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SOCIAL CONFLICT CAUSED BY A GOVERNMENT DECREE – HEATING ENERGY DISTRIBUTION IN BLOCKS OF FLATS

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Abstract: From 2005 to the last years, there was a large-scale call for tender for energy saving in Hungary. This was called "Panel Program". This tender offers the opportunity to the owners of flats in the big cities of our country to modernize the residential buildings, to improve their energy rating. We would like to summarize the method of heating cost sharing and the experiences of the past period in this article.

Keywords*: cost-sharing devices, heating fee, radiator, thermostatic valve*

1. INTRODUCTION

From 2005 to the last years, there was a large-scale call for tender for energy saving in Hungary. This was called "Panel Program". This tender offers the opportunity to the owners of flats in the big cities of our country to modernize the residential buildings, to improve their energy rating, from state and local government non-refundable grants, and by using their own contribution. This tender includes insulation of exterior walls, replacement of windows and modernization of the complete heating system or parts of it. This intervention greatly reduced the heating demand of buildings during the winter. Before the "Panel Program", the heating fee was distributed depending on the volume of each flats, regardless of the geographical orientation of the apartment and its location within the building. There was no other way to control the temperature of the rooms of the flats than opening the windows. The water temperature of the radiators was usually determined so that even in the coldest flats it was still acceptable. In the better-positioned, warmer parts of the building, there has been considerable energy waste for decades because of the frequently open windows.

Modern heating systems have enabled the installation of so-called thermostatic valves on radiators. By using these, the temperature of the radiators and the apartment became controllable, and so-called heating costs-sharing devices were installed on the radiators. These structures – according to the distributor company – will show a dimensionless unit, that is proportional to the heating energy consumed. The numerical values (unit of consumption) represent a proportional distribution to dissipate all the heat charges of the building to every single flat. The government believed that with the introduction of a fair and legally regulated system, all residents would pay as much energy as they consumed. Thus, environmental awareness and energy saving are realized simultaneously.

2. Regulatory laws

The first regulatory government decree did not take into account the fact that the heat demand of each apartment is different due to its location within the building. The law does not take into account that the walls between each apartment are thin and do not contain thermal insulation. For example, in other homes around an empty flat without heating, much more heating is required. The first government decree [157/2005. (VIII. 15.) Government Decree] was published without investigating the adverse financial consequences of the introduction of the Act for certain apartments. Typically, the ground floor apartments had to pay hundreds of thousands of forints at the end of the heating season. People living on the higher floors – who had almost no need to open the thermostatic valve to get the right temperature – got back tens of thousands of forints. A few years later, the number of (legitimate) outbursts has increased to such an extent that 104/2011. (VI. 29.) Government Decree had to make a fairer accounting system. One manifestation of this was the correction table introduced on the basis of the location of each apartment *(Figure 1)*.

The other most important change was that the maximum heat charge for an apartment should in no case exceed 2.5 times the heat charge calculated on the size of the apartment. This solution ensured that, after the settlement period, maximum 80–90 thousand forints should be paid for a flat. However, the Government Decree did not specify how the remaining part should be distributed to the other flats. Distribution is necessary because the heat supplier expects the full heat charge from the block of flats. The latter change was, in our opinion, a very big step towards a fairer distribution, but the differences between the individual homes are still too large. The relationship between the owners who had lived in relatively peaceful has deteriorated, everybody wants to get information about the heating bill of the others, and the envy of the residents has increased.

With over 10 years of experience, we can say that the losers of this current settlement system are really:

- people living in a ground floor apartment
- elderly, sick people, possibly with vascular lesion
- parents with small children who want to have higher temperature in their home.

Based on the aggregate statistics of the past few years, it can be stated that a minority group of flat-owners pays a disproportionately high price for a little extra warmth. In contrast, the majority of owners live comfortably in their warm flats with locked thermostatic valves and get a refund from the heating costs.

Category	Correction in %
1. Correction in ground floor:	
1.1. Ground floor if there is no room below	**–15**
1.2. Ground floor if there is a room below without heating	**–10**
2. Correction of the top floor:	
2.1. building with flat roof, directly under the roof	**–20**
2.2. under not built-in, unheated attic	**–15**
2.3. under built-in, unheated attic	**–10**
3. Correction of corner rooms:	
3.1. any room with at least two outer boundary surfaces (cooling wall surfaces)	**–10**
4. Correction according to direction:	
4.1. north side	**–5**
5. Other corrections:	
5.1. room above unheated corridor and above doorway	**–15**
5.2. room above unheated ground floor	**–10**
5.3. room near unheated staircase or corridor	**–5**

Figure 1. 104/2011. (VI. 29.) Government Decree – correction table

3. CURRENT FORM OF ACCOUNTING

In this chapter we would like to briefly describe how the settlement is done in a block of flats which was renewed with "Panel Program". To do this we have investigated a 10-storey detached house with 55 flats in the Miskolc Avas area. The data described below has been aggregated and included in charts on the basis of our own collection work. The amount of heat consumed by an apartment, and so the heating fee to be paid, consists of two parts *(Figure 2)*. One part comes from the air volume of the apartment, and the other is from the cost-sharing device mounted on the radiator.

