m^3), in Chemnitz (8000 m^3), Augsburg (6500 m^3) and Steinfurt-Borghorst (1500 m^3).

The store in Chemnitz was built in 1996, the maximum temperature of storage is 85°C and is charged or discharged by direct water exchange. The system is planned for an annual heat demand of 1200 MWh/a and a solar fraction of 42%. Since spring 2000, the store is charged with the collectors of the first phase.

In August 1998, the demonstration plant in Steinfurt-Borghorst was put in operation. 42 apartments,

15 single-family and 7 multifamily houses are provided by the store, which is a gravel–water heat store. It is charged or discharged by horizontal heat exchanger pipes.

The third type of seasonal heat store is the duct heat store. (See Fig.3.)

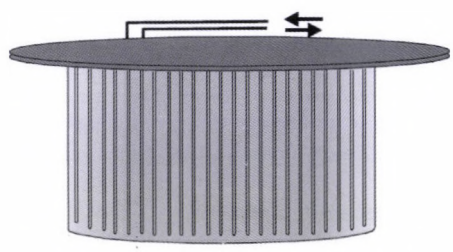

Figure 3. Duct heat store

In this type of heat stores, heat is stored directly into the ground. Suitable geological formations for this kind of heat storage are e.g. rock or water-saturated soils. Heat is charged or discharged via vertical borehole heat exchangers which are maximum 30–100 m deep. The construction of this store is showed by the Fig. 4.

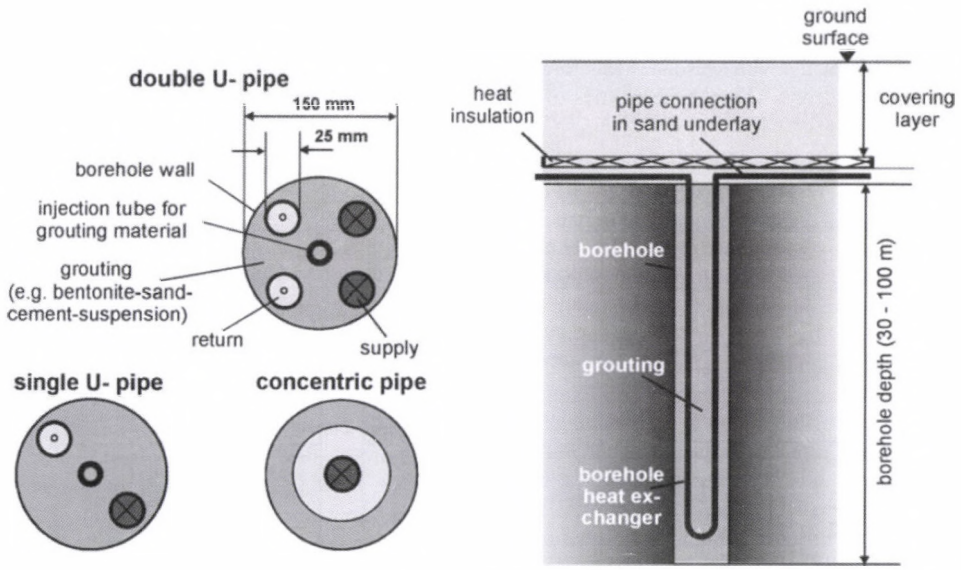

Figure 4. The construction of duct heat store

There is a heat insulation layer at the top of the store to reduce heat losses to the surface. In this case capacity at charging and discharging is lower too, so that usually a buffer store is used in the system.

In 1997, in Neckarsulm was built a pilot duct heat store with a volume of approximately 4300 m^3. The first part of the store (with 20,000 m^3) was built in 1998. In the year 2001, the second phase with an increased volume of 63,400 m^3 was realised.

In Attenkirchen too was built a seasonal heat store system. 30 low energy houses are supplied by the solar system with a collector area of 800 m^2. The heat store is a combined hot-water and duct heat store. A central concrete tank with a volume of 500 m^3 is surrounded by 90 ducts (30 m deep). Depending on the temperature levels in the two parts of the store, heat pumps use the ducts as heat source and deliver heat into the hot-water tank or use the hot-water tank as heat source and supply heat into the district heating network.

The last type the aquifers are below-ground widely distributed sand, gravel, sandstone or limestone layers with high hydraulic conductivity which are filled with groundwater. (See Fig. 4.)

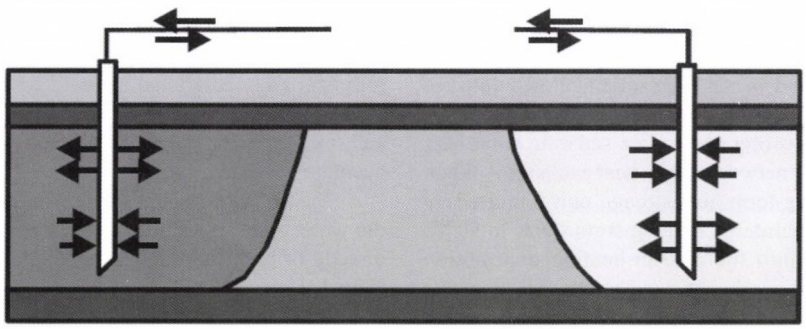

Figure 5. Aquifer heat store

During charging periods cold groundwater is extracted from the cold well, heated up by the solar system and injected into the hot well that we can see on the picture. In discharging-periods the flow direction is reversed. Because of the different flow directions both wells are equipped with pumps, production- and injection pipes. Especially for high temperature heat storage a good knowledge of the mineralogy, geochemistry and microbiology in the underground is necessary to prevent damage to the system caused by well-clogging, scaling etc. Aquifer heat stores are in operation in Rostock and Berlin.

In Rostock, in 2000, the first CSHPSS-system with an aquifer heat store went into operation. A large

multi-family house with 108 apartments is provided heat by the plant. The store is situated in a depth of 15–30 m below ground surface and is operated at a temperature level of maximum 50°C in order to reduce the heat losses and to avoid water treatment. A heat pump is integrated in the heat supply system to achieve a high storage efficiency. A low-temperature heating system with radiators has been realised for heat distribution in order to maintain low operating temperatures (maximum supply temperature 45°C) and consequently favourable operation conditions for the solar system and the heat pump.

The perfect integration of the solar system into the conventional heating system as well as a high design quality – of both the solar part and the conventional parts such as district heating network, transfer substations, HVAC-systems in the buildings etc. – are vital for its optimum functioning. To dimension and design a seasonal heat store, detailed system simulations are necessary. The price advantage of large plants compared to small ones is mainly caused by their more favourable system cost: while small plants come up to an average system cost of Euro 1000 per m^2 flat-plate collector surface, large plants

with diurnal heat storage reach about Euro 500 per m² when integrated into new buildings. A substantial part of the investment cost of central solar heating plants with seasonal heat storage is caused by the seasonal heat store. The cheapest types of heat stores are duct and aquifer heat stores. However, they also make the highest demands on the underground on-site.

The systems in Hamburg and Friedrichshafen were built according to a similar scheme, which is shown on Fig. 6.

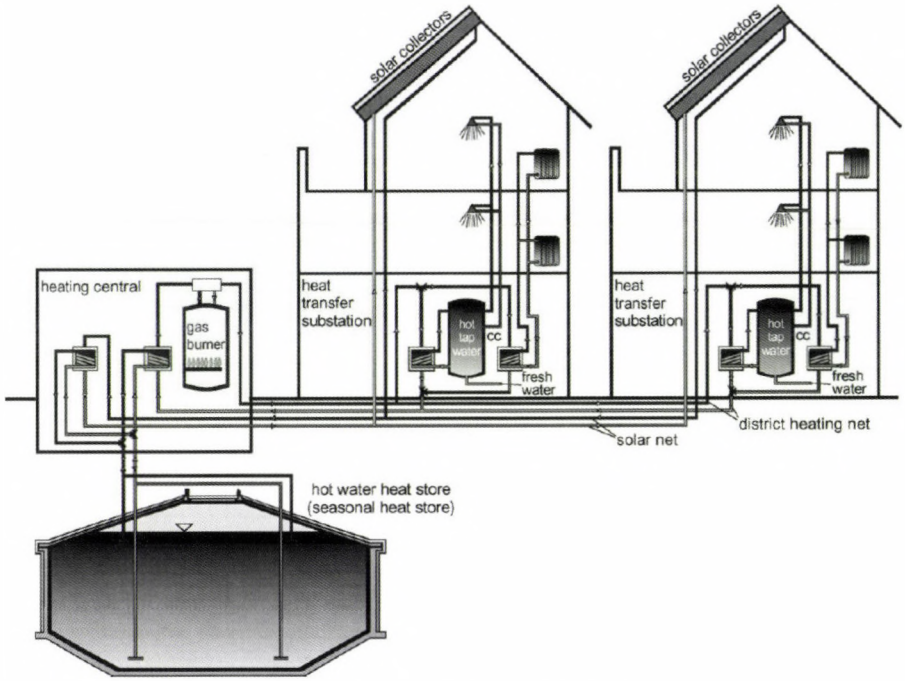

Figure 6. The system schema in Friedrichshafen

The heat obtained from the collectors on the roofs of the buildings is transported to the central heating plant via the solar network and directly distributed to the buildings when required. The surplus heat in the summer period is charged into the seasonal heat store to be used for space heating and domestic hot water supply in autumn and winter. The solar heat generated in summer will be fed into the storage recharging loop of the long-term storage unit in the heating plant via a separate solar-heat distribution network (solar network) and a heat exchanger. When the sun is shining the long-term heat storage unit is heated by the solar network to temperatures ranging from 40°C to 90°C. This heat is discharged into the district-heating distribution network (heat network) via another heat exchanger. The amounts of heat needed for heating and hot water in the individual quarters are, in turn, separated off via a heat exchanger in heat transfer stations.

In a systematic analysis of different system concepts with various backup systems those options with heat pumps showed technical and operational advantages as the useful temperature heave in the store is bigger. The high dependency of the system and storage performance on the return temperature of the district heating is avoided.

As shown in the system scheme in Attenkirchen discharging of the water store as well as of the borehole storage can be done directly or by heat pumps depending on the temperature levels. (Fig. 7.)

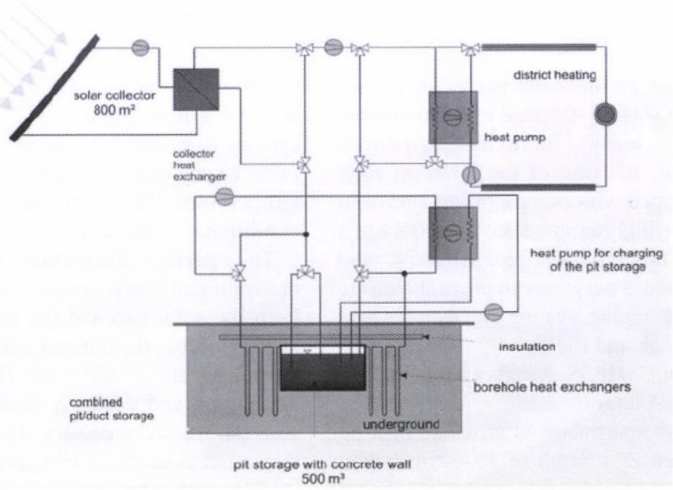

Figure 7. The system schema in Friedrichshafen

In the future maybe such system will be built in Hungary too, because this theme is interested by many Hungarian companies. Solar renovation of existing district heating systems will become increasingly important as a way of reducing fossil energy demand and CO_2-emissions in existing urban areas. Solar renovation of existing district heating systems will become increasingly important as a way of reducing fossil energy demand and CO_2-emissions in existing urban areas.

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MONITORING THE ROASTING PROCESS OF ARABICA COFFEE BY VISION SYSTEM, NIR AND ELECTRONIC TONGUE METHODS

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Abstract

Visual inspection and light reflectance method are generally used to determine the end of coffee roasting. Because of the lack of an exact method during the process, over-roasting can occur. Therefore our purpose was to evaluate the capability of NIR and Vision system to discriminate the differently roasted coffees and the ability of the electronic tongue for brewed coffee differentiation to monitor the various roasting phases. The prediction of roasting degree of ground coffee by NIR (R^2=0.98) and HUE (R^2=0.97) was promising. The Vision system can be a built-in tool to monitor and thus to avoid over-roasting.

Keywords

Arabica, electronic tongue, NIR, vision system, HUE spectra

Introduction

The determination of the roasting parameters such as roasting temperature, roasting time, are based on long year's experiences achieved by coffee experts and roast masters. One of the most commonly used criteria to evaluate the quality of coffee beans after roasting includes the measurement of color. During roasting it is perceived by visual inspection of the roast master. Several methods were applied to monitor the roasting process for the purpose to ensure the stable quality and thus make the roast master's work easier.

For the prediction of coffee roasting Alessandrini and his co-workers (2008) already applied near infrared (NIR) spectroscopy on the wavelength interval of 830–2500 nm taking into account density, weight loss and moisture. Different roasting degrees were predicted by partial least square (PLS) regression with high accuracy, leading to high correlation coefficient results between measured and predicted roasting variables. This method might be used for on-line quality control purposes, allowing a straightforward, reproducible and objective determination of roasting properties of unknown coffee bean samples.

On-line measurement of the brightness and surface kinetics was realized by a vision system in case of Colombian Arabica coffees roasted at different temperatures. On-line image analysis made possible a comparison between the measured grey level and a target grey level at each time point. The obtained roasted coffee after this experiment was very similar to the target coffee, and the prepared coffee brew was acceptable by the laboratory team (Hernàndez et al., 2008).

The electronic tongue is a relatively new tool to analyze liquid samples, mostly used for wines (Novakowski et al., 2011), beer (Rudnitskaya et al., 2009), etc. In 2006 the results of an experiment published showed that the electronic tongue is able to discriminate correctly the coffees with different concentration and also produced with different technologies, such as traditional, instant and caffeine free according to taste attributes (Kántor et al. 2006). However there is no reference available which shows the application of electronic tongue to discriminate differently roasted coffees.

Objectives

The purpose of the work reported here was to evaluate the capability of Near Infrared Reflectance (NIR) spectroscopy and Vision system to discriminate the differently roasted coffees in complete and grounded form and the ability of the electronic tongue for brewed coffee differentiation to monitor the various roasting phases.

Our further aim was to find an exact method to avoid over-roasting thus to replace the expensive color measurement method and help human work with a possibly automated built-in Vision system.

Materials and methods

Materials

100% Arabica coffee was roasted for our experiments to light (L1, L2, L3) and dark roast (D1, D2, D3) from the same batch with the help of a home roaster called IRoast2 (Hearthware, Inc., U.S.A.). The roasting temperature and the roasting time of the home roaster were programmable. The first phase of the roasting procedure was held for 1.5 min at 180°C, the second for 2 min at 200°C and the third at 200°C for 2, 3, 4, 5, 6 and 7 min respectively for L1, L2, L3, D1, D2 and D3 ("home roasted" samples). Each program finished with an automatic cooling part. The coffee samples were grounded for 0.393 mm particle size. Commercial samples (B1, B2, T1, FK, FE), chosen from the light and also from the dark roasted categories were analyzed (the same first letter signifies same brands).

Methods

The whole roasted coffee beans were measured by MetriNIR (Metrika Kft., Budapest, Hungary) device and Vision system without any sample preparation. MetriNIR performed the measurements in a range from 700 nm to 1700 nm. The Vision system was composed of a HITACHI camera. The required diffuse light was provided by 12 Tungsram halogen lamps. The number of the parallel measurements in case of NIR was 15, in case of Vision system 20.

The same methods were used for the ground roasted coffee samples with 10 repetitions in both cases because of the homogeneity of the ground samples. These analyses were completed by a color reflectance measurement usually applied in the industry as a reference method for the prediction of the coffee color. (DrLange Color Reflectance Meter LK-100). The device was equipped with a 640 nm built-in filter (US patent). The prediction of the roasting degree was realized by the results of the applied three measurement methods.

Each pixel of the image made by the camera of the Vision system is composed of three color components (R-red, G-green, B-blue) which were converted into the HSI (H-hue, S- saturation, I- intensity) color system. Hue represents the angular location (0 to 360°) of the color in the HSI color coordinate system. The HUE spectra based on the sum of saturation was computed for each picture. The statistical evaluation of the NIR and Vision system data was performed using Polar Qualification System (PQS) method. The polar qualification system is a general and powerful data reduction method rooted in the evaluation of NIR spectra. The quality of any spectra like data set is defined as the centre of its polar spectrum (polar coordinate system, where radius is the function of spectral value and angle is a function of wavelength.

To compute coordinates of the quality point there are 3 approaches: the point, line and surface methods (Kaffka and Seregély, 2002). We used all mentioned methods, the best results were obtained with the point method when the x, y coordinates were calculated. Partial least square (PLS) regression was applied to predict the color values/roasting degree of the differently roasted coffee samples based on the NIR and Vision system results. The obtained models were evaluated according to their determination coefficient and root means squared error of prediction (RMSEP).

An Alpha Astree Electronic Tongue (Alpha M.O.S., Toulouse, France) was utilized for the brewed coffee assessment. The device is composed of 7 ion-selective sensors with organic coatings and a reference electrode. The scheme of the instrument is presented on Figure 1. The Ref 803-0005, "sensor array #1 was applied including 7 sensors, named: ZZ, BA, BB, CA, GA, HA and JB sensors in agreement with the producer. The brewed coffee samples were prepared with 6g of coffees in 100 ml distilled water using pouring procedure according to the industrial practice. For the experiment they were filtered and 10-fold diluted. Before starting the measurement a conditioning procedure was needed with 0.01M HCl solution (AlphaM.O.S., 2003). The calibration was accomplished by the mixture of the coffee samples. Each sample was measured 9 times, between each measurement a cleaning procedure of the sensors was performed in distilled water. In the sequence the order of the samples was randomized.

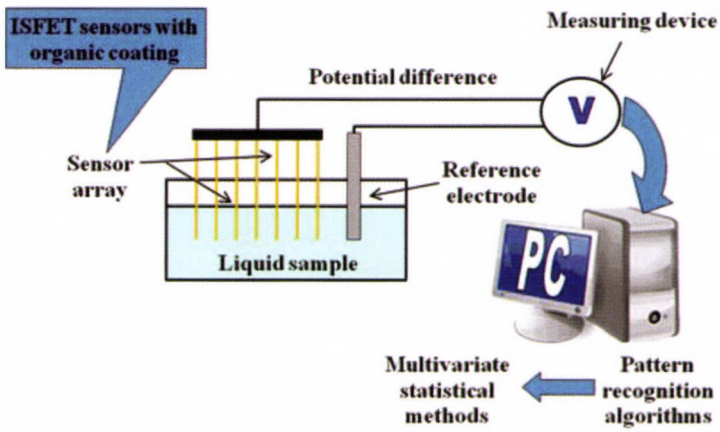


Figure 1. Setup of the Alpha Astree Electronic Tongue

The steady state of the electronic tongue sensor signals was applied as variables for the statistical evaluation considering an average value calculated from the last 10 seconds of each measurement result. The obtained matrix composed of the different sample groups with their repetitions as cases and with the 7 electronic tongue sensors as variables. The first step of the data processing was the outlier detection based on the results of PCA. PCA was used for data evaluation as well. PLS regression was used for the prediction of the color values/roasting degree of the differently roasted coffee samples by the electronic tongue results. The validation was performed by LOO (leave-one-out) method

The program R 2.13.2 (R Foundation for Statistical Computing, Vienna, Austria) was used for PCA and PLS prediction. HSI and PQS data were calculated by self made R-project script.

Results and discussion

Results of the Vision system assessment

On Figure 2 the HUE spectra of three coffee samples are shown for whole and ground form. The whole beans of the light sample are characterized mostly by red components which turn into blue in case of the darker roast. This color distribution is more concentrated and turns into violet already in the event of the light roasted sample.

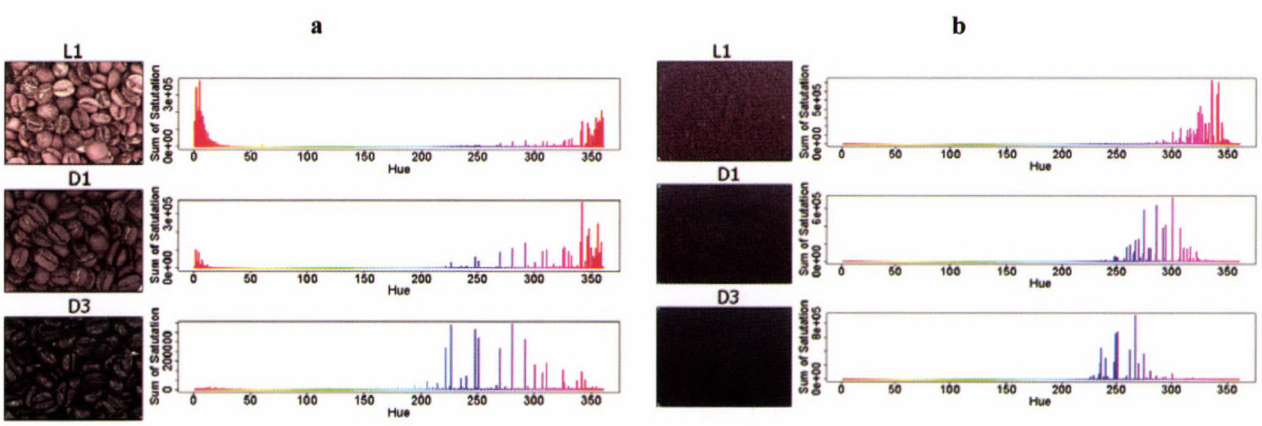


Figure 2. Color changes of the roasted beans (a) and ground coffee (b) measured by vision system

Because of the complicated handling of HUE spectral data, a data reduction method was needed. The point method of PQS was applied to determine the centre of gravity with two coordinates therefore the coffee samples were comparable. In case of the whole coffee beans the raw Arabica coffee was also analyzed.

On Figure 3 the PQS plots of the differently roasted whole beans and ground coffees are presented. In both cases (a, b) the represented points of coffee samples showed a monotonous change along a curved path in the right order of the roasting degree ("home roasted" samples). This curve was compressed due to the raw sample. The commercial samples from the same brands were on the same curve path, the difference between the brands' curves was possibly due to the different roasting procedure. A larger difference was observed between the dark roasted samples, 1 min may cause bigger differences in this area than in case of light roasted coffees.

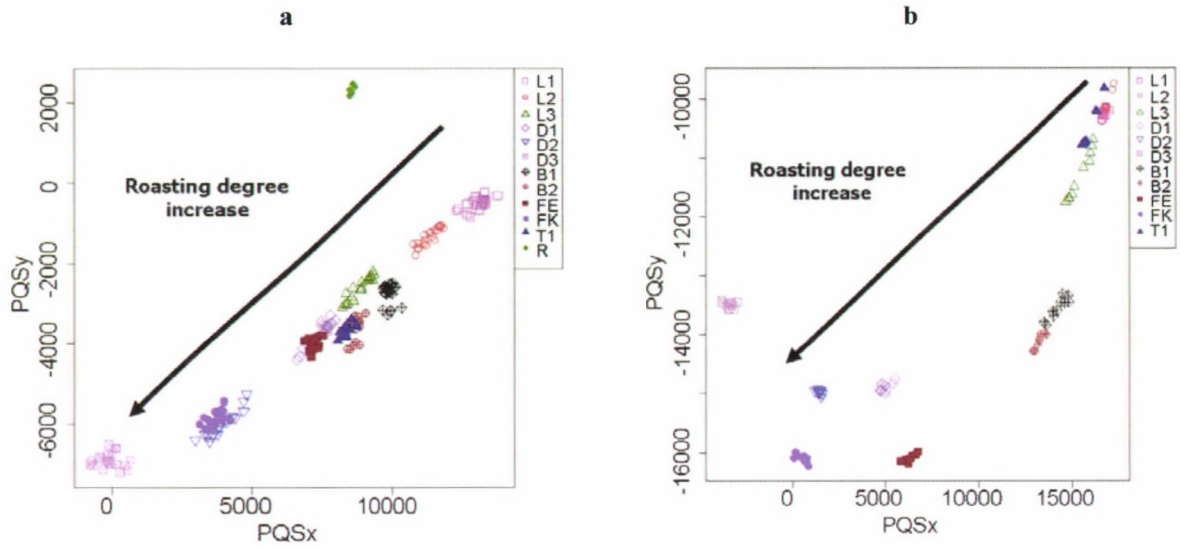


Figure 3. PQS (point method) of the differently roasted beans (a) and ground coffee (b) based on HUE measured by vision system

Results of the NIR measurements

The results of the PQS data reduction method are plotted on Figure 4, where the different wavelengths were handled as spectral data and the coordinates of the centre of gravity were calculated. The curved path was also observable in case of the whole and the ground coffees as well, but the obtained points had higher deviation. The light roasted coffee samples were overlapped (L1, L2, T1). The dark roasted samples were definitely distinguished from the light samples. In case of the ground coffees the measured points are more homogenous, the differentiation was more visible.