According to the Government Decree, the percentage after the airspace may be 30, 40 or 50%. The amount of heat calculated from the value shown by the cost-sharing devices is the remaining 70, 60 or 50%. The government decree entrusted the decision to the owners with which accounting ratio the heat fee would be distributed. The decision was made at the condominium assembly. It is interesting to note that when the settlement system was introduced and the owners had to vote about the percentage distribution system, nobody had any experience about the consequences of the vote. Since then, it has turned out that for the majority, the 30–70% allocation is favorable for purely financial reasons, while it causes heavy financial burden for the minority. This ratio can be changed at any time by the vote of the condominium assembly, but the minority can hardly enforce its interests against the majority.

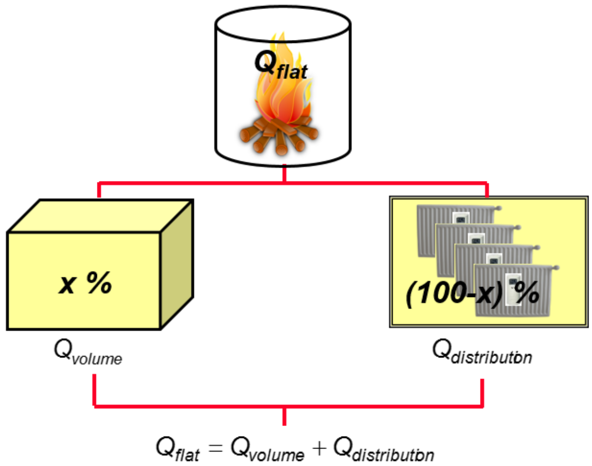

Figure 2. Determining the amount of heat consumed by an apartment

The next step in the calculation is to sum up the values shown by all cost-sharing devices. As a result, we get the total heating unit in the "E_{sum}" *(Figure 3)*.

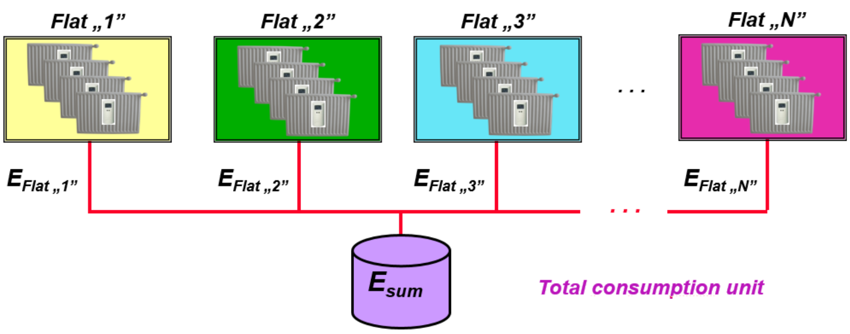

Figure 3. Determining of total consumption unit

At the end of each heating period, the heat supplier company provides information on the total heat consumption of the given block of flats, so it is easy to calculate how many GJ heat energy does one unit represent. From this we can calculate the total calculated theoretical heat consumption of the apartment *(Figure 4)*.

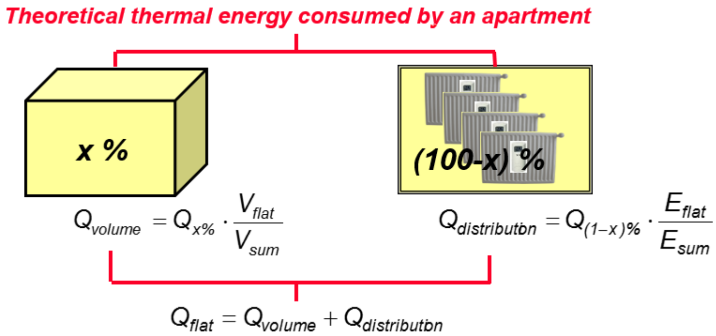

Figure 4. Total calculated theoretical heat consumption of an apartment

The heat supplier company calculates the amount of heat consumed in the so-called "Q_{flat}" expressed in GJ and invoices it to the owners.

4. STATISTICS OF A CONDOMINIUM EQUIPPED WITH COST-SHARING DEVICES

As already mentioned, we have been monitoring the heating data of a ten-storey, 55-apartment condominium located in the Avas area of Miskolc from the beginning to the present. If you look at the figure below *(Figure 5)*, you can make some interesting discoveries.