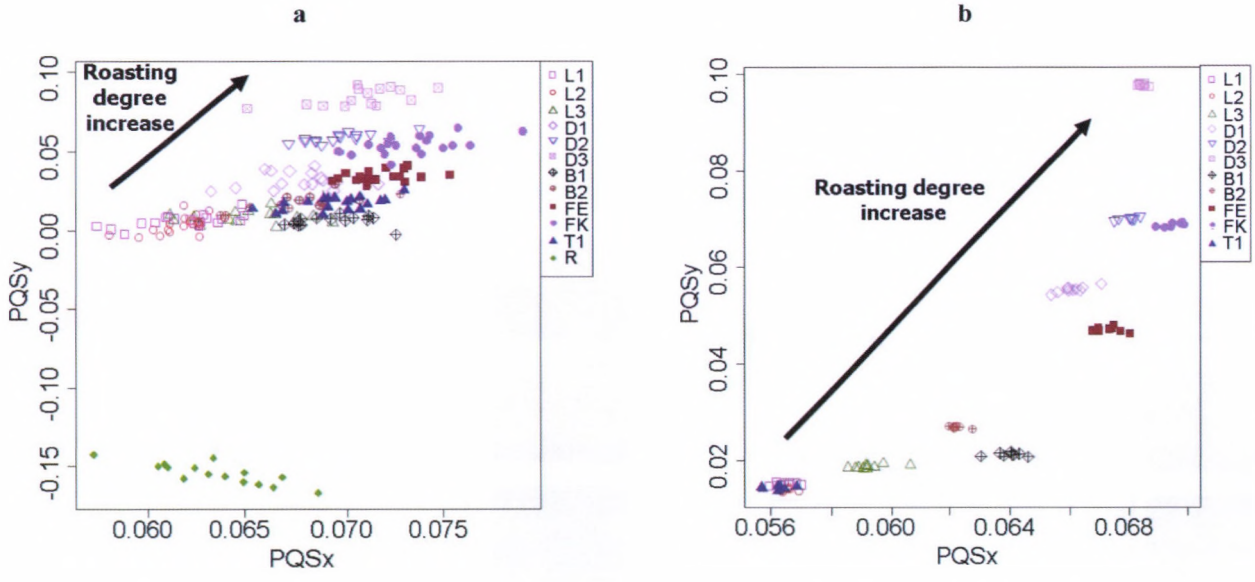


Figure 4. PQS (point method) of the differently roasted beans (a) and ground coffee (b) based on NIR results

Results of the DrLange color measurement

The ground coffee samples were measured with DrLange color reflectance meter, the dimensionless color values are presented on Figure 5. The classification of the samples into light and dark roast groups was arbitrary considering the industrial practice. The ground coffee sample points on the PQS plots of the Vision system and NIR measurement follow the same order according to the DrLange color values. However in case of the whole roasted beans the commercial T1 sample is overlapping with B2 based on the results of the two methods.

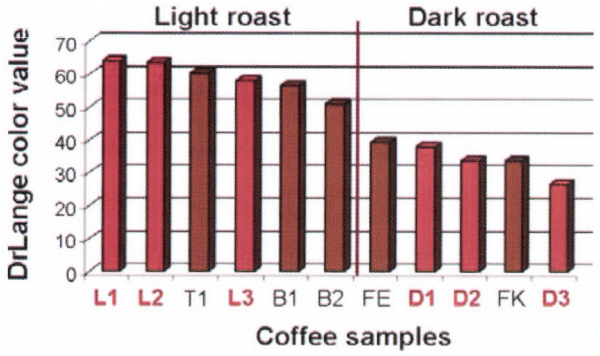
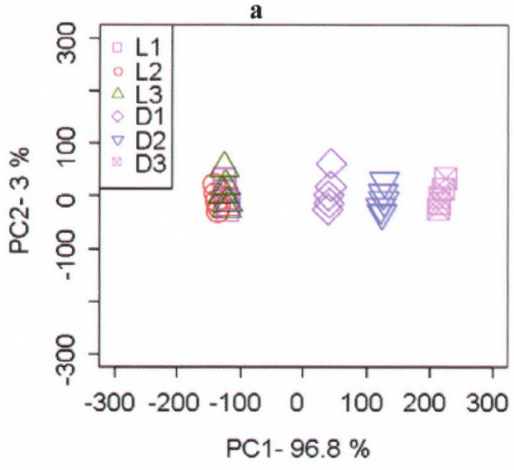


Figure 5. DrLange dimensionless color values of the differently roasted coffee samples

Electronic tongue (ET) measurement results for coffee brews During the preliminary data evaluation of the ET results three points out of the nine repetitions was found to be outliers. Figure 6 shows the PCA of the differently roasted coffee samples. The first two principal components contained more than 95% of the data variance on both plots. On Figure 6/a the samples were discriminated in the right order according to the roasting degree. The light roasted coffees (L1, L2, L3) were overlapped, however well discriminated from the dark roasted samples (D1, D2, D3). The dark roasted coffees were discriminated from each other, signifying that even 1 min can result large differences in taste approaching at the end of the roasting process.

On Figure 6/b among the light roasted coffees L1, B1 and B2 were overlapped. The measured points of T1 sample were discriminated from the light roasted samples; the reason can be the different roasting process of the different brands. The dark roasted samples FE and FK were close to each other, however discriminated from the darkest roasted sample.



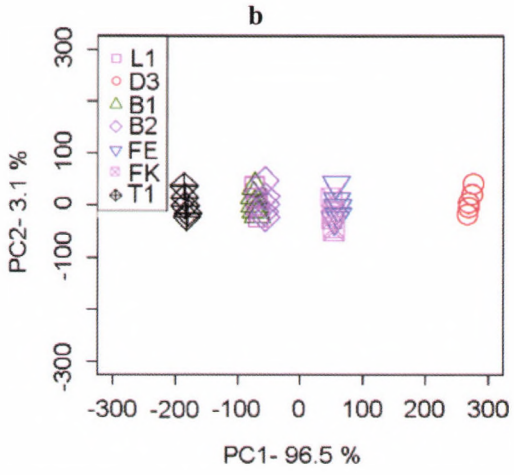


Figure 6. PCA of the electronic tongue measurement results in case of the „home roasted" samples (a) and the commercial samples with the lighter and darker "home roasted" samples (b)

PLS regression to predict the roasting degree by all the applied methods

The DrLange color values or roasting degrees were predicted with PLS regression by the Vision system, NIR and electronic tongue data. The best prediction was achieved by the NIR data (R^2=0.98, RMSEP=1.94). The prediction based on the HUE (Vision system) results was very promising showed by Figure 7, because the determination coefficient was very close to that of the NIR (R^2=0.97), and the RMSEP was relatively low as well (RMSEP=2.16). In case of the electronic tongue an acceptable R^2 value (R^2=0.88) and error (RMSEP=4.49) were obtained.

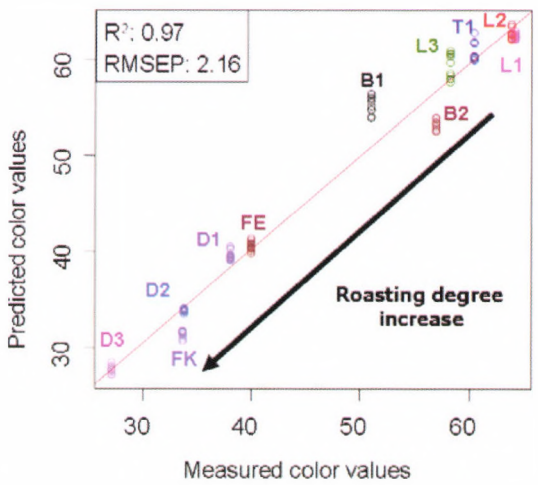


Figure 7. DrLange color/roasting degree prediction by the Vision system data with PLS regression

Conclusion

According to our results the evaluation by PQS using the so called point method a monotonous change along a curved path was observed for roasted coffee beans and also for the ground roasted coffees (NIR, Vision system). The electronic tongue showed a good discrimination of the differently roasted and commercial coffee samples according to their roasting degree. However the prediction of roasting degree (measured by DrLange) of the ground coffee gave better results by the expensive NIR method

(R^2=0.98), the determination coefficient of HUE (R^2=0.97) was also encouraging. The PLS of the roasting degree prediction by ET resulted the R^2 of 0.88. Thus the Vision system can be a promising, fast and cheap tool to avoid over roasting using a camera and HUE spectra data evaluation method. Further experiments are needed for the foundation of a database for the different coffees processed in a factory; in consequence the roasting procedure can be monitored and controlled.

Acknowledgements

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INVESTIGATION OF FRICTION COEFFICIENT BETWEEN VEHICLE BODY AND SOIL

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Abstract

If a vehicle leaves the on-road, and enters the terrain, its movement is determined by the physical and mechanical laws of terrain-vehicle interaction. The problem with the run-off-road accidents is that the effect of the soil physical properties are not known clearly, so that in many cases only approximate results can be provided by the accident analysts. The objects of the project were to create a soil-database, and determine the friction coefficient between the vehicle body and the terrain surface.

Keywords

terramechanics, accident, friction coefficient

Introduction

The travel resistance of a vehicle running on to terrain after collision is determined by the rolling resistance, bulldozing resistance, slope resistance, air resistance, slowing effect of engine brake or vehicle brake, if the vehicle spins around its vertical axis then resistance due to vehicle spin and if the vehicle turned over then frictional resistance of vehicle body (Kiss, 2009). The problem with the road-leaving accidents is that the effect of the soil physical properties are not known sufficiently, so that in many cases only approximate results can be provided by the accident analysts (Pillinger and Kiss, 2011).

Complex field measurement series were performed by the colleagues of Department of Automotive Technology of Szent István University. The purpose of the project was to determine the friction coefficient between the soil and the vehicle body in case of overturn.

Examination of friction coefficient

To determine the coefficients of friction, pulling tests were performed, and soil parameters were also measured by in situ and laboratory devices. Friction between the soil and vehicle body, traction force, speed, and different soil conditions (cone index, moisture content, physical properties) were examined during the experiment. The test vehicle was a UAZ-469B type off-road vehicle, and a John Deere 6600 was used as puller (Fig. 1-2.). A special converted forklift was used to turn over the test vehicle to its body side. A purpose-designed drawbar mechanism was used for the pulling tests (Fig. 3.). The measurements were carried out on different soil conditions: concrete, grassy field, stubble-field, disc-tilled field and cultivator-tilled filed at a speed of 5-10-15 km/h.

Figure 1. UAZ set up for measurement.

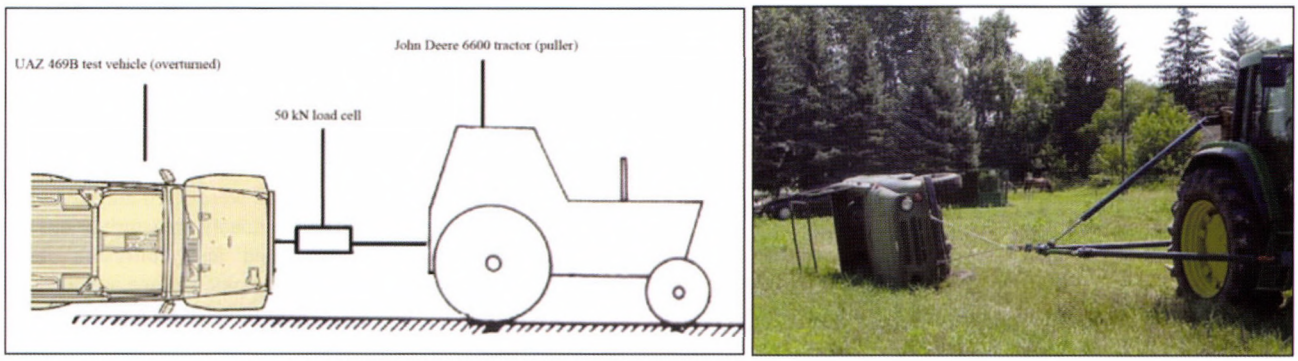

Figure 2. Set up of the field measurement.

Measurement devices

The following equipments were used at the measurements: purpose-designed drawbar mechanism and converted forklift (Fig. 3.), 50 kN load cell (Fig. 4.), measurement battery, Spider-8 data collection and measurement computer (GDS Instruments, Hampshire, United Kingdom), Eijkelkamp Penetrologger (Fig. 4.) (Eijkelkamp, Giesbeek, The Netherlands), PCE-SMM-1 field soil moisture meter (PCE Instruments, Southampton, United Kingdom), soil sampling cylinders (Fig. 4.), wheel load weighers to measure vehicle weight.

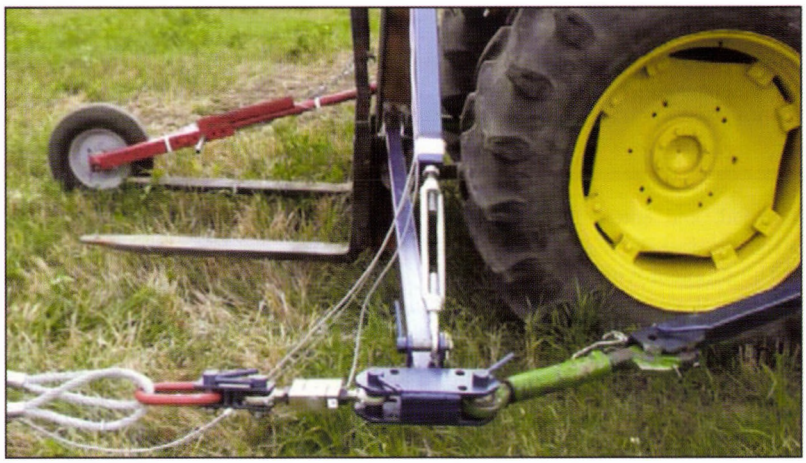

Figure 3. Purpose-designed drawbar mechanism with a converted forklift.

Figure 4. Eijkelkamp Penetrologger, soil sampling cylinders, load cell.

Results

Table 1. shows the physical characteristics of the test field. The measurements were performed with the help of staff of the Institute of Soil Science of Szent István University.

Table 1. Physical properties of the test field.

Field condition:		Stubble-field	Disc-tilled	Cultivator-tilled
Soil type:		Loamy sand		
Moisture content (% dry basis)	[%]	15.8	11.5	10.8
Pore volume	[%]	36	38	42
Dry bulk density	[g/cm^3]	1.61	1.65	1.52
Vegetation:	-	Stubble+weeds	A few weeds	No plants

Table 1. Physical properties of the test field.

$$F_t = \mu \cdot m \cdot g \cdot \cos\alpha \pm m \cdot g \cdot \sin\alpha \quad [kN] \qquad 1$$

$$\mu = \frac{F_t \cdot \cos\alpha}{m \cdot g} \mp tg\alpha \quad [-] \qquad 2$$

Where: F_t – traction force; m – mass of test vehicle; g – gravitational acceleration; μ - friction coefficient; α – slope angle.

The pulled vehicle's weight was measured by wheel load weighers. The measured mass was 1310 kg. The pulling force was measured in the tests. The speeds were 5, 10 and 15 km/h, and each test was performed on a previously undisturbed surface of grassy field, stubble, disc-tilled and cultivated land. Measurements were carried out on concrete surface as well.

The friction coefficients were determined at each surface type. Table 2. gives the values of the coefficients. The field coverage is an important factor during the investigation. The concrete was dry and without dirt. The grassy field was covered by 5-10 cm

high vegetation, mainly grass. The stubble field was covered by 15-25 cm high weeds and harvested corn stalks. On disc-tilled field only rare weeds were recognized and the cultivator-tilled field was without vegetation. Table 2 gives the cone index (CI) values at a depth of 5 and 10 cm as well, characterizing the soil's load-bearing capacity. The measurements were performed for all soil conditions, taking the soil moisture content into account. The average slope angle, that was taken into consideration during the evaluation, on the test field was $\alpha = 1.1°$. The slope angle on concrete was $\alpha = 0°$.

Table 2. Results of examination of friction coefficients.

Field condition	Traction speed (v) [km/h]	Traction Force (F_t) [kN]	Friction Coefficient (μ) [-]	Cone Index (CI_5) [MPa]	Cone Index (CI_{10}) [MPa]	Comment
Concrete	5	6.6	0.518	80	80	Dry, without dirt
	10	5.4	0.424			
	15	5.2	0.405			
Grassy field	5	7.8	0.591	2.146	2.345	5-10 cm high vegetation
	10	8.1	0.607			
	15	8.2	0.621			
Stubble-field	5	12.2	0.932	0.809	1.185	15-25 cm high vegetation
	10	-	-			
	15	-	-			
Disc-tilled field	5	12.4	0.946	0.427	1.498	Rare vegetation
	10	13.1	0.993			
	15	-	-			
Cultivator-tilled field	5	14.1	1.081	0.034	0.048	No vegetation
	10	16.1	1.227			
	15	-	-			

Conclusions

In case of two rigid bodies, the magnitude of friction force is commensurable to the normal force; its direction is parallel to the contact surface. In this situation the friction coefficient depends on the quality of the contact surface. If a rigid body gets in contact with a deformable surface, further factors affect the value of friction coefficient. Table 1. shows that on terrain the value of friction coefficients increased as traction speed increased as well, and the looser the soil structure became, the greater the value of friction coefficients. It can be seen on concrete that the value of friction coefficients decreased as speed increased. It is due to the multiple repeated pulling tests where the vehicle body side and the protruding parts were deformed and dulled, thus the value of friction coefficients decreased. It can be concluded from the researches that on terrain the coefficient of friction depends on more parameters. Their effects are different, field measurements are required to determine the significance of each factors, which are the following in order of importance:

Normal force: The greater the normal force (vehicle mass), the greater the soil deformation and the probability of bulldozing-effect.

Surface quality: The smoother the vehicle's and soil's surface, the smaller the friction coefficient. The vegetation can redound the bulldozing-effect.

Material of deformable surface: It is expressed by the cone index (CI) that describes the load bearing capacity of the soil. This is a measurable soil parameter. It depends on the moister content and the physical-mechanical properties of the soil

Area of contact surface: The contact area between the vehicle body and soil affects the soil deformation and increases the possibility of bulldozing formation.

Geometry of surface: The protruding parts of vehicle body increase the value of friction coefficient and these can cause bulldozing.

Speed: The higher the vehicle's speed on terrain, the greater the extent of bulldozing.

During the analysis of an off-road accident, the auxiliary tables and values, which can be found in technical literature, are not enough to determine the most important parameters. In situ field measurements are required after an accident in order to recognize the real factors that affected the accident.

Acknowledgement

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A NEW DIRECT SHEAR TESTING APPARATUS FOR THE EXAMINATION OF THE VELOCITY- AND TIME-DEPENDENT FRICTION

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Abstract

There are contacting surfaces in all mechanisms moving on each other. Between these surfaces friction occurs, because of this we have to take the friction in all cases into consideration during design. Nevertheless in certain cases the description of the friction process is very difficult; because it depends on multiple number of parameters. In case of polymers, granular materials or in geology the velocity- and time dependent friction have great importance. In this paper, development of a direct shear testing apparatus to examine the velocity- and time-dependent friction is proposed. This shear apparatus is attached to the INSTRON 5581 type universal material testing machine and suitable for shearing with different (very low) velocities and on different loads. With our new apparatus creep and relaxation tests can be made, so the velocity- and time- dependent friction can be better understood.

Keywords

direct shear test, friction, time-dependent friction, velocity-dependence,

Introduction

Description of the friction process is very difficult in certain cases, because this phenomenon depends on a lot of parameters (materials, roughness, temperature, shear velocity). In geology, mining- and earthquake science, in case of polymers, granular materials or other special materials the time- and velocity-dependent friction (creep and relaxation) have great importance and just few researchers deal with this time dependence of friction [6], [7]. The aim of our work is to develop a new direct shear testing apparatus, which is attached to the INSTRON 5581 universal material testing machine to examine the velocity- and time-dependent friction process. By using our new machine, the normal load and the shear velocity can be changed in a wide range (and the velocity can have a very low value).

Direct shear test

The knowledge on the shear strength is very important in description of a friction process. This parameter means the relationship between the displacement and the shear force and a lot of parameters have influence on this [1]. The shear strength can be evaluated by using direct shear test; in course of this the surfaces are pressed together with constant normal load meanwhile these moving on each other. During the shear process, the shear force as function of displacement is measured. The material properties, the roughness and the shear velocity have great influence on shear strength [1].

During the direct shear test of two smooth surfaces (under constant normal load and constant shear velocity) the shear strength increases to an initial peak, which is followed by slowly displacement weakening and then stabilization at a residual shear strength, which does not change or increases very slowly with additional displacement [1].

Based on shear tests with different normal loads, the shear strength is in linear correlation with normal strength. The slope of this line is the friction coefficient concerning to the materials, the designate constant of this line is the cohesion between the surfaces. The shear strength based on the Mohr-Coulomb equation:

$$\tau(\phi) = c + \sigma_n \cdot tg\phi \qquad 1$$

where c is the cohesion, ϕ_r is the friction angle between the surfaces.

The residual strength is:

$$\tau(\phi) = \sigma_n \cdot tg\phi_r \qquad 2$$

where ϕ_r is the residual friction angle between the surfaces.

Time- and velocity-dependent experiments

The time- and velocity-dependent friction have great importance in geology: faults may undergo decelerating postseismic slip (afterslip), long term stable slip (fault creep) in the absence of earthquake instability, and perhaps slow postseismic slip [2]. For this reason Dietrich et al. made laboratory shear experiments with clean surfaces of granite [3, 4] and with a layer of simulated fault gouge consisting of crushed and sieved granite [2]. The crushed granite fractions were $<250\ \mu m$ in all cases. These experiments were made with different shear parameters (normal load, shear velocity). The sample assembly consists of a three blocks, sandwich type direct shear configuration (Fig. 1.). In this layout there are two contact surfaces, which have dimensions *50x50 mm*. The purpose of this vertical arrangement is to reduce differences in the vertical elastic displacements within the blocks induced by the vertical load [2]. With this type of direct shear arrangement the vertical and horizontal hydraulic rams independently control the shear and normal stresses, respectively, on the contacting surfaces. Motion of the vertical ram (so the displacement) was generally servo-controlled on displacement using a high-speed servo control valve. Owing to these servo control valves the minimal shear velocity was *0.1 μm/s* [2].

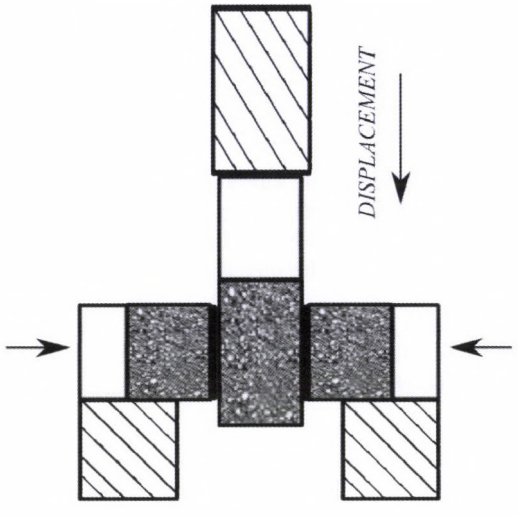

Figure 1. The sample assembly by Dietrich [2]

Three different types of tests were made: constant velocity, multiple velocity and time dependence shear tests. The constant velocity tests were made at *2.5 μm/s* (Fig. 2/a). In the multiply-velocity tests the shear velocity was constant for a predeterminated displacement, then suddenly changed by a factor of 10, held constant for another displacement then changed again and so on (Fig. 2/b). The third group of shear test was the time-dependence tests, in which constant velocity shear was interrupted at a specified displacement where the control displacement is held at zero for a specified time interval (Fig. 2/c) [2].