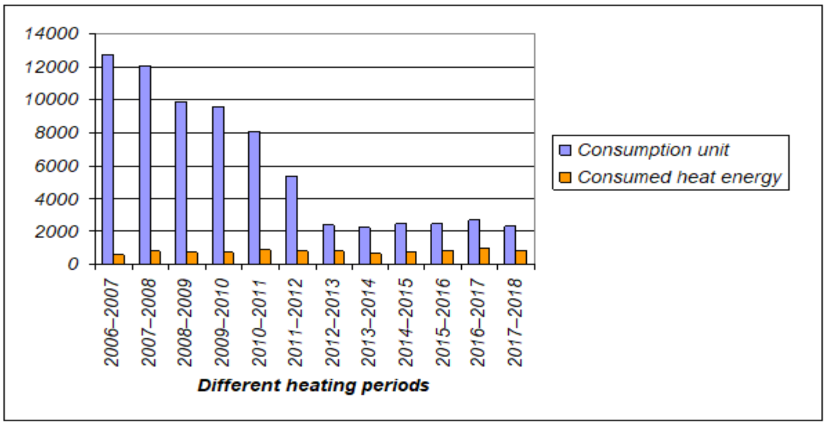

Figure 5. The evolution of the consumption unit and the amount of heat consumed

In the first year of installing the cost-sharing devices and in the following years it can be seen that the residents of the flats heated regularly several times, with the total consumption unit varying between 8–12 thousand. The reason for this is that the radiators were not controllable before, so it took years for the residents to get used to it. The downward trend shows this. For the 2012–2013 heating period, the residential community achieved the environmental awareness that was probably motivated by the significantly lower heat fee and not by energy savings. In the last 6 heating periods, all consumption units are stagnant, almost constant. We believe that the chart's trend could have been predictable. It is interesting, however, if we represent the total amount of heat consumed for the entire heating period in the same diagram. We would expect that larger consumption unit and the amount of heat consumed would show a similar trend. However, the chart shows that the total amount of heat consumed by the condominium during the 12 years of the study is approximately constant. The relatively small differences can be attributed to different winter temperatures.

However, if the amount of heat consumed and the amount of units visible on the cost-sharing devices do not correlate as it was expected, we can question the whole process of the accounting which is based on the values shown by the cost-sharing devices. According to the diagram, there is no linear relationship between the two quantities.

On the basis of the available data, we will examine how the price of one heating unit has developed in each heating period *(Figure 6)*.

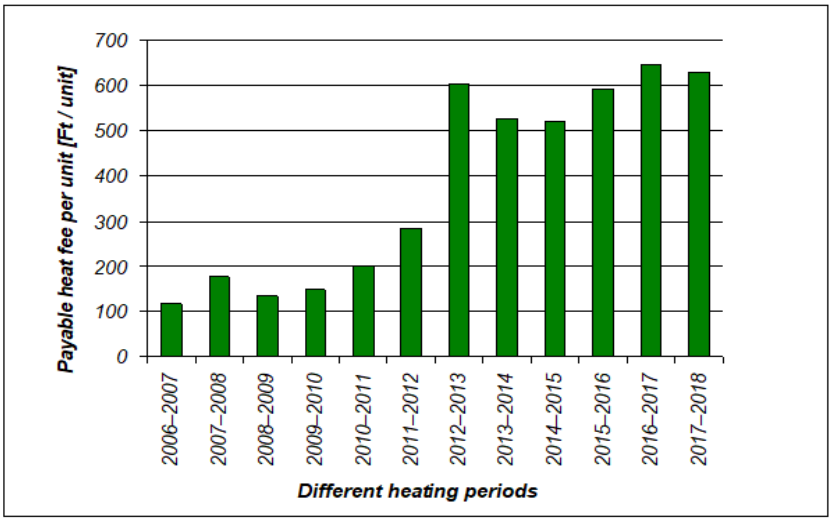

Figure 6. Annual change of the price of one heating unit

The figure shows that while in the first years of installing the cost-share devices one unit had a relatively low cost (120–180 HUF), currently it costs over 600 HUF. Experience has shown that during the winter months, one heating unit is produced in 4–8 heating hours, depending on the radiator temperature. However, the residents living at the higher floors do not need to open the thermostatic valves at all to reach the comfort of 22–23 ºC (heat dissipation of building heating pipes ensures the appropriate temperature). Therefore, the above-mentioned 600 HUF/unit heat charge only affects the owners of less-favored homes, where the temperature of the heating pipe is significantly lower.