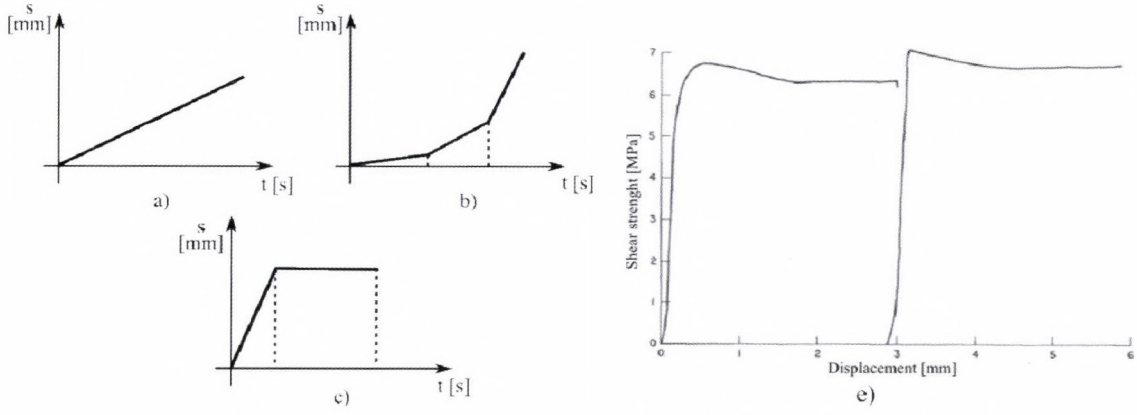

Figure 2. a) Constant velocity test; b) Multiply velocity-test; c) Time dependence test; d) Shear diagram with constant velocity and normal stress [2]

The aim of the constant velocity tests were to examine the overall from stress-displacement curves (Fig. 2/d) to permit reasonably direct comparison to be made for the control of strength by the fault parameters. Based on these curves the shear strength increases to an initial peak, which is followed by a slow displacement weakening and then stabilization at residual shear strength (Fig. 2/d). If the shear stress cycling to zero after reaching residual strength, acts to restore the peak in the stress-displacement curves. This cycling increases the total displacement and also the peak and residual strength [2].

The purpose of the multiply-velocity tests was to look for variations of strength as a function of velocity. A step increase of shear velocity results an immediate jump in frictional coefficient followed by displacement dependent decay and stabilization at a new steady-state friction. The reverse is seen if the shear speed is decreased (Fig. 3.) [3].

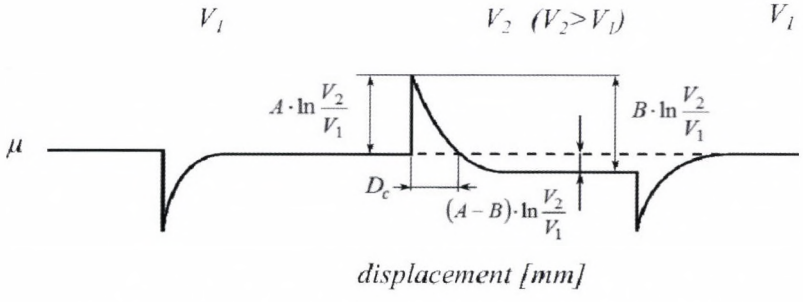

Figure 3. Effect of steps in shear speed on a friction coefficient [3]

Dietrich and Kilgore [3] made a shear rate- and state-dependent constitutive formulation for fault tests. This formulation provides a descriptive framework for the interpretation of the transient shearing phenomenon. The coefficient of friction can be represented [3]:

$$\mu = \frac{\tau}{\sigma} = \mu_0 + A\cdot\ln\left(\frac{V}{V^*}+1\right) + B\cdot\ln\left(\frac{\Theta}{\Theta^*}+1\right) \qquad 3$$

where τ and σ are shear and normal stress V is a shear speed and Θ is a state variable. Parameters μ_0, A and B are experimentally determined constants and V^* and Θ^* are normalizing constants [3].

Developing of a shear testing apparatus

The design was made on the basis of Dietrich's vertical shear apparatus [2]. In case of Dietrich's arrangement the displacement was vertical and the normal force was horizontal, while in our case the normal force is provided by an INSTRON 5581 type universal material testing machine, so it should be vertical thus the displacement must be horizontal. In order to avoid the change in contact surface during the shear process, one of the probes must be a longer one. We decided on a box type layout because this apparatus must be suitable for shearing also granular materials, for this reason this must contain a fixed, loaded part and a moving part. These parts are suitable for fixing the probes. The shear force was measured by a load cell which is at the holding point of the fixed part; the displacement was measured by an inductive displacement transducer at the moving part. The displacement was provided by a stepper motor (Fig. 4.).

To reduce the friction force between the moving part and the base-plate linear bearings were used. Owing to the stepper motor and the control electronics very low shear velocity can be set. The rotation of the stepper motor is transformed to linear displacement by a screw shaft, this connects to the stepper motor with a cased coupling.

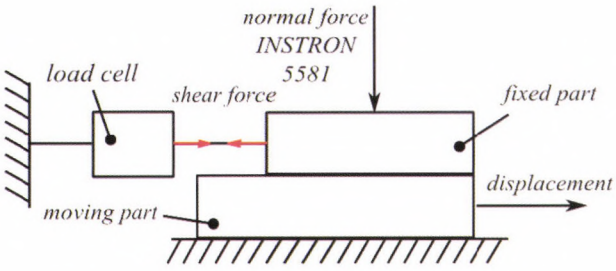

Figure 4. The sample assembly

The parts were designed based on Dietrich's experiments [2]: During his tests with granite the largest shear strength was 10 MPa, we supposed this value like maximum stress. Before designing of the geometry we had to choose the suitable stepper motor based on the torque demand of shearing. For this we need to know the parameters of the screw shaft and the maximum shear force, because the maximum torque is:

$$M_{max} = F_{max} \cdot \frac{d_2}{2} \cdot tg(\alpha + \rho'), \quad 4$$

where F_{max} is the maximum load on the shaft during shearing, d_2 is the effective diameter of the screw thread, α is the profile angle of the metric thread and ρ' is the modified friction angle. In case of 350 mm^2 shear surface and 10 MPa maximum stress during shearing, the maximum shear force is:

$$F_{max} = 10\ MPa \cdot 350\ mm^2 = 3500\ N \quad 5$$

M8x0.75 metric fine thread was chosen to the screw shaft. With this according to Eq. 5 the torque demand of shearing is M_{max}=5.2 *Nm*. Based on the torque demand a XINJE 86BYGH3125 3-phase stepper motor with a torque of *6 Nm* was chosen, because of its very low speed and small size. With the knowledge of dimensions of the stepper motor the geometry of the apparatus can be designed (Fig. 5.).

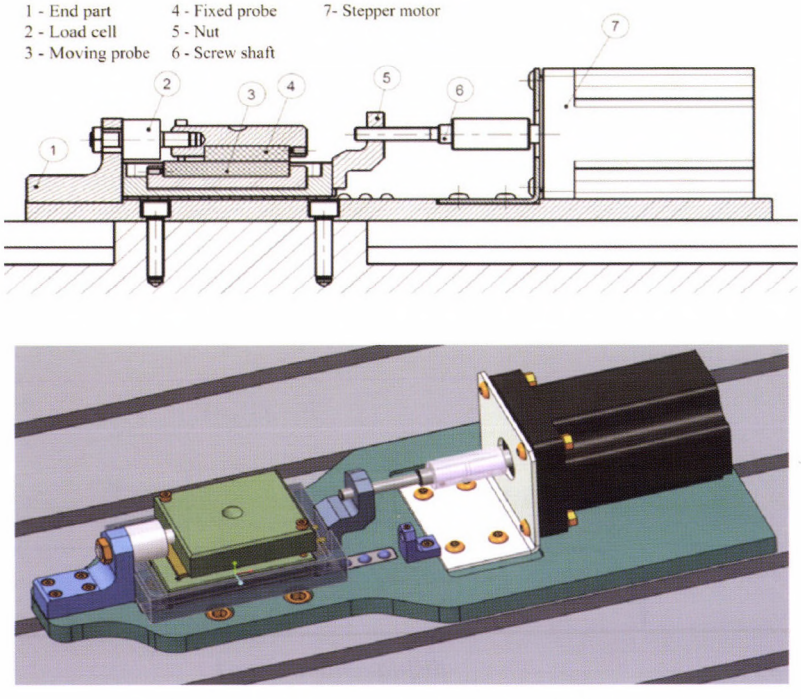

Figure 5. The test assembly and the 3D modell of the apparatus

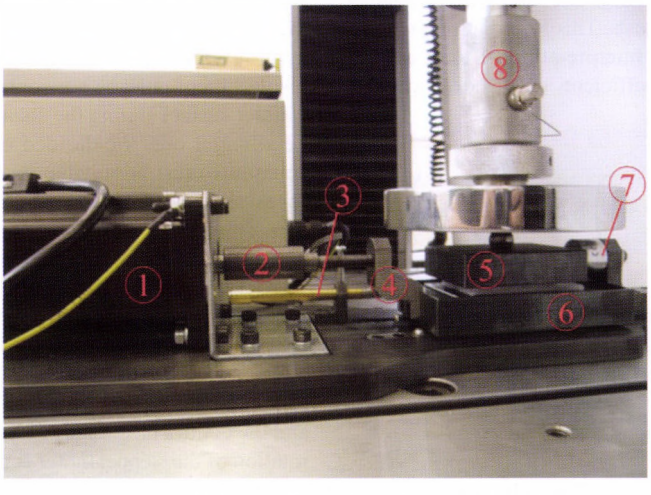

Figure 6. The finished apparatus

On Fig. 6 the finished shear apparatus can be seen: 1 – stepper motor; 2 – screw shaft and cased coupling; 3 – displacement transducer; 4 – nut; 5 – fixed part; 6 – moving part; 7 – load cell; 8 – INSTRON 5581. The normal load was provided by the INSTRON 5581 type universal material testing machine the load was transferred trough a steel ball, that ensures the punctual load to the fixed part.

The controlling electronics

The chosen motor is a three phase stepper motor that divides a full rotation into a number of equal steps, therefore in order to achieve the minimum speed a XINJE DP-7022 digital stepper drive was used. With its microstep function no more than *65535 step/rotation* can be set up which ensures the low and exact angular velocity of the stepper motor. Microstepping is a way of moving a stepper smoothly. Due to all square-impulse the stepper motor rotates with an angle which depends on the microsteps, therefore the number of the impulses determines the full rotation angle and their frequency determines the angular velocity of the rotation. The motor and the user interface are controlled by an own developed electronics which is based on an 8 bit PICF18F4550 microcontroller. The user interface consists of a 2x16 character LED display, 2 toggle switches, 5 press buttons and a potentiometer. The changing of the direction of rotation and the enabling or disabling of driving are possible with the help of toggle switches. The shearing velocity can be changed step by step between *0.075 μm/s* and *156.25 μm/s* and the displacement in a range of *0-25 mm* with a precision of *1 μm*. All parts of the controlling electronics are placed in a sheet cabinet and the user interface is on its face. The measurement system of the appliance is a separate module. The displacement is measured by an HBM WETA 1/10 inductive economic displacement transducer, the shear force by an HBM U9B *5 kN* force transducer. The Spider 8 and the Catman 4.5 software carry out the data acquisition.

Testing of the apparatus

The first tests were made with polyamide probes. The aim of these was checking of the constant velocity and making of constant velocity shear tests. In case of velocity checking shear test was made in unloaded state, and the displacement was measured in function of time:

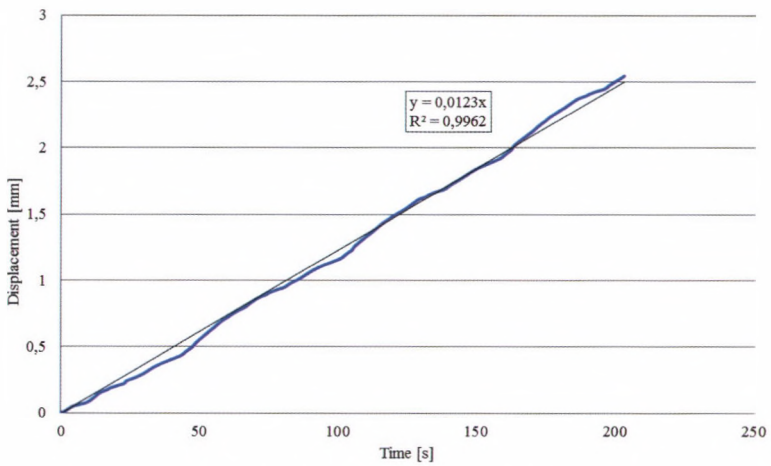

Figure 7. The displacement in function of time in unloaded state

During this test a velocity of *12.5 μm/s* was set. Based on the results of the linear regression the real velocity of the moving part was *12.3 μm/s* that means the difference between the set and the real velocity is 1,6%. Because the measured data and the theoretical values are in good relation the shear velocity is constant in an unloaded case.

After this shear tests were made with two different normal stresses. In first case the normal stress was σ_1=*40 kPa*, in second case σ_2=*80 kPa*. The shear velocity was *100 μm/s* and the sampling rate 10 Hz in both cases:

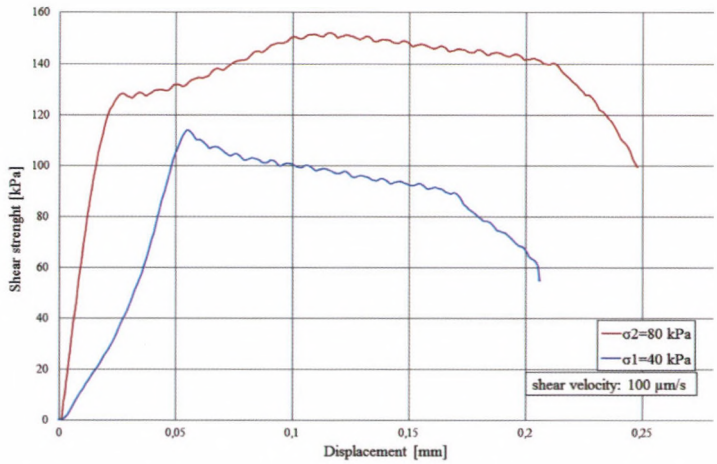

Figure 8. The shear diagrams

Results and conclusion

Based on the above the new direct shear apparatus is suitable for making direct shear test with very low velocity. This velocity is constant during a test, and its value is same as the set. During measuring the shear force and the displacement were acquired by a data acquisition system, thus the shear diagrams can be taken. The characteristic of these diagrams is same as described in a literature, based on this the apparatus is suitable for examine the velocity-dependent of friction. Following our further aim is a development a software with which the shear velocity can be changed during a test according to a predetermined program.

Acknowledgment

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EFFECTS OF TERMINATING COVER CROPS WITH ROLLING/CRIMPING AND HERBICIDES IN A COTTON NO-TILL SYSTEM

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Abstract

This two year study evaluated effects of rolling/crimping, different herbicides and rates on cover crop termination, cotton population and yield. Three weeks after rolling, in 2009, rye termination with herbicides ranged between 96-100%, and was lower for clover (75–82%) due to excess moisture. In 2010, rye termination was 96-100%, and 93-100% for clover. In 2009, treatments had no effect on cotton population; in 2010, it was lower with rye than clover due to weather conditions. In 2009, seed cotton yield was higher for rye compared to clover. The 2010 cotton yield was impacted by a dry and hot summer.

Keywords

Cover crops, roller/crimper, conservation agriculture, no-till cotton.

Introduction

Cover crops are an integral component in conservation agriculture because they provide important benefits that enhance soil quality and plant growth. To maximize benefits of cover crops they must produce optimum biomass (Brady and Weil, 1999). Commonly used cover crops in the Southern United States are cereal rye (Secale cereale L.) and crimson clover (Trifolium incarnatum L.). Rye produces up to 10 tons per hectare of biomass (Bowen et al., 2000) and crimson clover (legume) can produce up to 7 tons per hectare in addition to being an important alternative to fertilizers as a nitrogen source (Hargrove and Frye, 1987; Hubbell and Sartain, 1980). Major benefits of cover crops include soil protection from impact of rainfall energy, reduced runoff, decreased soil compaction and increased infiltration (Kern and Johnson, 1993; Reeves, 1994). Cover crops also provide a physical barrier on the soil surface which inhibits weed emergence and growth (Creamer et al., 1996). In addition to providing a physical barrier, rye has allelopathic properties that provide control similar to applying a pre-emergence herbicide (Hoffman et al., 1996). Long term soil quality effects are associated with improving soil physical/chemical properties due to increasing soil organic carbon, resulting in better crop growth and sustainable agriculture.

Rolling/crimping technology has been used to manage tall cover crops by flattening and crimping cover crops such as rye in conservation systems. Crimping cover crop tissue causes plant injury and accelerates its termination rate. In the southern United States conservation systems, terminating cover crops should be carried out three weeks prior to planting a cash crop. Typically, three weeks after rolling, the termination rate for rye is above 90 % when rolling is performed at an optimal growth stage (Ashford and Reeves, 2003; Kornecki et al., 2006; Kornecki et al., 2009). Most agricultural extension services recommend terminating the cover crop at least two weeks prior to cash crop planting to prevent cover crops from acquiring valuable spring soil moisture that could be used by the main cash crop after planting. Hargrove and Frye (1987) reported that a minimum time from cover crop termination should be at least 14 days prior to cash crop planting to allow for soil water recharge prior to planting.

When late winter months and early spring months are unusually cold and wet or dry, producers must wait longer for cover crops to reach the appropriate growth stage and desired biomass accumulation. Long delays in cover crop development may result in late planting which can compromise yields. Delays in termination of cover crop may decrease the time between rolling and cash crop planting and create problems with managing cover crop residue during planting. This is especially critical in vegetable production when delays in planting cash crops could negatively impact growth and yield. On the other hand, warm weather and plentiful rainfall in spring can increase weed pressure and insect populations, and if cash crops are planted too late, insects and weeds could substantially damage the yields of cash crops.

If there is insufficient time between cover crop termination and cash crop planting, the cover crop might not completely loose its elasticity, strength and moisture, thereby interfering with planting operations due to frequent wrapping and accumulation of cover crop residue on planting units, and hair-pinning. One effective way to reduce the time between cover crop termination and cash crop planting is to apply herbicide with the rolling operation using a sprayer with the nozzle boom mounted behind the roller. However, mechanical crimping and continuous herbicide application might exceed the amount of herbicide needed to effectively terminate cover crops. Applying herbicides in short spray intervals to injured cover crop areas may result in reduced herbicide use.

The objectives of this study were to determine the effectiveness of different application methods for three herbicides combined with rolling/crimping operations on termination of rye and how these treatments impacted cotton population and yield in a conservation system.

Materials and methods

The experiment was initiated in fall of 2008 at the E.V. Smith Research Station near Shorter, Alabama, where the winter cover crops cereal rye (Elbon variety, 100 kg ha^{-1}) and crimson clover (Dixie variety, 28 kg ha^{-1}) were seeded using a no-till drill. This field test was conducted on a Compass loamy sand soil (thermic Plinthic Paleudults). All rolling/herbicide treatments were applied in mid-April of 2009 and 2010 when rye was at the early milk growth stage equal to Zadoks #73 (Zadoks et al, 1974), and crimson clover was in the flowering growth stage (full bloom). Application rate for glyphosate (Roundup™ Weather Max)** continuous spray was 1.6 L ha^{-1}; rate for non-selective organic herbicide Weed-Zap™ (clove oil 45%, cinnamon oil 45%, lactose and water 10%) continuous application was 7.0 L ha^{-1}; and for Natural Horticultural Vinegar™ (20% acidity) continuous spray was 139 L ha^{-1}. Roller operating speed was set to 4.8 km h^{-1}. The following treatments were assigned to each cover crop (sub-main plots). To supply an equal amount of herbicide with the proper flow and pressure of water solution, a plastic 53 L tank (Fig. 1) with a pressure compensated vane pump powered by a 12-Volt electric motor from FlowJet™ (model # 4300-504) and flow regulator were used. The operating system working pressure was set to 207 KPa. A split plot design for this experiment was employed with two main plots (for each cover crop) with four replications. To each main plot, 11 treatments were randomly assigned (individual sub-plots 15 m long and 1.8 m wide) which also included standing (non-treated) rye and clover as controls.

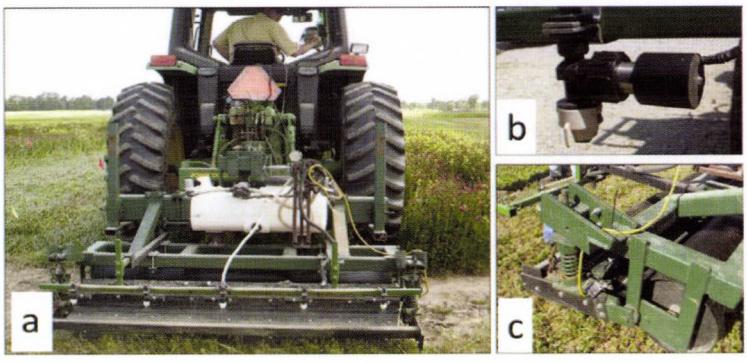

Figure 1. (a) Two-stage roller/crimper with mounted 53 L plastic tank and boom with 5 nozzles controlled by fast acting solenoid valves to discharge herbicides; (b) Close-up of the high speed solenoid discharge valve; (c) Location of the electric switch with the arm for the engagement with the rotating crimping bar's knob.

Herbicide application method was a steel boom with five nozzles mounted to the roller to provide continuous spray, at every other crimp and 3rd crimp (Fig 1a). Each nozzle was spaced 0.37 m apart and mounted to the steel boom providing a 1.8 m spraying width. Each nozzle assembly comprised of a fast acting solenoid valve and a narrow band nozzle (Fig 1b). Components of the control system were an electric micro-switch mounted to the roller's structural frame of the crimping drum (Fig 1c) and custom engagement bars were used to trigger the switch. The electrical switch featured an engagement arm adjustable in both length and angle of engagement. Three engagement bars (for every other crimp) and two bars (for every third crimp) were fastened to the end of crimping bars at equal intervals. When the engagement bar was in contact with the micro-switch arm, the arm was rotated and energized/de-energized the solenoid valves through the ON-OFF micro-switch (Fig. 1c). When the solenoids were energized and activated the fast acting valves, herbicides were discharged through the nozzles for a very short period of time on the crimped cover crop residue. Rye termination (based on visual observation) was estimated on a scale of 0% (no injury symptoms) to 100% (complete plant death) (Frans et al., 1986) and was evaluated at rolling and then one, two, and three weeks after rolling treatments. Cotton (Stoneville 4427 variety) was planted May 21, 2009 using a no-till vacuum planter (John Deere 1700 Emergence Plus and DAWNTM row cleaners). Cotton stand data were collected after seed emergence twice per week up to 5 weeks. Cotton was harvested on October 26, 2009 utilizing a 2-row cotton picker (John Deere 9920 model). Data was subjected to analysis of variance and treatment means were separated using the ANOVA GLM procedure with Fisher's protected Least Significant Differences (LSD) test at the 10 % probability level (SAS, 2009). Because significant differences in termination rates and cotton yield occurred between rye and crimson clover, data for each cover crop were analyzed separately.

Results and discussion

Cover crop height and biomass

In 2009, there were significant differences in plant height and biomass production between rye and crimson clover ($P<0.0001$). Average height for cereal rye was 167 cm whereas for crimson clover it was 74 cm. The dry biomass for rye was 9430 kg ha^{-1} and was significantly higher ($P<0.0001$) compared to crimson clover which produced 6558 kg ha^{-1}. Significantly lower rye biomass was obtained in 2010 (4098 kg ha^{-1}) whereas crimson clover biomass was even lower (3435 kg ha^{-1}). The main reason for low biomass production was unusually low winter temperatures and wet periods during early spring of 2010 which inhibited cover crop growth. The heights for cereal rye and crimson clover in 2010 were also lower (141cm for rye and 54 cm for crimson clover).