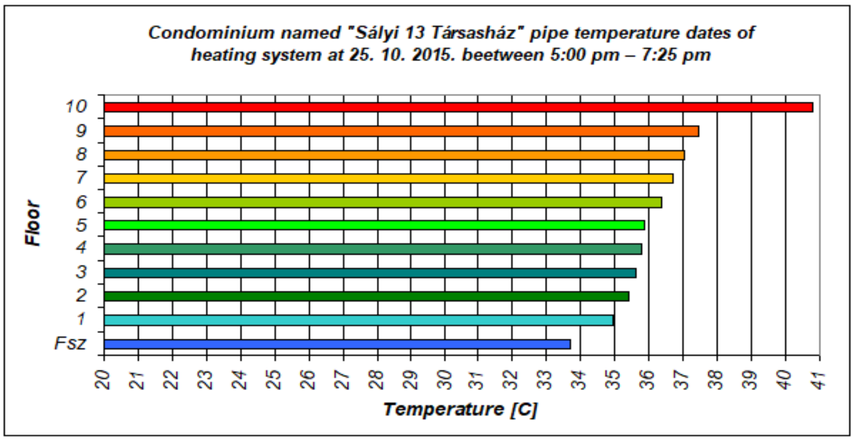

Figure 7. Heating pipe temperature in the investigated condominium

The reduction in pipe temperature from the upper level to the ground floor can be determined by measurement *(Figure 7)*. As shown in the figure, the pipe temperature on the 10th floor was 40.8 ºC at the time of the test, and on the ground floor the pipe temperature was only 33.7 ºC. In addition, the upstairs apartments have a return heating pipeline under the ceiling, which also has a significant heat transfer function. The test was carried out with a suitable non-contact temperature measuring device, because in some of the apartments the pipe was not directly accessible due to the furniture.

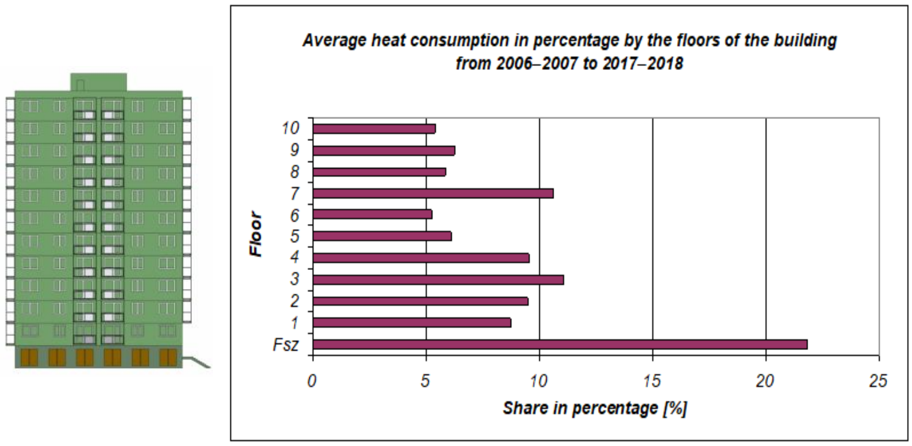

Figure 8. Average heat consumption in percentage by the floors of the building

We have also performed an analysis to show how much the average consumption in percentage has been on each floor over the past 12 years. *Figure 8* clearly demonstrates what we have already established, namely that the current account system is not fair. It can be clearly seen that the average heat demand on the ground floor is almost four times higher than on the top floor, but it also has more than double heat demand than any other floors. In contrast to this fact, the 104/2011. (VI. 29.) Government Decree provides only a 10% reduction for these owners. This is probably due to the fact that no such summary analysis was made at governmental or national level. We have also investigated other residential buildings with similar results.

5. Summary

In this article, we gave a brief overview of the calculation algorithm of the heating cost-sharing system that is prescribed by the Government Decree for block of flats renewed through "Panel Program". Special attention has been paid to the experience of the past 12 years, showing the serious failures of the system and the unfair accounting, which affects the minority of the residents continuously, even nowadays. Although government decrees have changed, and all of them have improved the situation, but an acceptable state is still not developed.

It would be very necessary to create a commission with expert engineers, which would produce a proven accounting system based on numbers, facts and data. This system would share the heating fee between the owners based on the comfort of the flat rather than the temperature of the radiator.

Acknowledgement

The described article/presentation/study was carried out as part of the EFOP-3.6.1-16-2016-00011 *Younger and Renewing University – Innovative Knowledge City – institutional development of the University of Miskolc aiming at intelligent specialisation* project implemented in the framework of the Szechenyi 2020 program. The realization of this project is supported by the European Union, co-financed by the European Social Fund.