Termination rates for cereal rye and crimson clover

Significant difference in cover crop termination rates were found for each cover crop in each growing season, thus data were analyzed separately for each year. In addition, because termination for cereal rye and crimson clover was significantly different each week after termination ($P<0.0001$), data were analyzed separately for each week. Termination rates for cereal rye are presented in Table 1 and for crimson clover in Table 2.

Table 1. Termination rates (%) for cereal rye in 2009 and 2010 growing seasons.

Growing season		2009			2010		
Treatment		Week 1	Week 2	Week 3	Week 1	Week 2	Week 3
No Roller (control)		49d*	85b	97b	46f	76d	92b
Roller only		90c	100a	100a	83e	94c	99a
Roller + Weed-Zap	Continuous	90c	99a	100a	86cd	96bc	100a
	Every other crimp	91bc	100a	100a	85d	96bc	100a
	Every 3rd crimp	91bc	99a	100a	85d	96bc	100a
Roller + Vinegar	Continuous	93b	100a	100a	91b	97ab	100a
	Every other crimp	92bc	100a	100a	88b	96bc	100a
	Every 3rd crimp	90c	100a	100a	85d	96bc	99a
Roller + Glyphosate	Continuous	97a	100a	100a	98a	99a	100a
	Every other crimp	96a	100a	100a	97a	99a	100a
	Every 3rd crimp	96a	100a	100a	96a	99a	100a
LSD at 0.1 level		2.55	1.57	0.26	2.20	2.45	0.79

*Same letters in columns indicate no significant differences among treatments.

Results indicated that in 2009 one week after rolling roller/crimper plus glyphosate application produced the highest termination rates for rye (96 to 97%). No significant differences were observed among continuous, every other and every third crimp of application implying that spraying glyphosate every third crimp was as effective as the continuous spray (Table 1). Two and three weeks after rolling, termination rates every third crimp for all herbicides (between 99% and 100%) were similar to these termination rates spraying continuously and every other crimp. These rates exceeded the recommended termination rate which is above 90% to allow planting cash crop into rye residue covers (Ashford and Reeves, 2003). In 2010, one week after rolling, termination rates for roller with supplemental application of glyphosate, was between 96 and 98% for continuous, every other, and every third crimp. These termination rates were high enough to plant a cash crop into desiccated rye residue. In contrast, with roller alone and organic herbicides, rye termination rates were below 95% level. Two and three weeks after rolling, rye termination rates for all rolled rye residue were between 94 and 99%. Termination rates for non-treated control of standing rye were 76% and 92%, second and third week after rolling. Lack of significant differences between continuous spray, every other and every third crimp indicates that reduced amount of herbicide (every third crimp) was as effective as continuous spray and this reduced the amount of herbicide recommended when herbicide is utilized with rolling.

Table 2. Termination rates (%) for crimson clover in 2009 and 2010 growing seasons.

Growing season		2009			2010		
Treatment		Week 1	Week 2	Week 3	Week 1	Week 2	Week 3
No Roller (control)		0d*	4f	25e	5d	19d	48d
Roller only		35bc	80bcd	86bcd	64c	81bc	84bc
Roller + Weed-Zap	Continuous	36bc	78cde	84cd	65bc	84b	84bc
	Every other crimp	35bc	76cde	89bc	65bc	82b	83c
	Every 3rd crimp	35bc	76cde	84cd	65bc	78c	79c
Roller + Vinegar	Continuous	35bc	70e	84cd	69b	84b	84bc
	Every other crimp	35bc	80bcd	83cd	65bc	83b	83c
	Every 3rd crimp	34c	73de	81d	65bc	84b	84bc
Roller + Glyphosate	Continuous	41a	95a	98a	74a	96a	99a
	Every other crimp	41a	88ab	93ab	69b	96a	98a
	Every 3rd crimp	38b	84bc	92ab	65bc	93a	94ab
LSD at 0.1 level		2.72	9.34	7.32	3.75	4.13	10.25

*Same letters in columns indicate no significant differences among treatments.

In 2009, termination rates for crimson clover were significantly lower than for rye one week after rolling and for glyphosate they were between 38% (every third crimp) and 41% (for continuous and every other crimp); for other treatments including roller alone the rates were between 34% and 36%. There were no significant differences in clover termination rates reported among continuous, every other and every third crimp for Weed-Zap and vinegar organic herbicide applications. Second week after rolling spraying glyphosate continuously resulted in the highest clover termination (95%), although no differences were found between continuous spray, and every other crimp (88%). Applying glyphosate every third crimp produced 84% termination. Except for vinegar continuous spray which produced 70% clover termination, no differences among Weed-Zap, vinegar and roller alone were observed and results varied between 73 and 80% (for roller alone) for clover termination. At two weeks after rolling, termination rate for control (untreated clover) was only 4%. At [three weeks after rolling, spraying glyphosate continuously produced 98% but no significant differences observed among continuous spray, every other (93%) and every third crimp (92%). There were no significant differences among roller alone (86%). Weed-Zap all spraying rates generated between 84 and 89% termination, and vinegar (all rates) was generating from 81 to 84% of clover termination. Data indicated that addition of organic herbicides to rolling did not increase clover termination rates. In 2010 rolling and glyphosate application (all rates) generated rates between 93 and 99%, two and three weeks after rolling. During this same period, two organic herbicides and roller alone generated rates between 78 and 84%, which were not high enough to plant a cash crop into desiccated crimson clover residue.

Amount of herbicide used

Amounts of herbicide used were based on application rates recommended by the Alabama Agricultural Extension service. To obtain factual herbicide solution amounts, fluid discharged from each nozzle was collected into plastic containers during a replicated dry run of 50 m long. Herbicide solution application amounts for continuous spray with rolling/crimping were 1.6 L ha^{-1}, 139.4 L ha^{-1}, 7.0 L ha^{-1}, for glyphosate, vinegar 20%, and Weed-Zap, respectively. The cost per one hectare was $5.00 for glyphosate, $270.00 for vinegar 20%, and $58.00 for Weed-Zap. The application amounts and the associated herbicide cost were reduced by 31% for every other crimp and 42% for every third crimp compared with the continuous rate. Because of low effectiveness in termination cover crops and the high cost for vinegar and Weed-Zap, these organic herbicides are not recommended.

Cotton population

Cotton population was based on the final cotton plant stand measured in the field. In 2009, there were no significant differences in cotton population due to different covers (P=0.168) nor due to treatments effects (P=0.750). Cotton plant population for cereal rye was 47344 plants ha^{-1}, which numerically slightly

higher than 44315 plants ha^{-1} for crimson clover. Conversely, the 2010 cotton population with crimson clover was significantly higher (47411 plants ha^{-1}) compared to populations in cereal rye residue (27291 plants ha^{-1}). The main reason for this reduction was a very poor rye residue cover in 2010 (two times lower than 2009) which caused higher weed pressure and competition with newly seeded cotton plants.

Seed cotton yield

Cotton yield for different covers and treatments are presented in Table 4. Significant differences in cotton yield were observed between years and between cover crop types (P<0.0001). In 2009, seed cotton with rye was 3494 kg ha^{-1} and was significantly higher compared to 1793 kg ha^{-1} in 2010. There was significant difference between seed cotton yield between growing seasons for crimson clover. Seed cotton yield due to crimson clover was 2858 kg ha^{-1} and 1638 kg ha^{-1} for 2009 and 2010, respectively. Comparing seed cotton yield between cover crops, in both years cereal rye influenced higher cotton yield of 2643 kg ha^{-1} averaged over two growing seasons compared to 2248 kg ha^{-1} for crimson clover. In both growing seasons there were significant differences in seed cotton yield among rolling treatments for crimson clover (Table 4). In 2009, the highest seed cotton yield was observed with roller only and roller plus glyphosate application for all rates. The lowest seed cotton was found with vinegar every other crimp and for control (standing rye). In 2010, the cotton yield was seriously reduced by dry soil conditions during growing season. The lowest cotton yield was observed with Roller and vinegar (continuous and every third crimp). The highest yield was observed for roller plus Weed-Zap every third crimp, followed by roller with glyphosate application and roller alone. It appears that cotton yield reduction is associated with unusual weather conditions rather than with treatment effects as supported by data.

Table 4. Treatment effect on cotton yield for rye and crimson clover cover crops in 2009 growing season.

Number	Name of the treatment		Seed cotton yield for cereal rye (kg ha^{-1})		Seed cotton yield for crimson clover (kg ha^{-1})	
			2009	2010	2009	2010
1	No roller		3049.3	1873.2	2621.8d	1596.2bc
2	Roller/crimper only		3564.8	1787.0	3019.9ab	1598.0bc
3	Roller/crimper + Weed-Zap	Continuous spray	3599.7	1792.5	2935.5abc	1671.4ab
4		Every other crimp	3478.6	1779.7	2695.2cd	1680.6ab
5		Every 3rd crimp	3418.1	1897.1	2801.6bcd	1735.6a
6	Roller/crimper + Vinegar	Continuous spray	3577.7	1796.2	2891.5abcd	1499.0c
7		Every other crimp	3412.6	1653.1	2618.1d	1684.3ab
8		Every 3rd crimp	3621.7	1710.0	2810.8bcd	1500.8c
9	Roller/crimper + Glyphosate	Continuous spray	3590.5	1757.7	3087.8a	1713.6ab
10		Every other crimp	3546.9	1792.5	2981.4ab	1735.6a
11		Every 3rd crimp	3570.3	1880.6	2977.7ab	1605.4bc
LSD (α=0.1)			N/S	N/S	274.3	122.6
P-value			0.5213	0.4321	0.0698	0.0149

*Same letters in columns indicate no significant differences among treatments.

In both growing seasons, surprisingly, crimson clover generated lower cotton yields compared to the use of a rye cover crop. It was expected that crimson clover as legume would produce nitrogen which could be utilized by cotton and consequently increase cotton yield. However, it was visible that in 2009 growing season, cotton plants for crimson clover were taller than with rye. In 2009, the average cotton plant height for crimson clover was 125 cm whereas for rye the height was only 111 cm. It appears that nitrogen released from crimson clover influenced vegetative growth of the cotton plant but did not increased cotton yield, and in fact lowered cotton yield by 18% compared to cereal rye cover. A similar trend was observed in the 2010 growing season where higher cotton yield was obtained with cereal rye, even though the cotton population was significantly lower compared to crimson clover. Because of consistent cotton yield data, it appears that using crimson clover as a cover crop in no-till cotton may not be advantageous. However, it is possible that for no-till/organic vegetable systems utilizing crimson clover may benefit selected vegetables.

Conclusions

Three different herbicides: Glyphosate (Roundup™), Weed-Zap, and vinegar 20% were applied continuously, every other, and every crimp on rolled/crimped rye and crimson clover. Data indicates that one week after rolling, the highest rye termination rates were recorded for glyphosate continuous spray (97%) for spray every other crimp (96%) and every 3rd crimp (96%). Organic herbicides (Weed-Zap and vinegar) and roller/crimper alone generated between 90 and 93% rye termination which was at the recommended termination level to plant a cash crop into residue rye cover. Contrary to rye, termination rates for crimson clover was lower, and one week after rolling, glyphosate application generated only between 38 to 41% termination. By third week after rolling the highest termination for clover was observed with all glyphosate treatments (92 to 98%) which exceeded recommended termination to plant cash crop into this cover. Other treatments ranged between 81 and 86% clover termination. In 2009, cotton population was neither affected by cover type nor rolling treatment averaging 45830 plants ha^{-1}. In 2010, cotton population planted into cereal rye residue was 58% lower (27291 plants ha^{-1}) compared to 47411 plants ha-1 for crimson clover cover, and was associated with very poor rye residue cover in 2010 (50% lower rye biomass compared to 2009). In 2009, seed cotton yields were 3446 kg ha-1, and 2780 kg ha^{-1}, following rye and crimson clover, respectively. In 2010, a rainfall deficit and high temperatures negatively impacted

cotton yield and substantially reduced yields compared to 2009 (1780 kg ha^{-1} following rye and 1610 kg ha^{-1} following crimson clover). Overall, rolling treatments did not affect cotton population and yield. In contrast, cotton population and yield were affected by different weather conditions during these two growing seasons of 2009 and 2010. Finally, data indicated that selecting crimson clover as a cover crop is not recommended since nitrogen released from crimson clover residue increased vegetative growth of cotton plants and did not influenced seed cotton yield.

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IDENTIFICATION OF OPTIMUM PARAMETERS OF THE MACHINE FOR CRUSHING OF FRUIT-AND-VEGETABLE RAW MATERIALS

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Abstract

Nowadays the process industry in Kazakhstan is aiming at increasing the competitiveness of domestic products of processing of fruit and vegetable raw materials. This sector gained emphases with Kazakhstan's plan to become member of the World Trade Organization. Major issues include increasing of operating ratio of production, decreasing energy consumption of technological process of fruits processing and expansion of the nomenclature of processing products assortment.

Keywords

the chopping machine, apples, a grinder (apples, pears etc.), knifes.

Introduction

In southern and southeast regions of Kazakhstan the diversified production of fruit and vegetable raw materials is made.

Small and medium sized farmers of the southeast of Kazakhstan harvest more than 290 thousand tons of fruits, berries, grapes annually. And total volume of the specified products shows steady growth. Unfortunately, the considerable part of a crop is lost because of impossibility of operative processing.

At the same time the cutting technology, realized with using of applied grinders, is imperfect and demands completion. In particular there are some problems limiting profitability and competitiveness of the production:

- cutting of fruit, berry and vegetable raw materials (apples, pears, eggplants, etc.) are carried out manually, that profitability of technology and competitiveness of a received product in the market limited.
- loading of the raw crushed materials prepared for drying is carried out by hand, that is labour-consuming and rather inconvenient operation.

The analysis of characteristics of fruits grinders and the universal machines are applied to their preparation for drying, shows that commercially available machines have a low quality and performance indicators, the high energy of a running process, metal-intensive.

The aim of this study is to improve the existing technology of crushing fruit and berry and vegetable raw materials, improving the efficiency of the cutting process and to obtain competitive products, as well as the profitability of shredders due to partial mechanization of the cutting process, raw materials and expanding the use of shredders, perfection of cut fruit with the justification settings chopper.

Materials and methods

Research objective is improvement of existing technology of chopping fruit, berry and vegetable raw materials, improving the efficiency of the cutting process and to obtain competitive products, as well as the profitability of grinders due to partial mechanization of the raw materials cutting process and expanding the use of grinders, perfection of fruits cutting with a substantiation of grinder parameters.

The primary research goals: to research of laboriousness of cutting process of fruit, berry and vegetable raw materials in applied technology; development of a device and process research are cutting initial raw materials; studying of technological chopping process and fruits and berries preparation, a substantiation of parameters and grinder modes.

Theoretical researches based on laws and methods of mathematics, physics and mechanics. Findings of experimental research and tests were integrated to operating standards and the developed methods.

On the bases of the analysis of fruits grinders ¬ ¬ classification of machines has been elaborated. The perspective ¬ revision of drum-type grinders is planned¬¬ as a possible way for further studies.

Existing research references provide valuable recommendations on possible development of the chopping equipment.

However this development must be based on physical-mechanical properties of the fruit material, and also on the interaction of raw material and the working parts of the machinery.

Therefore research is aiming at addressing the following problems:

- To develop model of preparation of fruits to solar drying;
- To execute theoretical research of crushing by machine with the use of new cutting machine parts taking into account operational parameters;
- To conduct experimental research of cutting of fruits, creating new models for the properties of apple and similar fruits;
- To make a pre-production model of a drum-type grinder, to test it under operational conditions and to identify an estimation of efficiency of its use.

Results

The models of technical systems describing processes, occurring are considered at preparation of fruits for drying. On fig. 1 the model of functioning of a grinder of fruits is resulted. In the simplified kind process of its functioning includes three interconnected blocks: grinder loading (S); crushing (R) and release of the crushed product (W). In grinder model external and internal influences characterize following vector functions: XS - conditions (means) of loading; Y_S - influence of parameters of loading on crushing and release of a ready product; X_R - influence of parameters of a grinder on crushing process, influence of parameters of a crushed material on crushing process; Y_R - influence of parameters of crushing on release of a ready product; X_W – parameters of a grinder and property of the crushed product;

$$X_S = X\{X1_S, X2_S, X3_S, X4_S\};$$
$$X_R = X\{X1_R, X2_R, X3_R, X4_R, X5_R, X6_R, X7_R, X8_R\}; \quad (1)$$
$$X_W = X\{X1_W, X2_W, X3_W\},$$

Y_W – influence of parameters of release on power consumption of process of crushing.

Vector functions X_S, X_R, X_W can be presented as:

Thus, considering functioning of a fruits grinder, we reveal the factors influencing this process and possibility of an estimation of the importance of each of them.

Features of technological process of fruits chopping in the machines are differing as the chopping mechanism, by the form подпора a material are considered at its chopping, on a design of chopping body with reception of a product of certain quality.

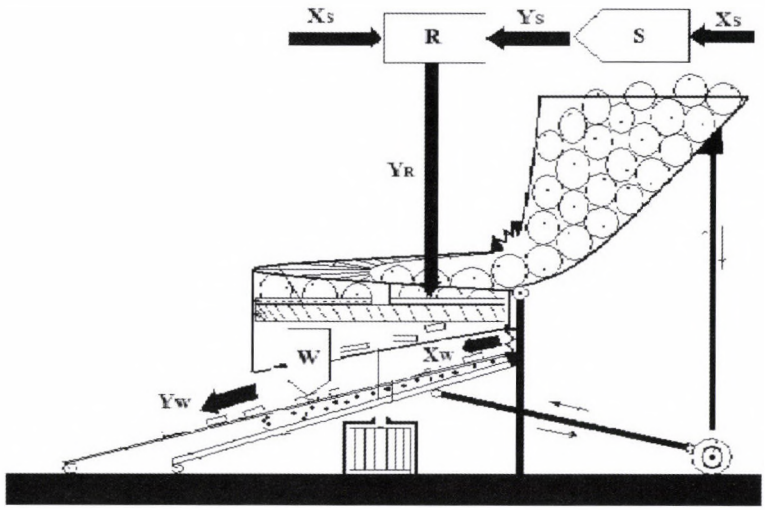

Figure 1. Model of a grinder work
S – grinder loading; R – chopping; W – release of the crushed product; X_{1S} – productivity of loading devices; X_{2S} – the sizes of loaded roots; X_{3S} – height of a layer of loaded fruits; X_{4S} – physic-mechanical and other properties of loaded roots; X_{1R}, X_{2R}, X_{3R}, X_{4R}, X_{5R}, X_{6R}, X_{7R}, X_{8R} – constructive and technological parameters of a drum of a grinder (a corner of knifes cutting, a cutting corner, cutting width, speed, cutting thickness, diameter of a drum, curvature and a surface roughness); X_{1W}, X_{2W}, X_{3W} – configuration indicators of a grinder final part.

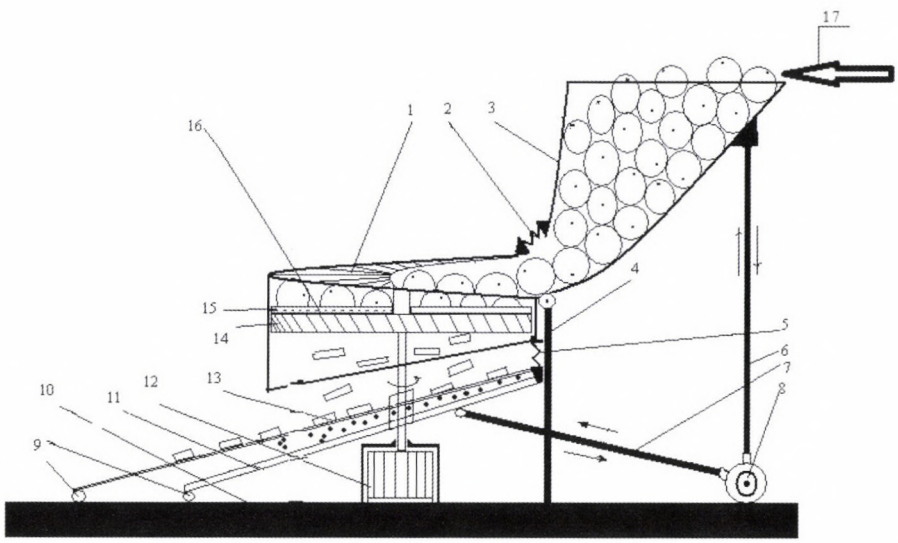

Figure 2. Scheme of an offered grinder of fruits:
1– spiral case; 2 – spring; 3 – vibration capacity; 4 – rack; 5 – spring; 6,7 – vibration racks; 8 – drive of vibration racks; 9 - wheels of vibrating mesh and vibrating fabric for seeds and residual juice; 10 – frame; 11 – vibrating fabric for seeds and residual juice; 12 – drive of a disk; 13 – vibrating mesh for the chopping fruits; Z4 – disk; 15 – cutting knife; 16– roll is controlling of thickness chip; 17 – conveyor.

Considering lacks of constructive schemes of the grinders applied at chopping of fruits, the machine design (fig. 2), having chopping mechanism of drum-type, the spiral case which is bending around a drum, 2-3 knifes providing simultaneous work and reducing unproductive movement of not crushed part of fruits is offered. The grinder works as follows: fruits subject to chopping move the conveyor 17 in a direction to vibrating capacity 3, get to the working chamber between knifes of a drum and a spiral surface of the case 1. Cutting knifes of 15 disks 14 divide a shaving into segments, cutting off it from a crushed material, and move a wedge of not crushed part, causing thereby its continuous advancement till the moment of full chopping. The chop thickness is set by radial moving of roll 16. Particles of the chopped product are thrown out downwards.

Conclusions

Proceeding from the literary review of theoretical bases of process of crushing of fruit-and-vegetable raw materials, we come to following conclusions:

- Quality of crushing is one of the basic indicators of an estimation having crucial importance at a choice of type and a design of a grinder;
- Every way crushing it is separately favorable only at destruction of certain group of materials, depending on physic-mechanical properties of a destroyed material;
- The variety of the machines applied to chopping of fruit-and-vegetable raw materials, testifies that till now search of the most rational type of the chopping machine which along with

high technological efficiency would provide the big productivity and a smaller power consumption in comparison with existing still proceeds;

- The grinders of fruit-and-vegetable raw materials working by a principle of cutting, practically on all indicators surpass grinders of other types;
- In the grinders working by a principle of cutting, the product does not heat up, as in other grinders, that considerably reduces power consumption;

On the basis of practical experience and the analysis of references on fruit-and-vegetable raw materials chopping the model of drying fruits preparation is developed. The analysis of the considered schemes has allowed offering a grinder with the spiral case, a bending around drum, at realization which productivity of a grinder can be raised.

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SIMULATION MODEL APPLIED TO BIOLOGICAL PEST CONTROL BY ENTOMOPHAGOUS SPECIES IN COMMERCIAL TOMATO GREENHOUSES

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Abstract

Our aim was to find a dynamic model describing the effect of the simultaneous application of the egg-parasitoid Trichogramma achaea and the predator Nesidiocoris tenuis to control the phytophagous pest South American Tomato Moth (Tuta absoluta). We found that a Lotka-Volterra type system could be well fitted to the data, estimating the phytophagous growth rate, the parasitoid and predator mortality rates, the predation and parasitism rates and the parasitoid emergence rate. The two-agent biological control mechanism can be applied to find optimal rates and timing of the release of parasitoid and predator agents in commercial greenhouse crops.

Keywords

biological pest control, phytophagous-parasitoid-predator system, Tuta absoluta, Trichogramma achaea, Nesidiocoris tenuis

Introduction

Biological control of pest insects in greenhouse crops has an unquestionable advantage in economic, environmental and public health terms (Shipp et al., 2007). While chemical protection has a single and immediate effect, in biological control, the time scale of the protection based on the interaction of insect populations is longer, and the eventually remaining entomophagous populations can reduce the damage caused by future infections (Van Driesche et al., 2008; Varga et al., 2010).

Pest control in greenhouse crops in Europe has shown an important development within the last 30 years through the replacement of chemical control by biological control, mainly due to pest resistance to insecticides (Van Lenteren, 2007; Blom, 2010). In greenhouse tomatoes, biological control programs used several natural enemies (predators and parasitoids), mainly two predator species for biological control of whitefly Bemisia tabaci (Gennadius) (Hem.: Aleyrodidae): Nesidiocoris tenuis (Reuter) (Vila et al., 2012) or Macrolophus pygmaeus Wagner (Hem.: Miridae) (Chailleux et al., 2013) in countries where the use of the first species is not authorized (Cabello et al., 2012a). This situation changed with the introduction of the South American tomato moth, Tuta absoluta (Meyrick) (Lepidoptera: Gelechiidae) (Desneux et al., 2010). For its biological control, different natural enemies (predators, parasitoid and entomopathogens) have been studied. Since then, by now the use of the egg-parasitoid Trichogramma achaeae Nagaraja and Nagarkatti (Hym.: Trichogrammatidae) has been developed, which is applied in several countries of Europe and the Mediterranean area at the commercial level (Cabello, 2010; Cabello et al., 2012a). However it has been shown, on the one hand, the predators N. tenuis and M. pygmaeus eggs Wagner also kill eggs of the pest species (T. absoluta) (Urbaneja et al., 2009), on the other hand, it was also found that intraguild competition took place, both predator species also kill eggs previously parasitized by T. achaeae (Cabello et al., 2012b; Chailleux et al., 2013). This competition makes it more difficult to manage both entomophagous in biological control programs in greenhouse tomatoes in Europe.

The economic utilization of the developed, fitted and validated population-dynamical model will consist in planning the time and abundance of the introduction of entomophagous insects that should be released for the biologically and economically most efficient plant protection, given a certain level of pest infection (Varga et al., 2010).

The objective of this work has been the elaboration of a practical method to be applied in greenhouse production. This method will have two main components: (1) Population dynamics of the pest species and (2) timing and determining the number of individuals of predator and parasitoid species that should be released for an efficient control of the pest species. Of course, this objective is being realized in collaboration with industrial producers of biological agents, when both the selection of the agent and the way of its utilization would be necessary for its applications by farmers and agronomists.

Material and methods

Experimental design: Trials were carried out from July and November 2009 at two different commercial greenhouses A and B (2,000 and 3,100 m^2) with soil with gravel-sand mulch located in Alhama (Almeria, Spain; 36.962321N, 2.555434S). The crop was tomato (Ikram ® variety, Syngenta, Madrid, Spain). The infestation by the pest species, T. absoluta, was natural. Furthermore, two natural enemies were used: T. achaeae and N. tenuis (Trichocontrol ® and Nesidiocontrol ®, Agrobio SL, La Mojonera, Almeria, Spain). Release doses and timing for both natural enemies were determined according to the requirements in biological control programs for greenhouses in Southeast Spain (Cabello et al., 2012a; Vila et al., 2012).

Weekly samples were taken for the three species: pest, predator and parasitoid. 50 plants, randomly selected in each greenhouse, predator number were counted in situ on 10 top leaves per plant. The pest and parasitoid numbers were sampled separately. Twenty-five young leaves recently expanded in the upper part of the plant, were taken in each greenhouse also randomly selected. The leaves were collected, labeled, and transported in an icebox to the laboratory and then examined under a stereoscopic microscope to determine whether eggs had hatched or had been killed by predators. Eggs not in these categories were individually isolated and incubated at 25±1 °C and 60-80% R.H. to assess T. achaeae parasitism. The found data (number of pest eggs, parasitoid adults and predator nymphs+adults) for each greenhouse and week were represented by their mean values per square meter and they were used in the mathematical model. Temperature and relative humidity values for each greenhouse were monitored by means of thermo-hygrometers (EBI 20-TH1, Ebro Electronic GmbH & Co. KG, Ingolstadt, Germany) placed inside a meteorological box.

Mathematical model: Fig. 1 shows the considered network interactions according to the nomenclature employed by Mill (2006) used in the model. Its mathematical expression is shown below:

$$\begin{aligned} &\text{Phytophagous species:} && x_1' = x_1(m_1 - \alpha \cdot x_2 - \gamma_1 \cdot x_3) \\ &\text{Parasitoid species:} && x_2' = x_2(-m_2 + \beta \cdot \alpha \cdot x_1 - \gamma_2 \cdot x_3) \\ &\text{Predator species:} && x_3' = x_3(-m_3 + \gamma_1 \cdot x_1 + \gamma_2 \cdot x_2) \end{aligned} \quad 1$$

Where x_1, x_2 and x_3 are the densities (number / m^2) of phytophagous, parasitoid and predator species, respectively; m1 the phytophagous growth rate; m_2 and m_3 the parasitoid and predator mortality rates, respectively; α the parasitism rate; β the parasitoid emergence rate; γ_1 and γ_2 the predation rates on phytophagous and parasitoid, respectively.

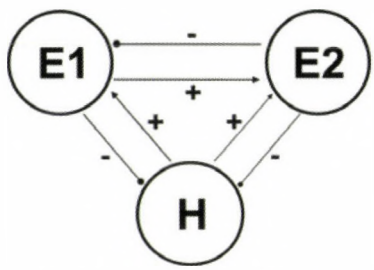

Figure 1. Network of interactions considered in the model herbivore – parasitoid – predator (H = Tuta absoluta; E_1= Trichogramma and E_2 = Nesidiocoris tenuis), the linking arrows and clubs show benefits (+) and losses (-).

Condition for local asymptotic stability equilibrium

For the stable coexistence of the population system, the following method will be applied. Let $f \in C^1(\mathbf{R}^3,\mathbf{R}^3)$ and $x^* \in \mathbf{R}^*$ such that $f(x^*)=0$. Consider the following system in $\mathbf{R}^3$

$$x' = f(x) \quad 2$$

Calculate the Jacobian

$$A := f'(x^*)$$

and let

$$p(\lambda) = \lambda^3 + b_1\lambda^2 + b_2\lambda + b_3$$

be its normed characteristic polynomial. Then by the Routh-Hurwitz criterion (see e.g. Chen et al., 2004) a matrix $A \in \mathbf{R}^{3x3}$ is stable or Hurwitz (all its eigenvalues have negative real part) if and only if

$$b_1, b_2, b_3 > 0 \quad and \quad b_1 \cdot b_2 > b_3 \quad 3$$

Under this condition x^* is an asymptotically stable equilibrium of system (2).

Optimal control of the population system

For system (1), we set up a general optimal control problem that will be solved for the dynamic model fitted to the data. Based on (1), consider the control system

$$x' = F(x_1,x_2,x_3,u_2,u_3) := \begin{bmatrix} x_1(m_1 - \alpha \cdot x_2 - \gamma_1 \cdot x_3) \\ x_2(-m_2 + \beta \cdot \alpha \cdot x_1 - \gamma_2 \cdot x_3) + u_2 \\ x_3(-m_3 + \gamma_1 \cdot x_1 + \gamma_2 \cdot x_2) + u_3 \end{bmatrix},$$

where functions u_2 and u_3 describe the time-dependent rate of release of parasitoid and predator agents, respectively, realizing the biological control of the pest. Fix a time interval $[t_1, t_2]$, and for each $\varepsilon > 0$ we define the class of essentially bounded ε-controls

$$U_\varepsilon[t_1,t_2] := \{u = (u_2,u_3) \in L^2_\infty[t_1,t_2] \mid 0 \le u_i(t) \le \varepsilon \ \ for\ almost\ every \quad t \in [t_1,t_2]\}$$

In order to steer the system from an initial state $x(0)=x^0$ to a final state with pest level $x_1^F \in]0, K]$, keeping the latter below K and minimizing the total release of agents, we have to solve the following optimal control problem, with c_2, c_3=0 or 1:

$$\begin{aligned} &\Psi(u) := \int_{t_1}^{t_2} (c_2u_2(t) + c_3u_3(t))dt \to \min, \\ &u \in U_\varepsilon[t_1,t_2] \\ &x' = F(x_1,x_2,x_3,u_2,u_3) \\ &g(x_1(t),x_2(t),x_3(t)) \le 0 \quad (t \in [t_1,t_2]) \\ &x(0) = x^0 \quad x_1(t_2) = x_1^F \end{aligned} \quad 4$$

where $g(x_1,x_2,x_3) := x_1 - K$. For the solution, the toolbox developed for MatLab in Banga et al. (2005) and Hirmajer et al. (2009) is applied.

Results and discussion

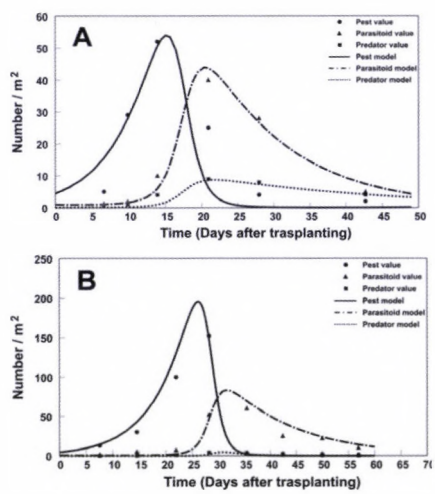

Figure 2. Densities obtained from the fitted model: Prey species = *Tuta absoluta* (egg stage), Parasitoid species = *Trichogramma achaeae*, Predator species = *Nesidiocoris tenuis*, in commercial tomato greenhouses A and B.

The model was well fitted to the data of three species, the obtained fitting parameters and the corresponding statistical parameters are shown in Table 1, the corresponding curves are plotted in Figure 2. The results show the importance of the egg-parasitoid species in the biological control of pest species in the first weeks of the crop cycle, and then its action as a biological control agent is lower. This is caused, first, by increasing predator populations and consequently, by the effect of intraguild competition. These results corroborate those cited in papers Cabello et al. (2012 a,b).

Table 1. Fitting of model (1) to the data of tomato greenhouses A and B.

Greenhouse	Fitting parameters							Statistical parameters			
	m_1	m_2	m_3	α	β	γ_1	γ_2	Variable	d.f.	r^2	P
A	0.14	0.06	0.26	0.01	0.23	0.00098	0.0009	Pest	5	0.7515	0.0254
								Parasitoid		0.9747	0.0002
								Predator		0.8399	0.0102
B	0.2	0.096	0.063	0.016	0.58	0.0067	0.00013	Pest	7	0.9697	0.0001
								Parasitoid		0.9065	0.0003
								Predator		0.8600	0.0009

Stable coexistence of the population system

For the fitting parameters corresponding to the greenhouse A the equilibrium x^*=(26.087,14,0) is asymptotically stable for system (1): the Jacobian at x^* is

$$A=\begin{pmatrix} -4.16334\times10^{-16} & -0.26087 & -0.0255652 \\ 0.0322 & 1.59595\times10^{-16} & -0.0126 \\ 0 & 0 & -0.221835 \end{pmatrix}$$

verifying conditions (3) implying asymptotic stability. In fact, the eigenvalues of A are

$$\lambda_1 = -0.221835$$
$$\lambda_2 = -1.2837\times10^{-16} + 0.0916515\,i$$
$$\lambda_3 = -1.2837\times10^{-16} - 0.0916515\,i$$

Since two eigenvalues have a very small negative real part, the convergence to the equilibrium is slow.

Solution of the optimal control problem

Due to the slow convergence of the population system to the equilibrium, we intervene in the dynamics with controls corresponding to the release of parasitoid or predator agents, in order to keep the prey (pest) at levels that do not harm the crop too much, minimizing the total release of agents. In the first phase only parasitoid, in the second one only predator individuals are released. That is why we intervene in problem (4), in a first phase with the parasitoid and in a second one with the predator with the following parameter values:

Phase 1: $[t_1, t_2]$:=[0,20];c_2:=1;c_3:=0; ε:=2; K:=20 and x_1^F:=7.

Phase 2: $[t_1, t_2]$:=[20,40];x_1^0:=x_1^F;c_2:=0; c_3:=2; ε:=2; K:=7 and x_1^F:=3.

In Figure 3 we can see the coordinates of the optimal trajectory and controls for both phases.ε

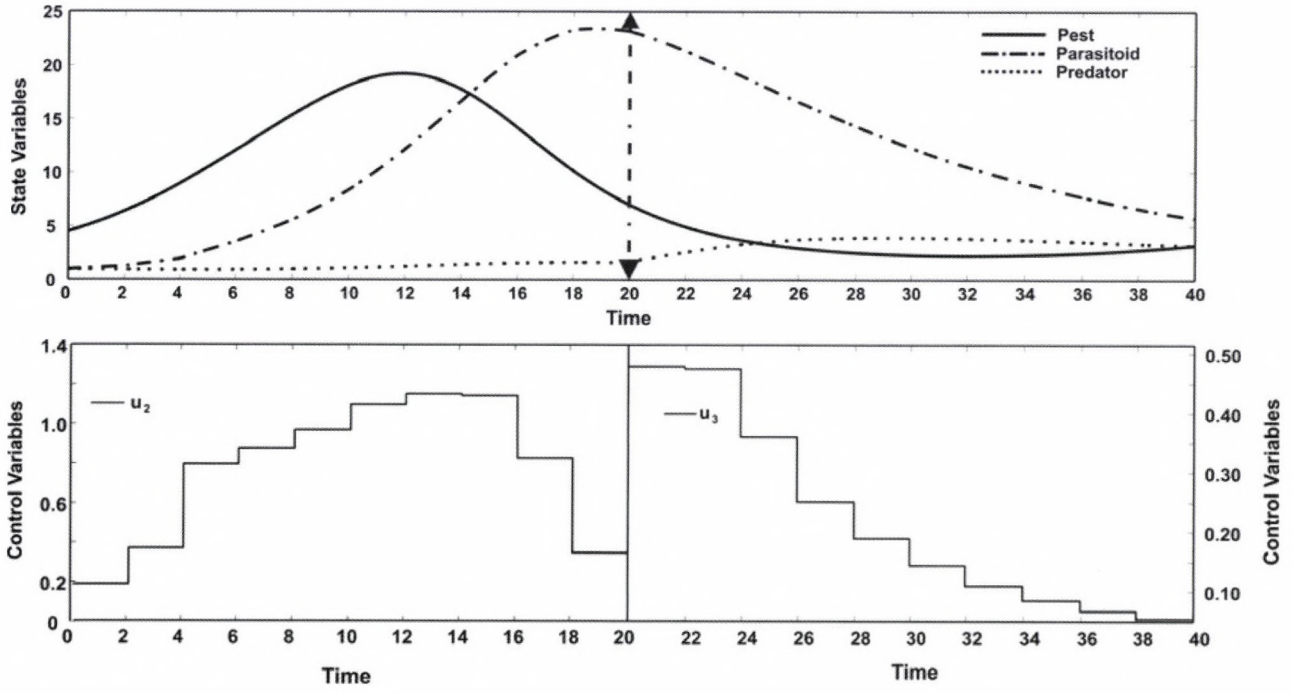

Figure 3. Optimal trajectory and controls of problem (4), for Phases 1 and 2. Pest species: *Tuta absoluta* (egg stage), parasitoid species: *Trichogramma achaeae*, predator species: *Nesidiocoris* tenuis in commercial tomato greenhouse.

The introduced optimal control model is a contribution to the methodological development of biological control of Tuta absoluta in greenhouse crops. On the one hand, in the early stages of the crop, by the release of the parasitoid agent, the pest density remains below a certain value, small enough not to cause serious economic damage to the crop. On the other hand, at the end of the first control period, the pest level must be sufficient for the colonization and subsequent establishment of the predator population. In the second part of the crop cycle, when predator population is higher, the action of the parasitoid is less necessary. This mathematical approach also makes it possible to minimize the cost of the application of agents, highlighting the importance of the proposed optimal control model in the integrated pest management (IPM) and/or biological control programs.

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INDICATORS OF SUSTAINABLE AGRICULTURE

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Abstract

This study attempts to set up an indicator system that enables us to measure sustainability of agriculture. The three dimension approach was chosen as a framework for the compilation of the indicator system. The indicators were compiled for the EU Member States for the years 2000-2010. A correlation analysis was carried out using Hungarian data in order to take out redundant indicators.

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Keywords

sustainability, agriculture, indicators

Introduction

There has been a general agreement between researchers and policy-makers that agriculture plays a crucial role with respect to the three pillars of sustainability, namely the environment, the society and the economy. It is also accepted that in order for a certain system to become sustainable it has to exploit its resources the most efficient way possible. However, studies centering on sustainable development have paid only a little attention to agriculture, especially in developed countries where the sector has only a marginal share in the national economy. This study attempts to set up an indicator system that enables us to measure sustainable development of agriculture.

The concept of sustainable agriculture

Several researchers and organizations have defined the concept of sustainable agriculture in many ways. However, there are some common items in the different definitions (SARE, 1997; Smith and McDonald, 1998; USDA, 1999; Kirchmann and Thorvaldsson, 2000; National Research Council, 2010; Robertson and Harwood, 2013):

- preservation of environmental quality,
- the provision of good quality food,
- the viability of agricultural operations, profitability,
- social justice, equality.

The EU defines the main goals regarding the sustainability of agriculture as follows (EU, 2012):

- producing safe and healthy food,
- conserving natural resources,
- ensuring economic viability,
- delivering services to the ecosystem,
- managing the countryside,
- improving quality of life in farming areas,
- ensuring animal welfare.

These definitions correspond to the 3 dimensions of sustainability: environmental (or ecological), economic and social dimensions. There are several approaches to the concept of sustainability. The most commonly used models are based on the 3 dimension and on the capital approaches. The latter one requires that at least the same amount of wealth is given to our children that we have inherited from our ancestors. The dimensional model (also known as mosaic approach) defines three components of sustainable development (Smith and McDonald, 1998):

- „ecological sustainability which requires that development is compatible with the maintenance of ecological processes,
- economic sustainability which requires that development be economically feasible; and
- social sustainability which requires that development be socially acceptable".

There are different requirements of the 3 dimensions. The ecological sustainability gives priority to the preserving and enhancing the soundness of environment and management practices. The economic sustainability aims for the profitability of the production and the income generated from agricultural activity while from a social perspective the equal possibilities, the living standard of rural areas are in the focus.

The criteria of the three approaches must be met at the same time. A farm can not be sustainable if it is productive but it does not take into consideration the environmental requirements or it follows an environmentally-friendly production pattern that is not viable.

Indicators of sustainable agriculture

Several international and national organizations have worked out their systems of sustainable development. As for the indicators of sustainable agriculture, there are also plenty of institutions and researchers formulating different sets of indicators with various goals, structure and methodology. Before compiling the indicator set, we had studied the available major indicator systems of sustainable agriculture (Eurostat, 2013a; OECD, 2013; SARE, 1997; Van Cauwenbergh et al., 2007). Summaries of the existing indicator systems are given by Binder et al. (2010) and Van Passel and Meul (2012). Previous research in this field was also used (Fekete-Farkas et al., 2007; Valkó and Fekete-Farkas, 2008). Since the European Union is in our focus, priority was given to the indicator sets compiled particularly for this region.

We chose the mosaic (3 dimension) approach for setting up the indicator system. The indicators were selected for the three dimensions separately and compiled taking into consideration the following requirements of indicators:

- relevance,
- reliability,
- accuracy,
- comparability,
- easy interpretation and
- good quality basic data.

There are two possibilities of selecting an indicator for a particular topic:

- using raw data (e.g. consumption of energy in agriculture),
- using a ratio (e.g. ratio of agriculture in energy consumption),
- using a relative indicator (e.g. energy consumption per gross value added).

When making a temporal comparison, pure raw data is the most proper indicator since there is no distortion of the information by another data. If our aim is a spatial comparison, using raw data may be misleading because there are considerable discrepancies between the different countries in size and in production patterns. Let us take the example of the indicator of energy consumption: using a relative indicator (energy consumption per gross value added) may not show the pressure on the environment correctly. In a certain year it may decrease because the gross value added increases due to the favourable weather for crop products while the energy consumption remained the same. The same applies, though less likely, to the ratio

type indicators. It may also be misleading to compare the indicators of different countries using raw data. The environmental performance of Hungary and France regarding the energy consumption of agriculture without using a ratio or a relative indicator can not be compared. It is a choice that has to be made when compiling an indicator set. Since our main goal is the temporal comparison, we usually use raw data and ratio type indicators in our compilation. In the future research, this compilation of indicators is intended to be used as a starting point in developing composite indicators for the dimensions of sustainable agriculture. In the process of developing composite indicators, a normalization will be executed which makes the indicators spatially comparable.

The main data source was the database of Eurostat for the compilation of indicators. Our main goal was to compile comparable data for the EU Member States for the years 2000 to 2010 therefore national data sources were not used. When selecting indicators, the data availability was an important factor. There were indicators where time series were too short (e.g. only 2010 data for soil cover and tillage methods). For some other indicators, data quality problems were encountered (e.g. waste generated in agriculture, 10-fold increase within 4 years for Hungary). In case of the environmental expenditure, data are not available for the majority of Member States. The result of the compilation of indicators is 26 indicators for the environmental dimension, 15 indicators for the economic dimension and 16 indicators for the social dimension.

Missing data were handled by trend function of Excel in case a clear trend could be observed, or by repeating the last (or first) available data if data were volatile.

Environmental dimension

Environmental data can be grouped according to Pressures-State-Response framework developed by OECD. A wide range of data is available for the pressures that are harmful to the environment. These domains include energy consumption, emission of air pollutants, use of fertilizers and manure, sale of pesticides, irrigation and production patterns (livestock density, share of arable land). Much less data are available on the state of the environment (nutrient balances and bird index of farmland species). Concerning the responses, data only exist on the participation in agro-environmental schemes and on organic farming. The 26 indicators give a wide selection of information however some areas (waste generation, tillage, pollutant content of water and soil, landscape) could not be covered in the indicator set.

Economic dimension

15 indicators cover the performance, gross value added and income generated by agriculture. Foreign trade, structure of the production, research and development and subsidies were also included in the indicator set. Prices were taken out from the set of indicators as it is not relevant for sustainability. The volatility of prices could be a possible sustainability issue; proper methodology should be developed for this indicator. Data were only partly available for the wealth of agricultural sector in terms of buildings, machinery and land prices.

Social dimension

Data were available and used in the system of indicators on farm managers with respect to their education, age and gender. Data were also applied on agricultural education and labour force used in agriculture. Rural development indicators on the ratio of rural population over 65 years, on changes in population and on unemployment rate were selected as well. Additional data from income statistics concerning thinly populated areas were included in the system. Data were not available for infrastructural supply and its quality and on food safety and security.

Examination of indicators

In order for the association of indicators to be measured, correlation matrices of Hungarian data were created separately for the three dimensions using the time series from 2000 to 2010. The objective of the analysis was to select those indicators that had a strong correlation with each other therefore they would not bring significant additional information to the system of indicators. For this purpose, the correlation matrices were analyzed and those indicators were selected whose correlation value is larger than 0.9 (or less than -0.9). In future research we plan to repeat this exercise with the data of other Member States so that a properly selected indicator set would be available.

Three indicators were taken out from the environmental dimension as a result of the analysis (Table 1.):

- Emission of sulphur oxides in agriculture (strong correlation with 5 indicators)
- Irrigable area in percentage of utilized agricultural area (strong correlation with 6 indicators)
- Livestock density (livestock units/utilized agricultural area) (strong correlation with 6 indicators)

In the economic dimension two indicators were selected to be taken out (Table 2.):

- Agricultural income – indicator "A" (strong correlation with 2 indicators)
- Entrepreneurial income/utilized agricultural area (strong correlation with 2 indicators)

Two indicators proved to be needless in the social dimension (Table 3.):

- Share of standard output of farm managers over 65 years (strong correlation with 2 indicators)
- Severe material deprivation rate in the thinly populated areas (strong correlation with 2 indicators)

For the rest of the indicators the correlation is acceptable. The indictors to be taken out are unnecessary or have an overlap with other indicators. For example in case of the economic dimension, the content of the two indicators to be taken out is similar to the remaining indicator "Factor income".