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A SOCIAL CONFLICT – PRESENT AND A POSSIBLE FUTURE OF THE HEATING ENERGY DISTRIBUTION

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Abstract: In the article *A Social Conflict, – Past and Present of the Heating Energy Distribution* we have described the system of distribution the heating costs in block of flats renewed through "Panel Program" which is controlled by a Government Decree. We have looked at facts proven by data which testify that there are some flats, that are required to pay extra costs. In this article, we would like to present some suggestions and tools for giving ideas.

Keywords: *cost-sharing devices, heating fee, radiator, thermostatic valve*

1. INTRODUCTION

In the article *Social Conflict Caused by a Government Decree – Heating Energy Distribution in Blocks of Flats* we have described the system of distribution the heating costs in block of flats renewed through "Panel Program" which is controlled by a Government Decree. We have looked at facts proven by data which testify that there is a minority ownership, that is required to pay extra costs either because of their social status, or because of their flat's location within the building. In the summary, we suggested that it would be very necessary to create a commission with expert engineers, which would produce a proven accounting system based on numbers, facts and data. This would reduce the serious tension in the communities of blocks of flats. Although we still have to wait for the formation of this commission, in this article, we would like to present some suggestions and tools for giving ideas.

2. SHORT PRESENTATION OF THE CURRENT PROBLEM OF THE COST SHARING

In this section, we would like to give a brief introduction to all those who have not been convinced by the article *A Government Decree have caused social conflict – heating energy distribution in blocks of flats* that some of the furious owners of flats are right when they consider the government decree on cost sharing unfair and thoughtless. If the condominium wants to use a different kind of distribution, then the government decree demands a complete, detailed energy calculation prepared by an expert.

Fulfilment of this regulation would mean such a great financial burden on the condominium budget that the community of owners cannot afford. Therefore, the owners of less-favoured flats are either trying to move away or have to accept the fact that they have to pay multiple fee to achieve same temperature as other flats. As evidence on this, we have collected the annually data on the largest and smallest heat-consuming apartments in the condominium *(Figure 1)*.

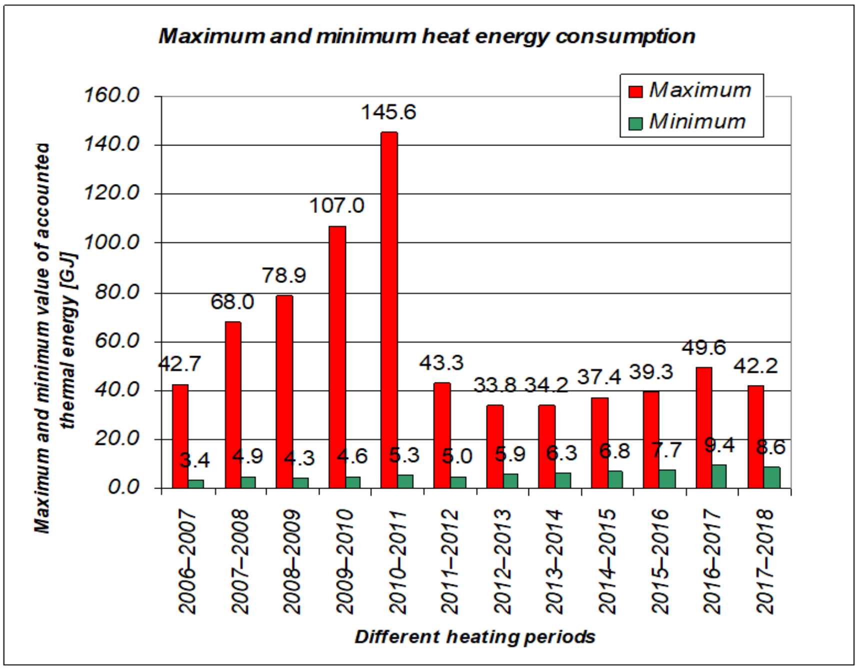

Figure 1. The most and least heat-consuming flats in the heating season of different years

The reason of the visible increase in the first part of the chart, is that people on the higher floors have realized over the years that they do not lose their comfort even if they completely shut off the radiator. On the other hand, people living in the ground floor apartments have been cold even when the thermostatic valves have been fully opened. It can be seen that in 2011 there was a difference of almost 28 times in the calculated heat consumption between two flats in one building. From a technical point of view, this is not a realistic result. After 2011, the introduction of the government decree on corrections and on maximum consumption, in particular the latter, has improved the situation significantly, but the difference is still remarkable. On average the amount of heat consumed by the largest heat-consuming apartments is 9 times the consumption of the smallest heat-consuming ones. This represents a ninefold payment for the owners of flats with unfavourable location. Such a difference implies that the entire settlement system is incorrect.