Conclusions

In our research it was proven that it is possible to set up an indicator system of sustainable agriculture using data available for the EU Member States. Although there is considerable lack of available information and also there is a need for imputation of the missing figures, the database that was compiled seems to be appropriate for developing a composite indicator of the three dimensions of sustainable agriculture. The analysis of correlation proved to be a proper method of taking out redundant indicators.

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Table 1. Indicators of sustainable agriculture for Hungary – environmental dimension

Code	Indicator	Unit	Selec-ted	2007	2008	2009	2010
EN1	Final energy consumption of agriculture	1000 tonnes of oil equivalent	Y	501	530	444	491
EN2	Emission of greenhouse gases in agriculture	1000 tonnes of CO_2 equivalent	Y	9237	9113	8578	8531
EN3	Emission of ammonia in agriculture	Tonnes	Y	68457	66915	66032	63656
EN4	Emission of sulphur oxides in agriculture	Tonnes	N	437	924	771	790
EN5	Emission of nitrogen oxides in agriculture	Tonnes	Y	2206	2385	2104	2122
EN6	Emission of non-methane volatile organic compounds in agriculture	Tonnes	Y	75	445	437	443
EN7	Emission of methane in agriculture	1000 tonnes	Y	194	194	194	185
EN8	Emission of nitrous oxide in agriculture	Tonnes	Y	16 715	15 949	15 258	15 547
EN9	Use of inorganic fertilizers - nitrogen	kg/ha	Y	76	67	61	60
EN10	Use of inorganic fertilizers - phosphorus	kg/ha	Y	9	6	4	4
EN11	Nitrogen balance per hectare of UAA	kg/ha	Y	35	-24	-4	9
EN12	Phosphorus balance per hectare of UAA	kg/ha	Y	-6	-20	-17	-16
EN13	Use of manure per hectare of UAA	kg/ha	Y	27	24	24	23
EN14	Sales of pesticides	tonnes of active ingredients	Y	11178	12084	11103	9911
EN15	Irrigable area in percentage of UAA	%	N	3.3	2.3	1.9	1.5
EN16	Water use of agriculture per UAA	M^3/ha	Y	71	63	59	55
EN17	Biomass production of agriculture	1000 tonnes	Y	29773	43361	36784	33094
EN18	Ratio of low input farms	%	Y	62	62	62	62
EN19	Share of mixed crops-livestock farms	%	Y	15	15	15	15
EN20	Share of not utilised area in the agricultural area	%	Y	10	12	13	15
EN21	Share of arable land in UAA	%	Y	84	83	82	81
EN22	Livestock density (livestock units/UAA)	livestock units / ha	N	0.6	0.5	0.5	0.5
EN23	Grazing rate (livestock units/fodder area)	livestock units / ha	Y	1.0	0.9	0.9	0.9
EN24	Bird index of farmland species	2000=100	Y	99	105	88	91
EN25	Share of UAA under agro-environmental measures	%	Y	27	27	19	21
EN26	Share of organic farming in percentage of UAA	%	Y	1.7	1.4	1.1	0.8

UAA: utilized agricultural area; source: Eurostat (2013b), own estimation

Table 2. Indicators of sustainable agriculture for Hungary – economic dimension

Code	Indicator	Unit	Selec-ted	2007	2008	2009	2010
EC1	Output per intermediate consumption in agriculture		Y	1.3	1.7	1.6	1.5
EC2	Gross value added	million Euro, constant prices (2005=100)	Y	1478	2677	2051	1601
EC3	Gross fixed capital formation	million Euro, constant prices (2005=100)	Y	643	689	820	619
EC4	Exports of agricultural products	million Euro	Y	3462	3850	3476	4058
EC5	Foreign trade balance of agricultural products	million Euro	Y	900	1185	709	975
EC6	Agricultural income (Indicator "A")	2005=100	N	116	153	104	122
EC7	Crop output / animal output		Y	1.2	1.8	1.6	1.4
EC8	Factor income	million Euro, at current basic price	Y	2267	2944	1912	2337
EC9	Output of non agricultural activities	million Euro, constant prices (2005=100)	Y	175	149	125	111
EC10	Number of holdings with other gainful activities	number of holdings	Y	31830	36925	42020	47270
EC11	Research and development in agriculture	million Euro	Y	10	10	11	13
EC12	Subsidies in percentage of entrepreneurial income	%	Y	93	83	143	112
EC13	Total area under 20 ha / total area over 100 ha		Y	0.2	0.2	0.2	0.2
EC14	GDP of the rural territories	Euro per capita	Y	7246	7720	6511	6605
EC15	Entrepreneurial income / UAA	Euro per ha	N	281	421	195	280

UAA: utilized agricultural area; source: Eurostat (2013b), own estimation

Table 3. Indicators of sustainable agriculture for Hungary – social dimension

Code	Indicator	Unit	Selec-ted	2007	2008	2009	2010
SO1	Share of farm managers with full agricultural training	%	Y	56	51	46	42
SO2	Share of standard output of farm managers over 65 years	%	N	7	8	8	9
SO3	Share of standard output of farm managers under 35 years	%	Y	4	4	4	4
SO4	Share of standard output of female farm managers	%	Y	6	7	8	9
SO5	Labour force in agriculture	1000 annual working units	Y	459	430	442	440
SO6	Share of graduates in agriculture and veterinary field as % of all fields	%	Y	2.6	2.0	2.0	2.4
SO7	Ratio of rural population over 65 years	%	Y	16	16	16	17
SO8	Rate of natural change of rural population	%	Y	-3.9	-3.9	-4.4	-5.1
SO9	Rate of net migration of rural population	%	Y	-2.5	-2.5	-1.9	-2.1
SO10	Share of households with risk of poverty or social exclusion in the thinly populated areas	%	Y	34	32	33	35
SO11	Share of households with very low working intensity in the thinly populated areas	%	Y	14	15	15	15
SO12	Share of households below 60 % of the median equalised income in the thinly populated areas	%	Y	8	8	8	9
SO13	Share of households with housing cost overburden in the thinly populated areas	%	Y	11	11	9	11
SO14	Severe material deprivation rate in the thinly populated areas	%	N	22	19	21	23
SO15	Severe housing deprivation rate in the thinly populated areas	%	Y	14	22	12	19
SO16	Rate of unemployment in the thinly populated areas	%	Y	9	10	12	13

COMPOSTING OF THE SOLID RESIDUE FROM A ROSE OIL PRODUCING PLANT

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Abstract

This paper focuses on the composting of the exhausted rose petals, residue from the essential oil industry, using a low-cost method. The residue was mixed with straw and composted in a passively aerated open pile. Occasionally, the pile was turned manually to enhance aeration and sustain uniform moisture conditions. Physicochemical quality properties of the material were monitored. Aerobic conditions were difficult to be sustained throughout the pile mainly because of the high moisture content of the input material. However, the warm weather conditions resulted in reaching the desired moisture level within the first 6 weeks. The composting time necessary for a good quality end product with the proposed method was 6 months.

Keywords

rose compost, passive aeration, composting monitoring, physical – chemical compost properties

Introduction

The exhausted rose petals, which are produced as a residue during the rose oil extraction procedure, constitute an organic material that could potentially be recycled back to the soil to ameliorate soil conditions. This study focused on the case of a SME (small-medium enterprise) in Kozani, northern Greece, which produces essential oil extracted from the damask rose (Rosa damascena).

The oil extraction involved the steam distillation procedure. The residue, resulted from the oil extraction procedure, consisted of exhausted rose petals and hot water. Composting was chosen as the most favourable option for the management of the solid residue, mainly due to the low costs involved and the potential for the end product to be recycled back to the soil as a soil conditioner and fertilizer. Several studies have shown that compost produced from plant material may increase soil organic matter and nutrient content (Nevens, F. and Reheul, D., 2003; Kokkora et al. 2008; Kokkora et al. 2010; Tits et al., 2012), ameliorate several soil physical properties (Zebarth et al., 1999; Brown and Cotton, 2011) and increase crop production (Nevens, F. and Reheul, D., 2003; Arthur et al. 2012).

This paper describes the pilot study undertaken for the composting of the solid residue. The aim of the study was to investigate whether the solid residue, which was characterised by high moisture content, could be by successfully composted using a low cost composting method: the passively aerated static pile.

Materials and methods

The solid residue consisted mainly of exhausted rose petals, and there was also a smaller portion of rose sepals and receptacles (Fig. 1.a). The residue was sampled and analysed for dry matter content (DM), pH, organic matter (OM) and total Kjeldahl Nitrogen (TKN). The quality properties of the residue are presented in Table 1. The moisture content of the residue was 88.4%. The high value of the moisture content, along with the texture of the residue promoted the development of anaerobic conditions within the residue. As shown in Fig. 1.a, the exhausted rose petals tended to get compacted at the output of the distillation procedure. The laboratory bulk density of the residue was 0.84 g mL^{-1}.

Table 1. Exhausted rose petals properties.

DM (%)[a]	pH	OM (%)	TOC (%)	TKN (%)	C:N
11.6	4.5	91.6	50.9	1.92	27.6

[a] All properties are quoted on dry weight basis, except for DM which is on fresh weight basis

On the other hand, the C:N ratio of the residue was optimum for composting. To advance aerobic conditions within the pile, the residue was mixed with straw in a ratio of 100:1, so as not to increase the C:N ratio of the mixture higher than 30. The residue and straw mixture was composted in a passively aerated open pile (Fig. 1b), located at the campus of the Technological Educational Institute of Thessaly, central Greece. The pile was aerated through convection and open-ended perforated pipes. This particular method was chosen as the costs involved for establishing and operating such a composting facility by the SME were affordable, and also due to the limited available area in the SME.

The composting process started in June 20, 2012 and was completed in November 16, 2012. The weather conditions of the composting period are summarised in Fig. 2.

Physical and chemical quality properties (bulk density, moisture content, pH, EC, NO_3, NH_4) of the material were monitored throughout the process. Compost bulk density evaluation was based on the BS EN 13040:2000. The compost DM was estimated according to BS EN 13040:2000, by oven drying at a temperature of 103 °C until it reached constant weight. For the pH measurement fresh samples were extracted with water in an extraction ratio 1+5 (v/v) (BS EN 13037:2000). The electrical conductivity was measured in the water 1+5 (v/v) extract of the fresh compost sample (EC) (BS EN 13038:2000). For the soluble nitrate nitrogen (NO_3-N) and ammonium nitrogen (NH_4-N) determination, fresh samples were extracted with water in an extraction volume ratio of 1 + 5 (BS EN 13651:2001).

The end product was further analyzed for OM and total N. The OM of the composts was calculated as the loss of mass on ignition (450 °C) of the dried compost sample (BS EN 13039:2000). Compost total organic carbon (TOC) was estimated as the quotient of the OM by a factor of 1.8 (Iglesias-Jiménez and García, 1992). Compost total N was determined using the Kjedahl method. The C: N ratio was calculated as the quotient of the TOC over TKN.

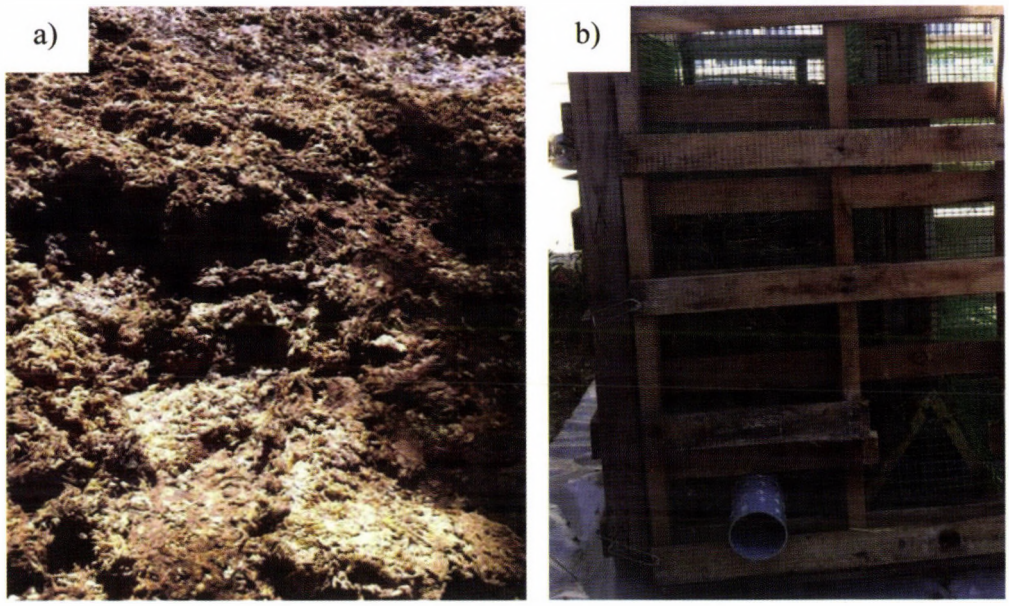

Figure 1. a) The solid residue. The picture was taken at the output of the plant, immediately at the end of the distillation procedure. b) The pilot passive aeration pile used for the composting of the residue – straw mixture

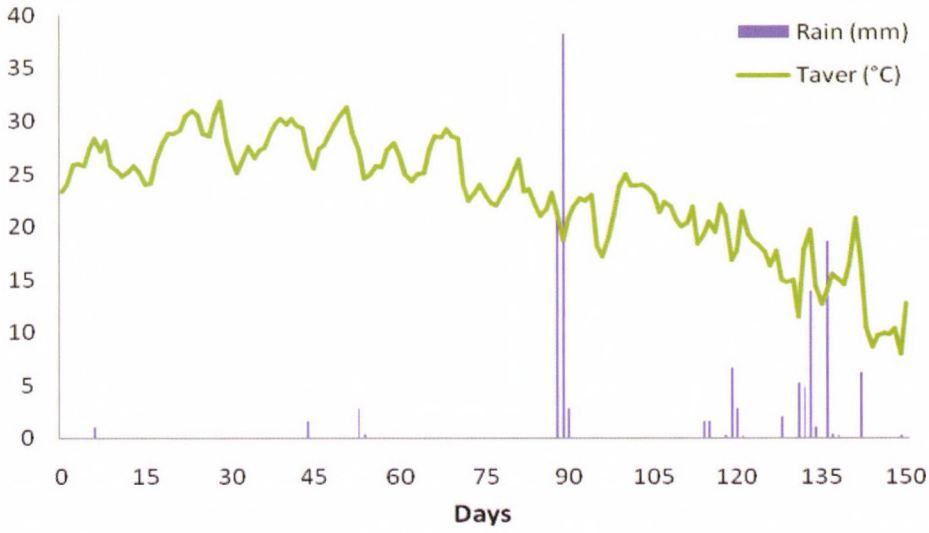

Figure 2. Average daily temperature (°C), and daily rainfall (mm) during the composting period

Results and discussion

Composting process

Aerobic conditions were indeed difficult to be sustained throughout the pile mainly because of the high moisture content of the input material. Excessive moisture in the composting mixture reduced porosity and increased compaction thereby limiting the movement of air into the mass. Within the first 17 days of composting, the temperature within the pile did not exceed 30 °C. During the anaerobic activity in the beginning of the process, odour was released from the pile, as expected. To enhance aerobic conditions within the pile, the mixture was thoroughly mixed and turned.

The compost pile was mixed and turned again on day 24. Till day 35, the DM content of the pile remained lower than 25% (Fig. 3), whereas the optimum range for composting is between 40-50%. As the air temperature was getting higher, the outer part of the compost started to dry out. The high air temperatures resulted in reaching the desired moisture level within the first 6 weeks. However, moisture content conditions were uneven within the pile, despite the pile turning and the water addition at the outer part of the pile. It should be noted that as the material was getting drier, firm aggregates started to form. The aggregates enhanced the aeration within the pile, but within the aggregate itself the conditions were anaerobic, resulting to a dark-black colour inside the aggregate.

As the excessively hot weather conditions prolonged, the pile started to drying out. Compost DM reached 94% at week 7 (day 49). Regular water addition and thorough mixing and turning of the pile were necessary to bring the moisture content of the pile into the desired levels. The practise of wetting, mixing and turning the compost pile continued until day 108, and the moisture content of the pile remained within the desired levels until the end of the composting process (day 150).

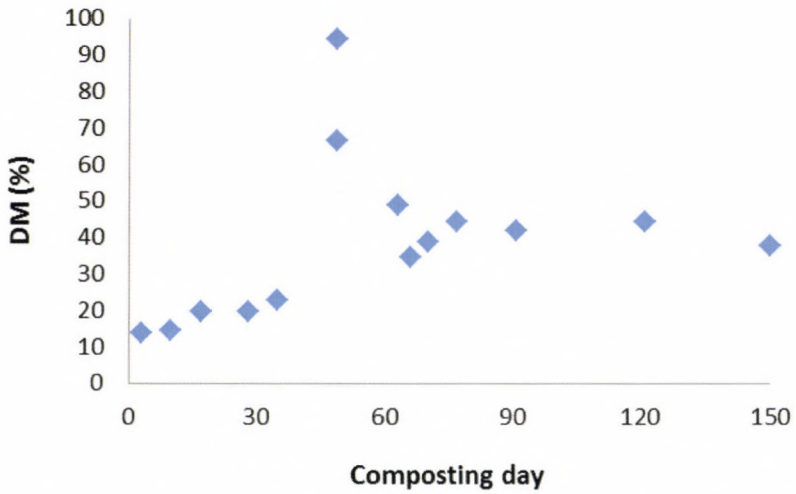

Figure 3. The dry matter content of the mixture during the composting process

Passive aeration was not an effective method for the composting of the exhausted rose petals, under the conditions of this study. Turning of the material was essential to avoid compaction and enhance aeration. Also, once the moisture content of the mixture falls below 50%, water addition is necessary. Ideally, and taking into considerations the weather conditions of the area, heap turning and water addition should be carried out once or twice a week.

Compost quality monitoring

The laboratory bulk density of the compost mixture ranged between 0.7 and 0.9 g mL^{-1} (Fig. 4), with the exception of a low value of 0.4 g mL^{-1}, which corresponds to sampling within 24 hours following heap turning and mixing. In general, heap turning and mixing resulted in lower bulk density, namely less compaction, and subsequently improved aeration.

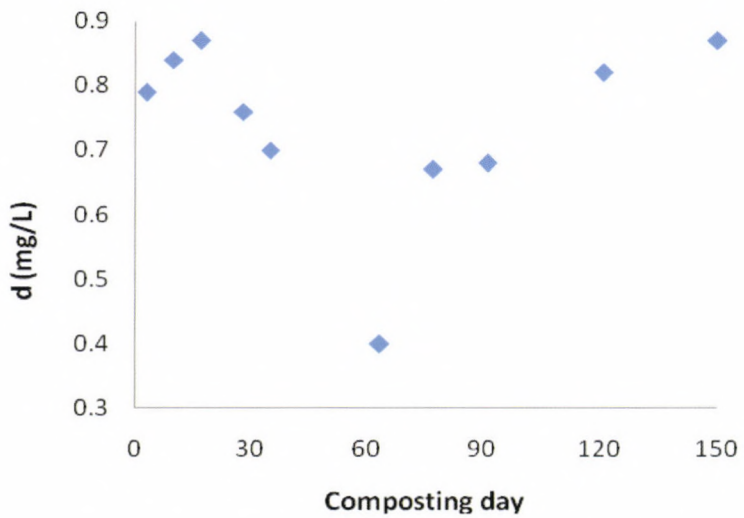

Figure 4. Laboratory bulk density fluctuation during composting

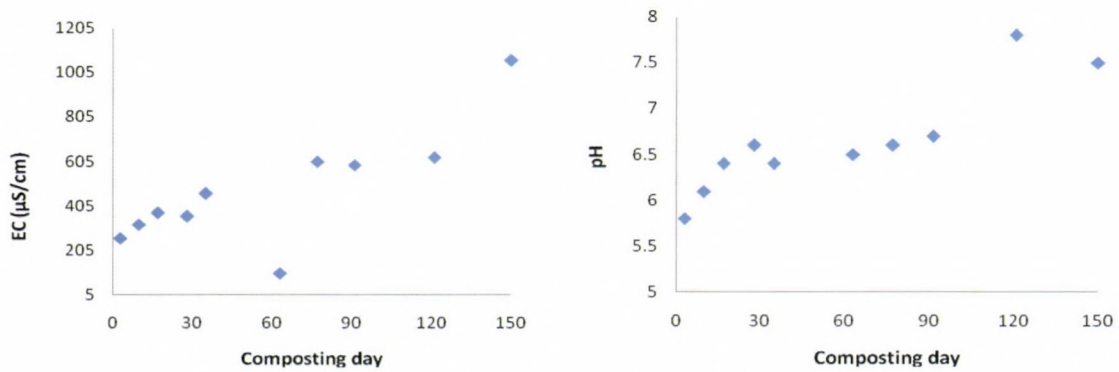

Figure 5. EC and pH fluctuation with composting time

As presented in Fig. 5, compost EC increased with time. Higher values of compost EC indicate higher mineralization of organic substrates. This is in good agreement with the findings for compost ammonium nitrogen content (Fig 6). Increased mineralization of organic substrates results in increased availability of nutrients, hence increasing the fertilisation potential of the compost.

Compost pH increased with time (Fig 5). The pH of the input material was low. However, as the composting proceeded, pH increased to desired levels. The increase of pH above 7 indicates increased ammonification, which is in accordance with the results shown in Fig 6.

Increase in soluble NH_4-N results from ammonification of easily mineralizable organic N. Compost NH_4-N content was 0.046%. A compost NH_4-N content below 0.04% constitutes an indicator of compost maturity (Bernal et al. 1998) and suitability for agricultural use. The NH_4-N content of the rose compost produced with the proposed method, decreased from month 4 to 5, and so did the pH indicating that the ammonification stage was ending and the nitrification process was expected to commence, increasing the NO_3-N content. At the time point of day 150 (5 months of composting), compost NO_3-N content was low, and the NH_4: NO_3 ratio was 28. A NH_4: NO_3 ratio below 0.5 is also indicative of compost maturity. These results indicate that a curing stage of about 1-2 months is necessary for improving compost maturity and subsequently the fertilization potential of the compost.

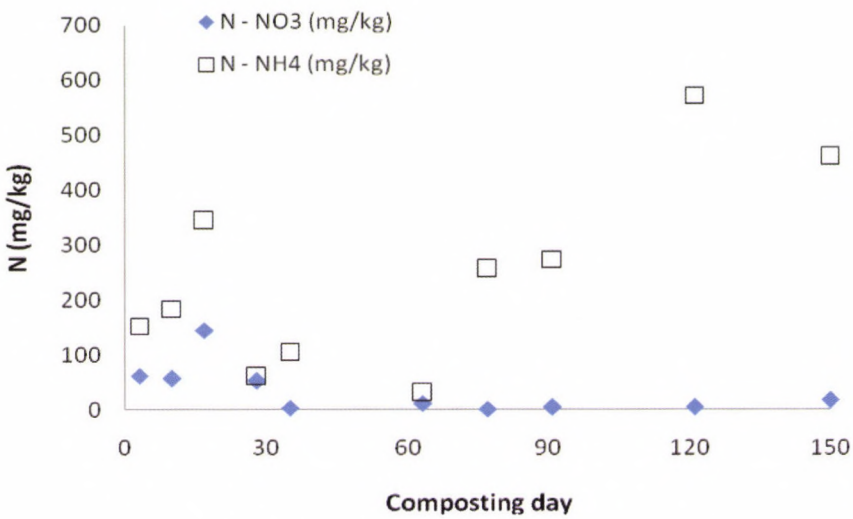

Figure 6. NO_3 and NH_4 fluctuation during composting

The end product had an OM content of 67.12%. Other work has demonstrated that compost OM may range from 18% to 77% (Zmora-Nahum et al. 2007; Kokkora et al., 2010). In general, the compost OM was higher compared to soil OM, indicating that the compost produced could be applied to land as soil conditioner to increase soil OM content (He et al. 1992; Kokkora et al. 2008).

Compost TKN was 2.1%, and the C: N ratio was 17.8. The reduction in the C:N ratio compared to the input material was 41%, reflecting an increasing degree of development compared to the raw materials. Further lowering of the C:N ratio to a level lower than 15 is desirable, as the soil application of organic materials with C: N ratio higher than 15 may result in limited N availability due to immobilization (Gutser et al., 2005). Organic materials with C: N ratio > 25 are expected to result in net immobilization of native or added inorganic N (Sims, 1990).

Within 5 months of composting the exhausted rose petals resulted in good quality, but not very mature compost. A curing period of 1-2 months was necessary for a higher degree of maturity (lower NH_4-N content and C:N ratio, and higher NO_3-N content). The compost produced would be applied to land in spring. By that time, mineralization of more recalcitrant to decomposition organics and higher rates of nitrification are expected, thus resulting in lower C: N ratio and higher NO_3-N. Such a compost is of high quality and its utilisation in agriculture is expected to ameliorate soil conditions and increase crop production.

Conclusions

Exhausted rose petals from the essential oil industry can be successfully composted under Mediterranean conditions, despite the high moisture content of the input material. The use of a bulking agent, such as straw, and heap turning and mixing are necessary for better results. The minimum composting time necessary for a good quality end product with the proposed method is 6 months. Further research is necessary to manage the application of the produced compost to damask rose and other crops cultivation.

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AIR LOAD OF THERMAL WATER

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Abstract

Due to its special geological attributes, Hungary is extraordinarily rich in medicinal thermal water and mineral water. However, extraction and utilisation of thermal waters means a load for environmental air because of high methane and/or hydrogen-sulphide content, among other factors. We would like to describe the air load of these two components, which was based on data provided by thermal spas and our own measurements, utilising passive monitoring procedure. We determined that the Zsóry-bath in Mezőkövesd and in the surrounding area – depending on the weather conditions – detectable rotten egg scent means a hydrogen-sulphide concentration that is below the hygienic threshold limit. High methane content does not only mean an issue but also a possibility for thermal baths which fact is not taken advantage of in many cases.

Keywords

air load, air pollution, thermal bath, methane, hydrogen-sulphide

Introduction

We utilise our thermal water wells of enormous volume and extremely versatile compound mostly in the following areas: balneology, drinking-water supply, agriculture. Beside the properties we have to emphasise what effects of extraction of thermal water resources and qualitative parameters of those have on the quality of environmental air. In the recent years different by-gases of thermal wells, especially methane and hydrogen-sulphide, have gained a more and more crucial role.

Since methane is a greenhouse-effect generating gas, and simultaneously has reasonably high energy content, therefore letting it exhaust into the atmosphere does not cause local and global pollution only but also it is considered as wasting the resources. As a result of this the relatively constant methane-content of thermal wells determines the correct method of usage and handling of these facilities, which means both environmental and economical advantage.

The importance of characteristic, rotten egg scented hydrogen-sulphide is due to its contradiction attributes, as it is a toxic and flammable gas considering the chemical properties; it can be detected even in low concentration, in higher concentration or in case of longer exposure the ability of smell is dulled persistently; at 0.07% respiratory organs might as well be paralysed. On the other hand its balneology-attributes are excellent, because wells containing hydrogen-sulphide – in other words: sulphuric wells – are able to compensate for the sulphur-deficiency of human system, in a form of a bath. Therefore it has a vital role in curing vascular- rheumatic- and certain skin-syndromes as well. Concerning the quality of the environmental air it is one of the most important sulphur-compounds.

Thermal wells might be discovered on nearly 70% of Hungary's area, because Hungary, given its location inside the Pannon-Basin has favourable geothermal features. The geothermal gradient – ie. temperature increase pro each unit of depth increase – which is nearly 5°C/100 m in Hungary, is approximately times 1.5 of the worldwide average value (2-3.3 °C/100 m), furthermore Earth crust in the Carpathian-Basin is only 24-27 km thick, whereas the average thickness is 30-35 km all around the Earth. Additionally, some thick layers of formations with good thermal insulation capabilities can be found; these layers have water draining abilities, this way water contained and flowing inside them becomes the transfer medium of Earth's heat. (Gáspár, 2009)

Some hydrocarbon-research drillings' negative results played a vital role during the development of discovering the country's thermal well resources; as a result of this seeking for hot wells has been operational in Hungary for more than 140 years now. The first sets of drilling were executed by the excellent mining engineer, Vilmos Zsigmondy in 1866 in Harkány and on the Margaret-Island, as a result of the drillings, wells with 61.2°C and 43.8°C temperature were discovered, from depths of 37 m and 118 m. From the next decade on they kept on drilling successfully in the Városliget, Hajdúszoboszló, Debrecen, Szeged, Szolnok and in various places of the country. (Hárs, 2006)

Based on the data of a register – titled „Hungary's thermal water resources" – which was composed with the support of National Technical Development Committee and published by VITUKI Rt. Hydrology Institute in 1993, there are 1152 thermal wells recorded in Hungary. Based on these data nearly 50 % of these wells bring methane-containing by-gases of different compound and output rate to the surface. Methane (CH_4) is an organic compound which can be found in the greatest volume in the atmosphere amongst all other organic compounds. Atmospheric methane is an important greenhouse-gas on the one hand; on the other hand it actively participates in controlling the chemical processes of the stratosphere and troposphere. (Bozó et al., 2006)

As per edict Nr. 12/1997. (VIII.29.) KHVM classification of thermal water based on gas content calculated at 1013 millibar pressure and at 20°C is shown in Table 1.

Table 1. Classification of thermal water based on gas content

Classification of thermal water based on gas content	Gas content
„A"	<0.8 l/m^3
„B"	0.8-10 l/m^3
„C"	>10 l/m^3

Methane furthermore (CH_4) forms a flammable and hazardous explosive mixture when exposed to air between 5-15%, therefore the edict determines that for the good of gas-release technical safety measures in the area of waterworks shall be taken which would exclude the risk of explosion in the waterworks and the supplied locations as well. In case of gas-content classification „A" no gas-release shall be accomplished, classification „B" : gas-release methods and safety measures shall be implied, classification „C": a gas-release instrument compliant to MSZ-10-226 national standard shall be utilised.

Based on the above, it is without any doubt that methane content originating from thermal water is going to play a more and more crucial role both from environmental and economical perspective.

Concentration of hydrogen-sulphide in the atmosphere is exceptional due to complex reasons. Hydrogen-sulphide (H_2S) is an achromatic, characteristically rotten egg scented gas, the density of which is higher than that of air. Hazard originates from the fact that heating of H_2S might cause rapid combustion or explosion. After burning it disintegrates, generating poisonous SO_2 additionally it rapidly reacts with strong oxidants, causing fire- and explosion hazard. (Géczi and Béres, 2011) Its benefit is mainly realised in the balneology, absorbed through the skin reduces blood pressure due to its vasodilating-effect, improves blood supply of the veins and sulphur-content of vein cells therefore reducing the risk of arteriosclerosis. An additional beneficial feature is inflammation-reduction, it improves metabolism, and contributes to curing certain skin-syndromes as well.

As per edict Nr. 4/2011. (I. 14.) VM hydrogen-sulphide is considered as a category II., increasedly hazardous polluting substance based on its affects on health and environment. This edict determines the design value for activities which are bound to undergo environmental effect-analysis in order to evaluate air-pollution levels of the areas in question, additionally design values required and recommended for completing the spreading models and effect-analyses.

The hereby presented data and facts obviously verify the importance of tracing the gases originating from thermal water from atmospheric, environmental, health- and economical perspectives as well.

Material and methods

As determined in the classification of thermal water based on gas content – Table 1. in the previously mentioned edict Nr. 12/1997. (VIII.29.) KHVM, thermal baths are obliged to have the methane content of their water resources controlled every five-, three-, or two years. Ten Hungarian baths provided the already existing measuring reports on our request furthermore they allowed us to visit the wells and observing the gas-release methods. Three units of Budapest Gyógyfürdői és Hévizei Zrt. participated in the data supply procedure: Széchenyi Gyógyfürdő, Rudas Gyógyfürdő és Uszoda and Lukács Gyógyfürdő és Uszoda. From the trans-danubian region Bükfürdő Gyógy- és Élménycentrum and Nagyatádi Termál- és Gyógyfürdő were at service, from the Eastern part of the country Cserkeszőlő Gyógy- és Strandfürdő, Túrkeve Termál- és Élményfürdő, Mezőkövesd Zsóry Gyógy- és Strandfürdő, Berekfürdő Termál- és Strandfürdő and Füzesgyarmati Kastélypark Fürdő participated.

Hydrogen-sulphide concentration of environmental air was determined by our own measurements. Mezőkövesdi Zsóry Gyógy- és Strandfürdő which possesses thermal water resource with high hydrogen-sulphide content, was willingly at service and provided continuous admittance for completing our measurements. Determining of hydrogen-sulphide concentration was executed by allocating and thereafter laboratory evaluation of passive monitoring probes. KVI-PLUSZ Environmental Measurement Ltd. was giving us a helping hand with usage of the measuring instruments and completing the analyses. During the measurements we examined territorial distribution of the load and setup of concentration under different weather conditions. Measurements also included examination of air quality of indoor spaces.

Figure 1. Radiello passive monitor probe and its allocation

Passive monitor probes have gained a more and more crucial role in field of air quality measurements since they are simple and relatively cheap tools. Resulting from this fact we utilised the Radiello manufactured passive measuring instrument that consists of a holder, a pipe and a cartridge impregnated with adsorbent. For determining the hydrogen-sulphide we used RAD 170 type cartridge and RAD 120-1 type blue diffusion jacket. As for the working method, hydrogen-sulphide gets bound on a special, zinc-acetate impregnated, cylindrical micro-fibre structured polyester surface where it transforms into zinc-sulphate during a chemical reaction. After water extraction, in the presence of complex-former compound this phenomenon can be examined by means of spectrophotometric method in the visible range. Hydrogen-sulphide gets bound on the surface of the cartridge matching proportionally with the concentration of the pollution. (Figure 1.)

In connection with Zsóry Gyógy- és Strandfürdő the hydrogen-sulphide monitors were placed for 7-9 days 4 occasions in March, May, July and September 2013. We used 3-3 sensors in all occasions: one in the area of the spa (outdoor) close to the pools (A), another one in the office of the technical manager (B), which is very close to the indoor thermal pools and the third one in the backyard of a terraced house which is located 3 km away from the spa (C). (Figure 2.)

For describing the country-wide situation we have fulfilled the July measurements with further sites. Apart from the existing three measuring points we placed instruments directly in the pool chamber of the spa and very close to the thermal water well where the gas-release takes place. Simultaneously with this we executed further measurements in the Pápa Várkert Gyógy- és Termálfürdő area and engine room, in Győr, the Rába Quelle Gyógy-, Termál- és Élményfürdő, in the area of Veresegyházi Termálfürdő, and in the pool chamber of Velence Resort Spa.

Figure 2. Location of passive monitors
A- bath area outdoor; B – bath area indoor; C – Mezőkövesd family house 3 km away from the bath

Results and conclusion

The specific accumulated methane content of thermal water from baths participating in the data supply procedure is displayed in Chart 2. All the gas-content examinations were executed by laboratories approved by the National Accreditation Board – we have to add concerning the presented results. Based on the gas content values the applicable methods are: free exhaust into the atmosphere, gas-release, respectively operating a gas engine. According to Table 1. we can establish that operating a gas-release instrument by national standard MSZ 15285:1998 (formerly MSZ-10-226) is required with more than half of the 16 wells. Experience shows that already above 200 l/m^3 gas engines can economically be utilised for generating electric power. (According to other sources balanced and continuous water flow rate plus minimum 10m^3/h methane gas extraction – which is independent from flow rate – is a basic requirement.) For this we only found examples at Túrkeve Termál és Élményfürdő, at Füzesgyarmati Kastélypark Fürdő and Berekfürdő Termál és Strandfürdő during our research. At Nagyatádi Termál és Gyógyfürdő feasibility studies and calculations have already been made, as soon as they can manage, they are going to purchase a gas engine which is capable of generating electric power.

Table 1. Classification of thermal water based on gas content

Name of the bath	Examined well	Relative accumulated methane content	Grade (Table 1)
Cserkeszölő Gyógy- és Strandfürdő	I.	8,03 l/m^3	B
	II.	9,40 l/m^3	B
Túrkeve Termál- és Élményfürdő	K-26	205,12 l/m^3	C
Bükfürdő Gyógy- és Élménycentrum	I.	164 l/ m^3	C
	III.	103 l/m^3	C
	IV.	15,18 l/m^3	C
	VIII.	33,46 l/m^3	C
Nagyatádi Termál- és Gyógyfürdő	B-65	258 l/m^3	C
Zsóry Gyógy- és Strandfürdő	Nr. 3.	0,02 l/m^3	A
Berekfürdő Termál- és Strandfürdő	Nr. 3.thermal well K-173	507,32 l/m^3	C
	Nr. 4. thermal well B-192	879,54 l/m^3	C
Füzesgyarmati Kastélypark Fürdő	B-34	342,8 l/m^3	C
Rudas Gyógyfürdő és Uszoda	Attila Nr. 2. well B-4	0,05 l/m^3	A
	Hungária Nr. II. well B-6	0,00 l/m^3	A
Lukács Gyógyfürdő és Uszoda	Roman well	0,00 l/m^3	A
Széchenyi Gyógyfürdő és Uszoda	Nr. II. well B-13	0,88 l/m^3	B

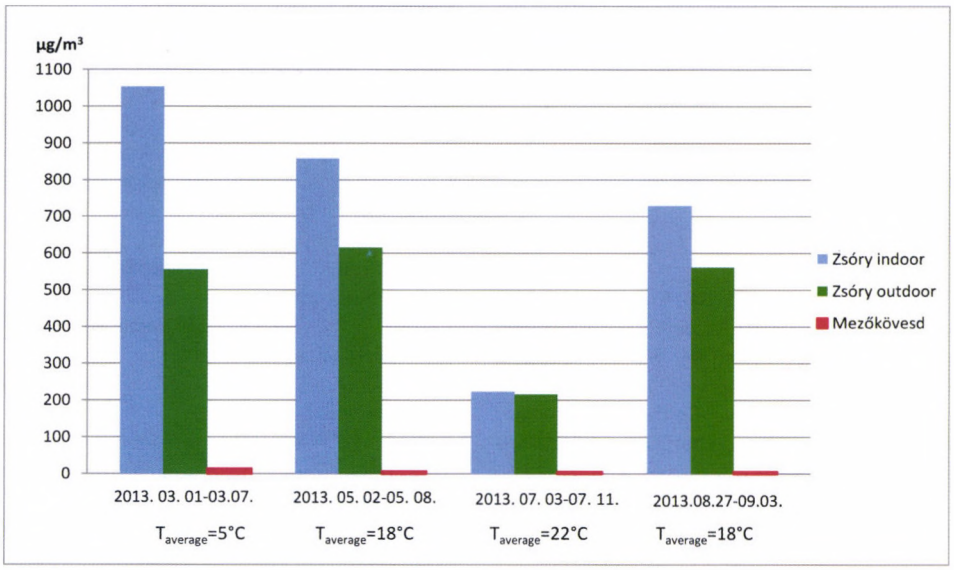

Figure 3. Forming of hydrogen-sulphide concentration in 2013 in Mezőkövesd and Zsóry Gyógyfürdő

We can observe the hydrogen-sulphide concentration determined by means of passive monitors allocated in Mezőkövesd and at Zsóry Gyógyfürdő in the diagram of Fig. 3. During the measurements average temperature in March was 5°C, in May and August 18°C, in July 22°C. The scent of hydrogen-sulphide resembling to rotten egg can be clearly detected in all cases at Zsóry bath, however it never reached the average concentration (AC) referring to workplace atmospheres as described in edict Nr. 25/2000. (IX.30.) EüM-SzCsM AC_{value}=7000 µg/m³ and peak concentration (PC) which is PC_{value}=14000 µg/m³. It can be determined based on our measurements which were carried out in Mezőkövesd that hydrogen-sulphide concentration did not ever exceed the design value of 8 µg/m³ which is described in Appendix Nr. 2. of VM edict Nr. 4/2011.(I.14.). Here we would like to add that in the area of the town we could not detect in any of the 4 occasions the characteristic scents and based on a survey executed in the town we have been told by the inhabitants that rotten egg scent can rarely be detected, with severe north-western winds only.

Based on the diagram it is clearly visible that we can face higher hydrogen-sulphide concentration at lower ambient temperatures, the explanation of which is that vertical air movement originating from density-differences is lower at lower ambient temperature.

The results of wider range hydrogen-sulphide measurements executed in July 2013 are presented in Figure 4. Our goal was that we can get a clear scope on the air's hydrogen sulphide content even with thermal baths which have different properties from "sulphuric" thermal water. In Győr we could examine the hydrogen-sulphide concentration getting into the atmosphere from „iodine"-, in Pápa from the very high (4410 mg/l) dissolved mineral substance containing- and in Veresegyháza, the practically with Széchenyi Gyógyfürdő identical compound thermal water. In Velence we measured indoor area detectable hydrogen-sulphide content of thermal water which is rich in minerals and in Pápa we did the same in the engine room. We compared these results with values measured in the indoor and outdoor of Zsóry Gyógyfürdő. It reveals from the figure that the ratio of the examined component in the „non-sulphuric" waters is smaller by several magnitudes.

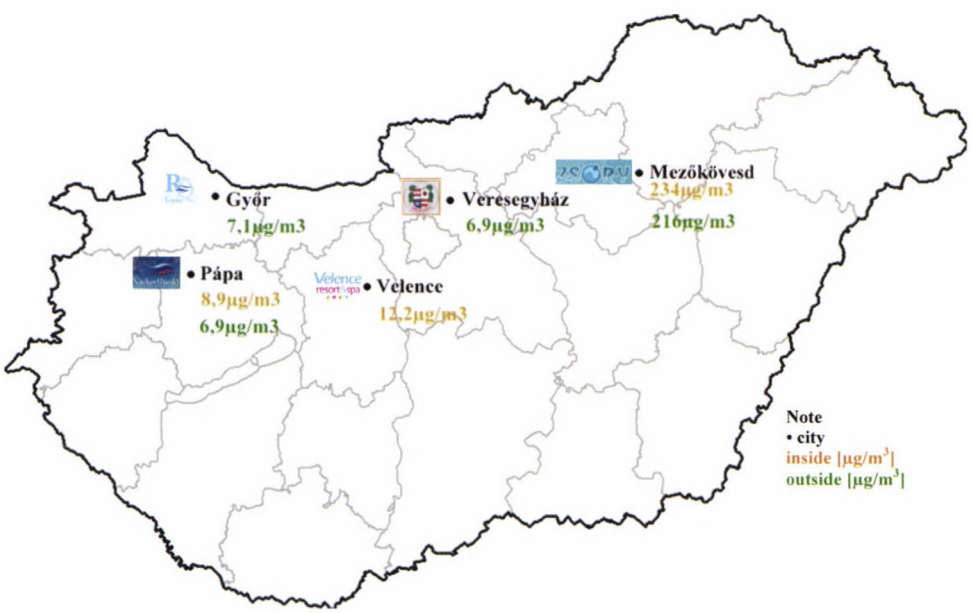

Figure 3. Forming of hydrogen-sulphide concentration in 2013 in Mezőkövesd and Zsóry Gyógyfürdő

We have set it as a goal, however it has not been realised yet due to financial reasons, that we also place passive measuring instruments in the area of Harkányi Gyógy- és Strandfürdő as well. The measurements which are planned to take place there might provide further interesting results because of the also "sulphuric" water. We trust that we are going to have the opportunity to execute the measurements later on.

Acknowledgements

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4/2011. (I. 14.) VM rendelet a levegőterheltségi szint határértékeiről és a helyhez kötött légszennyező pontforrások kibocsátási határértékeiről

MSZ 15285:1998 – Termelt és szolgáltatott vizek gázmentesítő berendezéseinek általános műszaki követelményei.

WIND POTENTIAL CALCULATIONS ON DIFFERENT RELIEFS

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Abstract

The yearly energy production calculation of wind farms is based on the IEC 61400 standard with direct and mean usage of meteorological data. Previously the analysis of measurement data was done with limited complexity.

The methods used at determination of energy production, the factors influencing flow (changes of meteorological features, complexity of terrain, obstacles which interrupt airflow) became more complex. The calculation of energy production is hardened by the increasing importance of economic factors.

Often territory proportional performance increase (MW/m2) is the aim at wind farms installation projects.

In these cases the wind plants became obstacles which modify air flow. Accurate and punctual data collection is needed for wind calculations. The punctually can be increased with the lengthening of the measurement period and with parallel measurement systems.

In the TÁMOP 4.2.1.B-11/2/KMR-2011-0003 program we analyzed three areas with different terrestrial conditions in Hungary. On the basis of measurement data the energy potential was defined at the measurement heights and at the operating height of wind power plants. The results show that the surface of Hungary shows low complexity, although the definition of wind conditions needs complex measurements and evaluation. At plain surfaces wind speed measurements on two heights and sonic measurements on more levels are sufficient.

With the increase of surface complexity the number of measurement levels and heights must be increased. In the past a one year long measurement period was sufficient. Nowadays it is a minimal demand. The accepted measurement intervals must be lengthened to at least three years.

Keywords

wind potential, wind measurements, wind energy production

Introduction

For 25 years, the Wind Atlas Analysis and Application Program (WAsP) has been employed within wind power meteorology and in the wind power industry – and has become the industry-standard PC-software for wind resource assessment and siting of wind turbines. Much of the success of WAsP lies in the application of the Wind Atlas Method (Troen and Petersen, 1989) for the vertical and horizontal extrapolation of measured wind data. WAsP has proven very successful within its operational boundaries. However, the microscale flow model (BZ) built into WAsP limits the applicability in very complex terrain.

A unique solution to this problem was recently found by combining the new with the old; advanced Computational Fluid Dynamics (CFD) with the proven Wind Atlas Method.

The application of wind energy in very complex terrain requires new procedures for deriving better estimates of the wind resource. This is the case, as the traditional calculation models may prove erroneous in some of these situations. A straightforward idea would be to try and implement a state-of-the-art computational fluid dynamics (CFD) code in the analysis procedures. Several commercial products utilizing CFD for wind energy purposes are on the market. The present CFD interface in WindPRO makes it convenient to interact between these CFD tools and WindPRO. The CFD interface consists of two parts:

- PREPROCESSING: Generates the data files to CFD software based on already established data in WindPRO.
- POSTPROCESSING: Import CFD results for comparison with WindPRO (WAsP) results.

In addition wind resource maps generated from CFD products can be utilized in PARK calculations so the CFD Wind distribution calculations can be used as input for PARK calculations.

The WAsP and CFD results are taken from the resource file where the Weibull A and k parameters are saved.

The mean wind speeds are calculated from the A and k parameters, using the following relationship:

Where Γ is the gamma function

A, k is the Weibull distribution parameters (normally denoted scale and form parameters)

It should be noted that the Weibull parameters are fitted to the measured distribution using the requirement that:

- The total wind energy in the fitted Weibull distribution and the observed distribution are equal.
- The frequencies of occurrence of the wind speeds higher than the observed average speeds are the same for the two distributions.

These two requirements show that the WAsP fitting routine does not assure that the calculated mean wind speed is not necessarily close to the observed value. Thus, it would be preferable to compare the energy content in the wind from the two methods. The parameter chosen for comparison is now the ratio between the mean wind speed calculated from your CFD software and WAsP: This parameter, R, is calculated as follows:

$$R = \frac{\mu\left[U_{10,\mathrm{WindSIM}}\right]}{\mu\left[U_{10,\mathrm{WAsP}}\right]} = \frac{A_{\mathrm{WindSIM}} \cdot \Gamma\left(1+1/k_{\mathrm{WindSIM}}\right)}{A_{\mathrm{WAsP}} \cdot \Gamma\left(1+1/k_{\mathrm{WAsP}}\right)}$$

Where AWAsP, kWAsP are Weibull distribution parameters (WAsP calculation)

AWindSIM, (kWindSIM=2) are Weibull distribution parameters (WindSim)

In extend to comparing the mean wind speed it is also possible to compare the following parameters:

Weibull A-parameter (total distribution)

Weibull k-parameter (total distribution)

Energy level (total distribution)

The plotting of the parameters may be done as a simple distribution, as a function of the distance from the meteorological mast or mapped onto a 3d graph showing the height contours.