In order to find out the reasons, we examined one arbitrary selected radiator of the condominium using a thermal imager camera *(Figure 2)*. Recording was done in a range of 18.1 °C to 42.1 °C with a Fluke TI 20 thermal imager. The uneven heat output of the radiator is clearly seen and the rectangular light blue area around the centre shows the location of the heating cost sharing device. At this point, the temperature of the radiator is significantly lower than on the incoming pipe, but it can also be seen that the lower part of the radiator is room-temperature, so no water flows through this area. This anomaly could be greatly improved by the diagonal connection of the radiator.

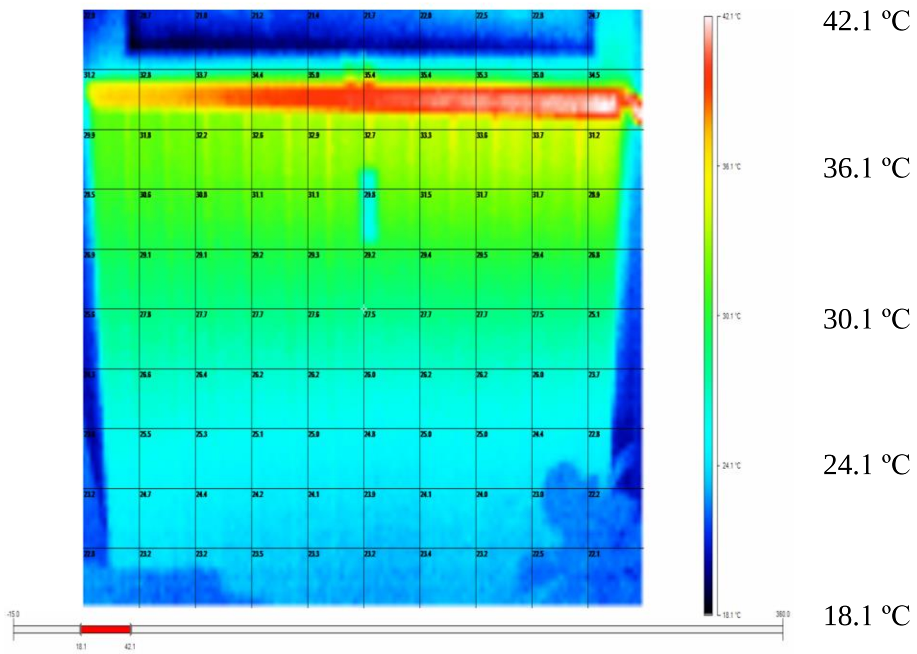

Figure 2. Recording of an arbitrary selected radiator using a thermal imager camera

We have also prepared the temperature dispersion diagrams of the above described radiator. They also show that the efficiency of the devices is very poor. The uneven heat output can have a causal relationship with the calculated heat consumption differences previously discussed.

On the basis of the facts described above, it can be concluded that under such conditions it is not possible to build a fair accounting system based on the heat cost-sharing devices.

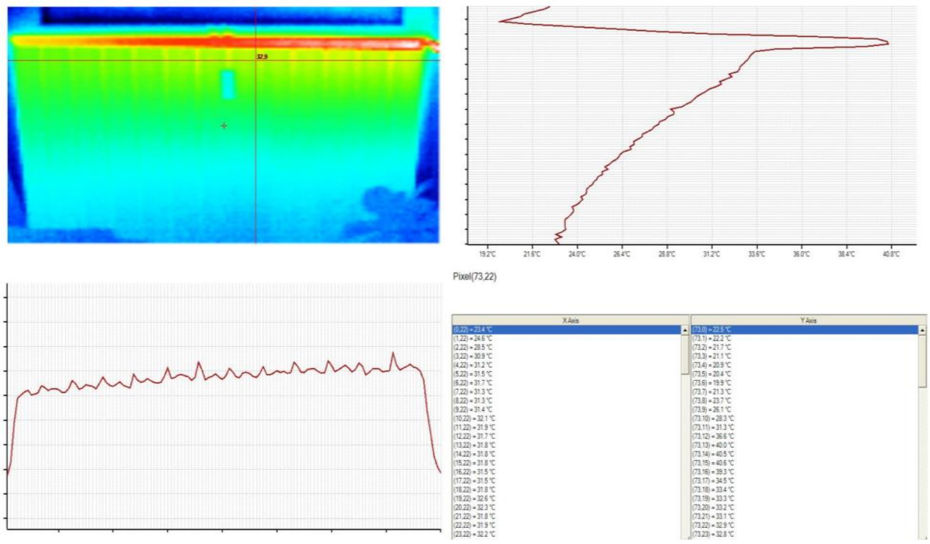

Figure 3. Temperature dispersion diagrams for the selected radiator

3. Suggestion for a different settlement system

According to our recommendation, the settlement system should not be built based on the value of the heat delivered by the radiator but based on the comfort of the apartment. This means that the same heat fee should be paid for apartments of the same airspace having an average temperature during the heating period, regardless of the location of the apartment within the building. Hence, apartments with lower average temperatures would cost less, and apartments with a higher average temperature would cost more, inversely than the current settlement system. However, the differences using this system would not be as huge, because the temperature values can spread within a building in a much smaller range. Of course, it would be necessary to discriminate negatively the owners who intentionally leave the windows open for a long time in their absence.

This accounting system would encourage the owners of too hot flats (because of the location) to further environmental awareness. In these flats, the owner would contribute to the insulation of the heating pipes with a so-called pipe shell. This could significantly reduce the total heat consumption of the whole building.

4. Opportunities for implementation

Suggestions and ideas are of no use if there is no adequate technical background for the implementation.

Fortunately, in the century of digital technology, there are temperature collectors available *(Figure 4)* – on a much lower price than the current cost sharing devices – that can record the actual temperature in their internal memory at intervals of up to a few minutes.

Figure 4. Temperature measuring units with data storage

These data can be downloaded at the end of the heating season with an USB connector on a computer for further analysis. As a test case, we performed a series of such measurements in a flat. The result is shown in the diagram below *(Figure 5)*.

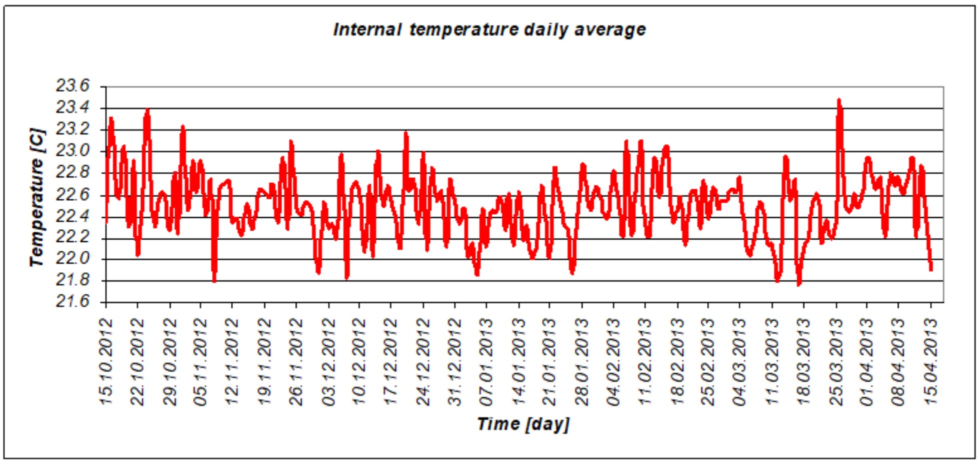

Figure 5. Temperature chart recorded inside the apartment in the heating season

It is important that not only the temperature of the apartment is taken as the basis of the settlement, but also the temperature of the external environment. Therefore, an external unit was also located which registered the outside temperature *(Figure 6)* in time synchronization.

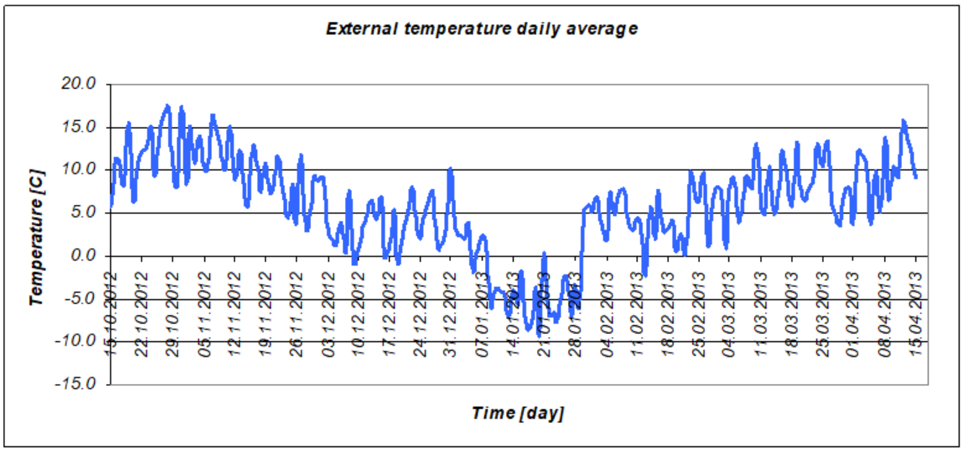

Figure 6. Temperature chart recorded outdoor in the heating season

The amount of heat delivered by the radiators is not the same as the difference of the two temperatures, but can be regarded as almost proportional *(Figure 7)*. By integrating the area below the curve, we get a so-called single metric (ºC unit), which characterizes the heat consumption of the apartment. In a warmer apartment we get a higher value, in a less warm apartment we get a smaller value, but according to our opinion and preliminary calculations, their greatest difference would be not more than 6–8 ºC.