Methods & Materials

Comparing WAsP and WindSim CFD Results

The main statistics of the ratio between the WindSim and WAsP results are shown in Table 1. The mean value of the ration is 97.2%, which mean that the WindSim calculations in general seem to underestimate the mean value of the wind speed distribution. However, this difference may also be due to differences in fitting techniques when fitting the Weibull parameters. The coefficient of variation is 2.4%, which is judged acceptable. When looking at the energy level, the WindSim calculation underestimates approximately – in mean - 9 % as compared to WAsP.

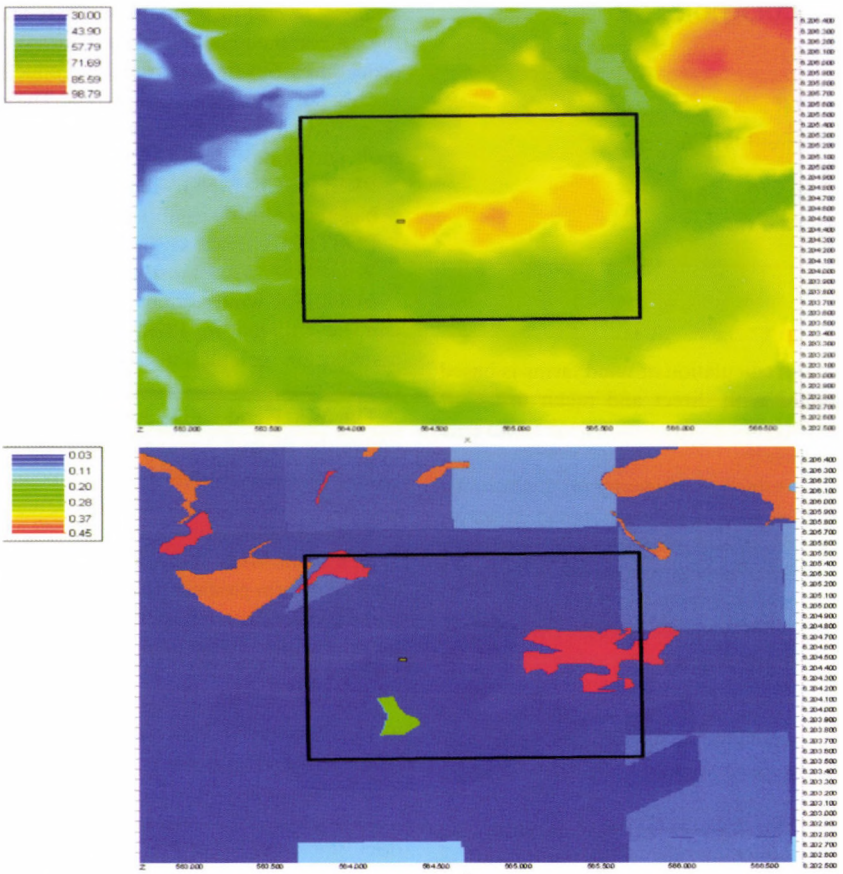

Figure 1. Orography and roughness from the initial extraction (orography in [m], roughness in [m])

Table 1. Statistics on the ratio, R, between the mean wind speed or energy level calculated from WindSIM and WAsP

Mean wind speed			Energy level		
μ	σ	$COV=\sigma/\mu$	μ	σ	$COV=\sigma/\mu$
0.972	0.023	0.024	0.907	0.069	0.076

The dependency on the distance from the meteorological mast and the height above ground is shown in Figure 9. It is obvious, that the WindSim model seems to underestimate increasingly as the distance from the meteorological mast increases.

A larger variation is seen as in a distance approximately 1000 meters from the mast. Inspecting the Figure 10 and comparing with the roughness map in Figure 8 find the reason for this larger variation. Here it is seen, that the large ratio comes where the roughness is high (a small city is situated). Near the site, the two models predict quite similar, and the difference in mean wind speed is within a few per cent.

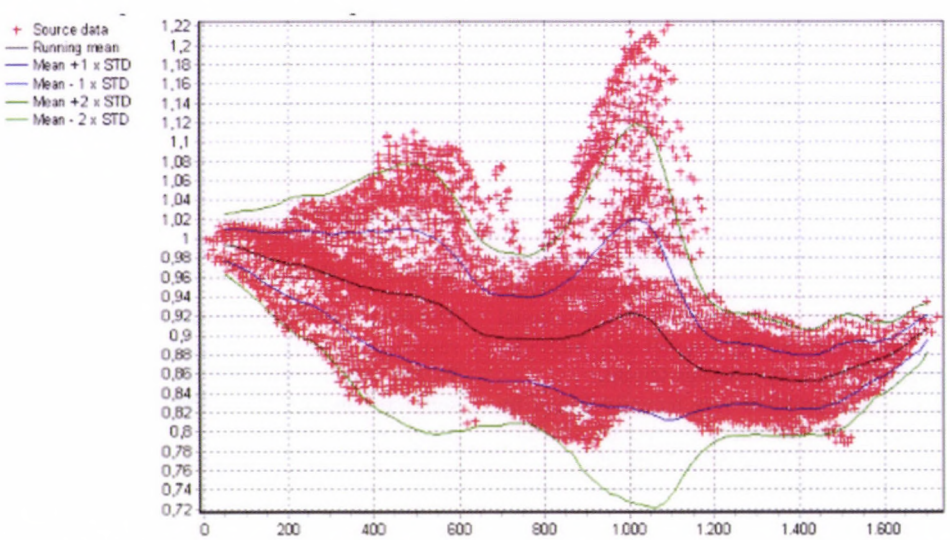

Figure 2. WindSim/ WAsP mean wind speed ratio conditioned on the distance from the met mast

Comparing Results at the Meteorological Mast

In order to compare how the different models perform, it is sought to estimate the wind climate at the position of the meteorological mast. I.e. it is possible to compare the model predictions with the original measured data.

WAsP v. 9.0 is used to fit the Weibull parameters in all models in order to overcome the known problems of using different Weibull fitting algorithms.

When comparing the measured and modelled Weibull A-parameters, the WAsP model has a tendency to slightly over predict the A parameter at the 30 meters height. The WindSim model gives a result that is very close to the measured data (as it is supposed to as the speedups and direction changes are 0). By the A-parameter at 70 meters and 100 meters, the WindSim model predicts a lower A-parameter than the WAsP model.

In this test case, the modelled directional probabilities are not very different from the measured ones.

WindSim results

The measured distributions for the 17-day period and the estimates of the new wind and directional distributions. It is obvious that the predicted distributions at the other position looks very much like the one that they are derived from. This is due to the very small modification factors for all dominating sectors (SSW to NNW). It seems that our model has not been able to capture the large differences in the two measured distributions. However, when over viewing the site, then it is obvious that both of the meteorological masts are operating in wind turbine wakes for long periods.

WAsP results

In order to support the conclusions regarding the main differences in measured wind distributions a WAsP analysis has been performed, analysing differences in two meteorological stations by using 'long term' data. By the Weibull A-parameter the differences at the two sites are almost negligible, supporting the conclusion that the main differences in the measured wind statistics comes from the wake effects.

Comparing with production data

The production data from WTG's have been analysed, and the results from this reference is used here. The WindSim results have been save in a rsf-file and processed using the PARK module in WindPRO in order to include wake effects. The results from the analysis can be plotted in a diagram whit data from the 'Goodness' indexes for all turbines on site. The 'Goodness' is defined as the ratio between the actual measured production and the calculated (modelled) production, i.e. a 'Goodness' larger than 1.0 is an underestimation of the actual measured production.

Conclusions

The actual case study shows, that the site fits the WAsP model best – it is a typical Hungarian site – event if the orography is some of the 'roughest' that we may find in Hungary. The WindSim model seems to have problems with taking complex roughness into account, but it also seem to improve handling of the orography. In addition, it must be noted that the WindSim model has its strengths in sites with complex orography and not sites with complex roughness - as the current site.

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THE INFLUENCE OF THE MAIN DESIGN PARAMETERS OF THE MACHINE FOR PICKING ONIONS FROM THE SOIL ON TRAJECTORIES OF POINTS ITS VIBRO TRANSPORTER

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Abstract

We propose a mounted machine for onion harvesting, kinematics is shown in Fig. 1. Here O_1A crank rotating at a certain angular velocity, moves suspension O_2B that causes vibration of the conveyor BE_0, creating a continuous movement of onion tossing. The roots initial velocity is given by a brush drum 1.

Keywords

vibrating transporter, connecting rod, suspension, a crank, amplitude of oscillation, spacing on centers.

Introduction

Currently, the industry of Kazahstan is not producing machines for harvesting onions, hampering the development of the harvest, increases production costs by one unit of production result in large losses in crop yields. This is especially true for harvesting onions (more than 50% of labor costs account for their cleaning).

In abroad, mainly in the U.S., there are a number of patents for the collecting machines, but they still have not found a specific application.

The maturation process of onions takes a long time and this is not simultaneous, so they should be removed completely.

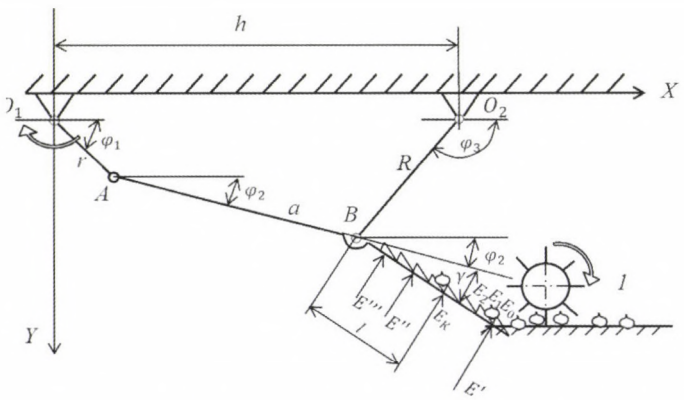

Figure 1. Kinematics of the outboard machine for picking onions from the soil

Based on the research conducted under the guidance of prof. A. F. Ulyanov in the thesis Yuri Efremov "Mechanization rebounds onion" found to "that the energy perceived fetus on impact may be more deformable energy when pressed at 1.3-1.8 times, while the maximum deformation are identical, the residual deformations are less on impact".

This indicates the feasibility of establishing the machine with relevance to by dynamic impacts.

In order to investigate of vibrating conveyor (BE_0) in continuous tossing it is necessary to describe the motion characteristic of various points in the initial position. Afterward we can change the design parameters (r -crank, a – connecting rod, R - suspension, and h - distance between centers) to analyze their effect on the working point trajectory.

This article contains the results which can describe the effects of these parameters on the different trajectories of change spaced points vibrating transporters.

Method of trajectory description

Point E vibrating transporter is located at a distance l from the end of the suspension of B in rectangular system XO_1Y which beginning is at the point O_1, invariably associated with the machine. Axis O_1X is directed to horizontal side movement of the machine, O_1Y - vertically downwards (Fig. 1). The kinematic equations of motion of a point E have the following form:

$$\begin{aligned} X_E &= r\cos\varphi_1 + a\cos\varphi_2 + l\cos(\varphi_2+\gamma) \\ Y_E &= r\sin\varphi_1 + a\sin\varphi_2 + l\sin(\varphi_2+\gamma). \end{aligned} \quad (1)$$

Projections of its velocity

$$\begin{aligned} V_{Ex} &= -\left[\begin{matrix} r\omega_1\sin\varphi_1 + \omega_2(a\sin\varphi_2 + \\ +l\sin(\varphi_2+\gamma)) \end{matrix}\right] \\ V_{Ey} &= r\omega_1\cos\varphi_1 + \omega_2(a\cos\varphi_2 + \\ &\quad +l\cos(\varphi_2+\gamma)) \end{aligned} \quad (2)$$

and accelerating the

$$\begin{aligned} W_{Ex} &= -\left[\begin{matrix} r\omega_1^2\cos\varphi_1 + \omega_2^2(a\cos\varphi_2 + l\cos(\varphi_2+\gamma)) + \\ +\varepsilon_2(a\sin\varphi_2 + l\sin(\varphi_2+\gamma) \end{matrix}\right] \\ W_{Ey} &= -\left[\begin{matrix} r\omega_1^2\sin\varphi_1 + \omega_2^2(a\sin\varphi_2 + l\sin(\varphi_2+\gamma)) + \\ +\varepsilon_2(a\cos\varphi_2 + l\cos(\varphi_2+\gamma)) \end{matrix}\right] \end{aligned} \quad (3)$$

to specified axis of,
where

$$\omega_2 = \frac{d\varphi_2}{dt} = \frac{r\omega_1 \sin(\varphi_1 - \varphi_3)}{a \sin(\varphi_2 - \varphi_3)} -$$

- the angular velocity of connecting rod;

$$\omega_3 = \frac{d\varphi_3}{dt} = \frac{r\omega_1 \sin(\varphi_1 - \varphi_2)}{R \sin(\varphi_3 - \varphi_2)} -$$

- angular velocity of the suspension;

$$\varepsilon_2 = \frac{r\omega_1^2 cos(\varphi_1 - \varphi_2) + a\omega_2^2 - R\omega_3^2 \cos(\varphi_3 - \varphi_2)}{R \sin(\varphi_3 - \varphi_2)} -$$

- angular acceleration

of connecting rod;

$$\varepsilon_3 = \frac{r\omega_1^2 cos(\varphi_1 - \varphi_3) + a\omega_2^2 \cos(\varphi_2 - \varphi_3) - R\omega_3^2}{a \sin(\varphi_2 - \varphi_3)} -$$

- angular acceleration

of the suspension;

$$\varphi_2 = arc\ cos\left(-\frac{B(\varphi_1)}{2A(\varphi_1)} \pm \sqrt{\frac{B^2(\varphi_1)}{4A^2(\varphi_1)} - \frac{C(\varphi_1)}{A(\varphi_1)}}\right) -$$ rotation angle of

connecting rod;

$$A(\varphi_1) = 4a^2[(r\ cos\varphi_1 - h)^2 - r^2 sin^2\varphi_1]$$

$$B(\varphi_1) = 4a^2(r^2 + a^2 + h^2 - R^2 - 2rh\ cos\varphi_1)(r \cos\varphi_1 - h)$$

$$C(\varphi_1) = r^2 + a^2 + h^2 - R^2 - 2rh\ cos\varphi_1 + 4a^2 r^2 sin^2\varphi_1;$$

$$\varepsilon_1 = \frac{d^2\varphi_1}{dt^2} = 0 - \text{the angular acceleration of the crank,}$$

as $\varphi = \omega t,\ \omega = const.$

Given equations allow at any given time to determine the position, velocity and acceleration of an arbitrary point vibrating transporter. Analytical determination of its trajectory, although in principle and possible, the equations of the system (1), but it is very difficult and uncertain. Therefore, these trajectories are obtained experimentally for different values of the main design parameters. On a specially designed stand of the experiment was conducted for three points vibro transporter E', E" and E"' (Fig. 1), the distance by the suspension of which is respectively 208, 355 and 535mm. Figure 2 shows the change in the trajectory of these points, depending on the center distance 753 <h<1278 mm with 25 mm intervals at r = 30 mm, a = 898 mm. Here the trajectory of 1 corresponds to the distance between centers is 753 mm, 2 - 778, 3 - 803, ..., 22 - 1278 mm.

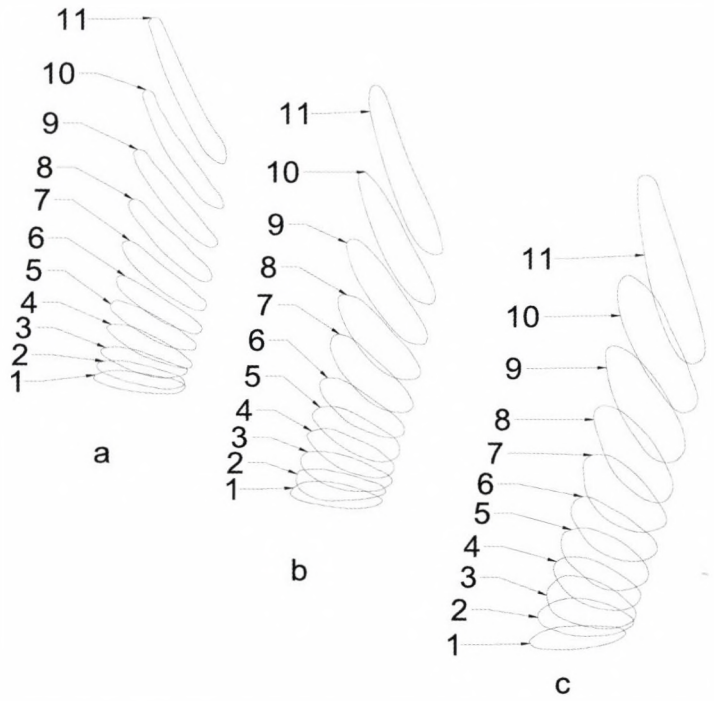

Figure 2. The dependence trajectories of the points E', E", E"' vibro transporter from changing center distance:
a - the trajectory of E', b - the trajectory of E", c - the trajectory of E"'

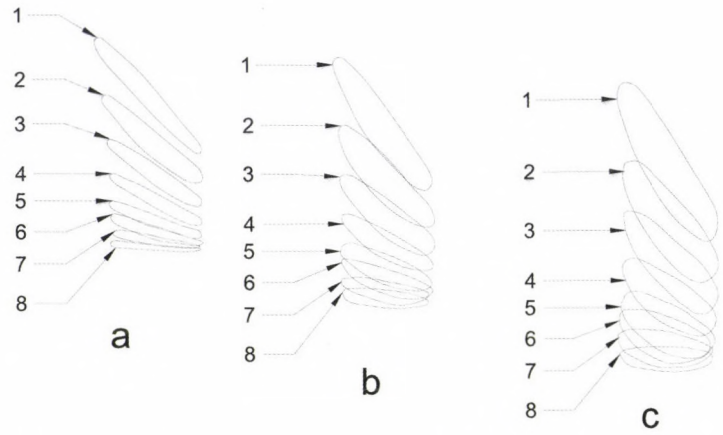

Figure 3. The dependence trajectories of the points E', E'', E''' vibrating transporter from changing the length of the connecting rod: a - the trajectory of E', b - the trajectory of E'', c - the trajectory of E'''

From Figure 2 it can be seen that with the increase in center distance of 753mm to 988 (1-10), the trajectory of each point, falling, coming to a specific position (10), turning in a clockwise direction, changing the shape of elongated line, expanding to form close to ellipse. Continuing to rotate in the same direction, the trajectory points climbing up, expanding to a certain limit (for x = 1178mm), taking an egg shape with the convexity to the ground, then the trajectory of the point of beginning, tapering stretch. From figure 2 it follows that, obviously, the optimum size range for centering data will be the size links of in which the trajectory of the points correspond to the line (Fig. 2), since in this case the greatest amplitude of oscillation.

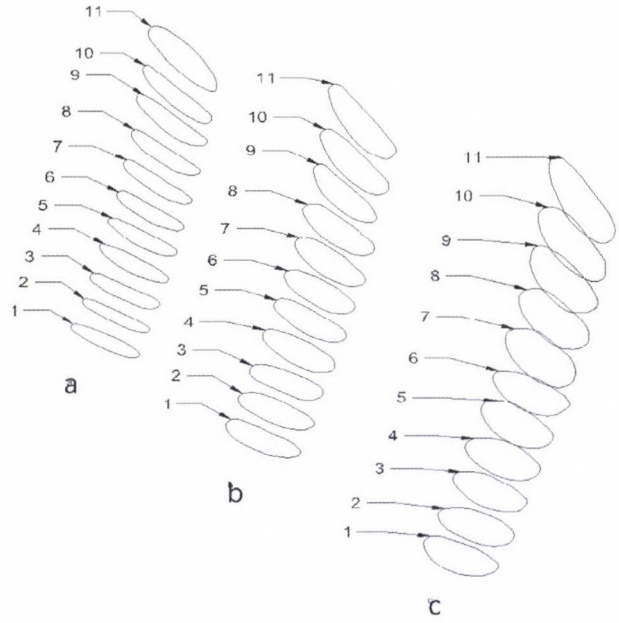

Figure 4. The dependence trajectories of the points E', E'', E''' vibrating transporter on the length of suspension: a - the trajectory of E', b - the trajectory of E'', c - the trajectory of E'''

Figure 3 shows the dependence of the change trajectories of the same points vibrating transporter from changing the length of connecting rod within 723<a<1173 mm at 25mm intervals for r = 30 mm, R = 330 mm, h = 1128 mm.

From Figure 4 can be seen that the connecting rod length is varying from 723 to 1073mm trajectory, dipping and turning counterclockwise tapers, and than expands.

The largest amplitude of oscillation is:
to point

E' at a = 748 mm ÷ 848 mm (figure 2 c);
E'' at a = 698 mm ÷ 773 mm (figure 2 b);
E''' at a = 698 mm ÷ 793 mm (figure 2c).

Figure 4 shows the dependence of trajectories of the points vibro transporter from changing the length of the suspension within 210 <R<410 at intervals of 20 mm, a = 898 mm, r = 30 mm, h = 1128 mm. Figure 4 also shows that the change in the length of the suspension mainly affects only the change in the vertical position of the trajectory relatively to the soil. Shortening the length of the suspension entails lifting and turning points of trajectories of vibro transporter clockwise.

Figure 5 shows the change in trajectories of the points E', E'', E''' on the size of the crank. For h = 1128 mm, r = 330 mm, a = 898 mm crank sizes ranged from 5 to 40 mm at intervals of 5 mm. By increasing the crank increases trajectory and amplitude points of vibro transporter.

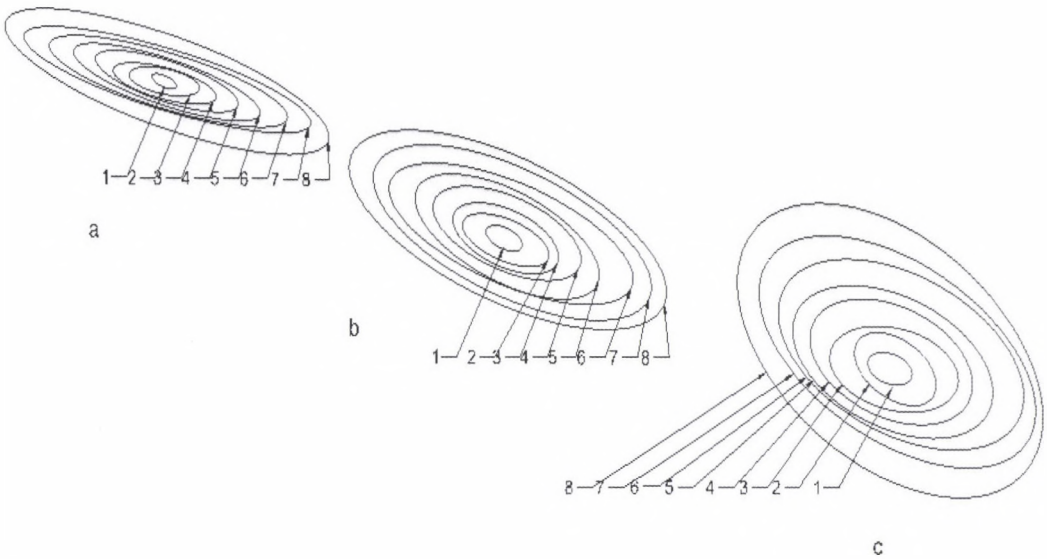

Figure 5. The dependence trajectories of the points E', E'', E''' on the length of crank:
a - the trajectory of E', b - the trajectory of E'', c - the trajectory of E'''

Conclusions

Analysis of the given experiments shows that change in the magnitude of connecting rod, suspension and center distance causes displacement of trajectories points of the vibro transporter. With an increase in the suspension they descend, and with increasing connecting rod or center distance points first descend to a certain limit, and then go up.

The increase in center distance or the suspension causes rotation trajectory of these points in a clockwise direction with lengthening connecting rod, and with the increase they turn their counterclockwise. Lengthening of connecting rod at the beginning reduces the amplitude to a certain limit, and then it intensively increases. If extending the center distance amplitude initially increases up to a certain limit, then as you get closer to a suspension bracket reduced. Change the crank does not move the trajectories of the points vibro transporter height, but elongation of it increases the amplitude.

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