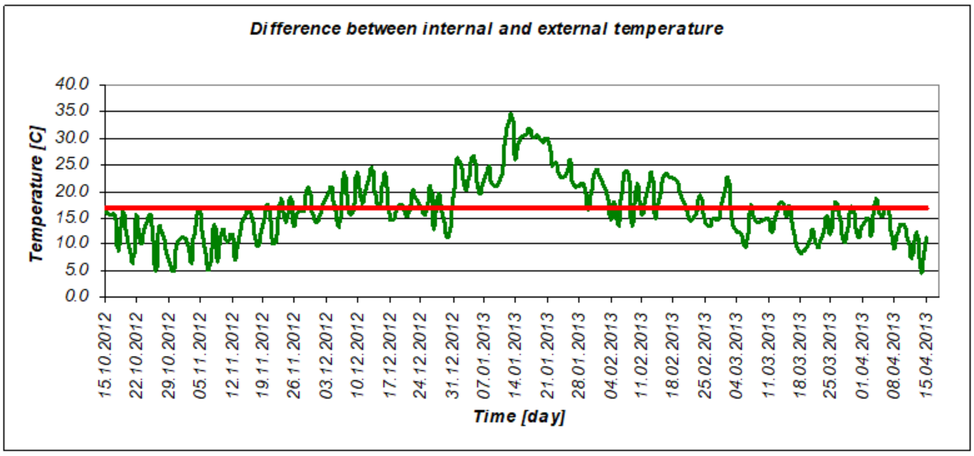

Figure 7. Difference of the internal and external temperature within a heating period

This would mean that the difference between the monthly heating bills of the flats could be much smaller (according to preliminary calculations, in worst case maximum a few thousand forints). However, in our opinion, this may be enough to motivate the residents to be economical and environmentally conscious. The introduction of this cost accounting system could create peace in the residential communities of condominiums through an appropriate burden sharing.

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The described article/presentation/study was carried out as part of the EFOP-3.6.1-16-2016-00011 *Younger and Renewing University – Innovative Knowledge City – institutional development of the University of Miskolc aiming at intelligent specialisation*" project implemented in the framework of the Szechenyi 2020 program. The realization of this project is supported by the European Union, co-financed by the European Social Fund.

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EVALUATION OPPORTUNITIES OF SEM PICTURES BY CAD SOFTWARE

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Abstract: Nowadays the different 3D printed components are often produced for direct use. In this case the components need to be mechanical designed, therefore the material properties must be well known. It is a fact that the printing parameters have a significant effect on the printing quality. The interference between the printing parameters and the mechanical solidity is well known however the reason for this phenomenon is not. For a deeper investigation a scanning electron microscope is needed. Our study is focused on the potential evaluation of results with the help of the CAD software.

Keywords: *SEM, NURBS, Additive Manufacturing, material investigation, material properties*

1. INTRODUCTION

Due to the popularity of the 3D printing the printed parts can be used as prototypes, tools and in case of small series, even components can be directly produced this way [1], [2]. It is important to note if the 3D printed part is used not only as a prototype (marketing accessory) the part also has to be mechanically resistant [3]. Because of the layer by layer production, most of the 3D printed technologies are characterised by the orthotrop material model, which means that the material properties differ in different directions [4]. It also means that some independent material properties have to be specified exactly, in order to define the behaviour of the material [5]. Furthermore, it is also clear that besides the manufacturing parameters like temperature, layer thickness or printing speed, the position of the part affects the mechanical strength too [6], [7]. The mechanical properties were defined by many research but the reason for these parameters have still not been determined. The researches until now has shown how the possible settings can change the parameters, for example, how the nozzle temperature affects the strength of the whole part [6]. Usually the reason for this effect is not defined because it needs a much deeper analysis. However, by a scanning electron microscope it might be possible to analyse the specimens more precisely. This can help us much more information could be collected about the connection layers what is decisive about the mechanical strength of the parts. The analysis of the SEM pictures is very complicated, it needs experience. There are some patterns that could be easily noticed by a professional but an exact numerical value requires a lot of time. Our study is aimed to demonstrate the possible methods for creating reliable, numerical evaluations required for analysis.

2. METHODOLOGY

For our investigations was used the most widespread 3D printing method named FDM (Fused Deposition Modelling). The specimens were created with different specifications which was changed separately. The printing parameters could be changed independently within the limits, and these modifications can highly influence the quality. For this reasons these parameters like printing speed, temperature and layer thickness were separately changed during our investigations.

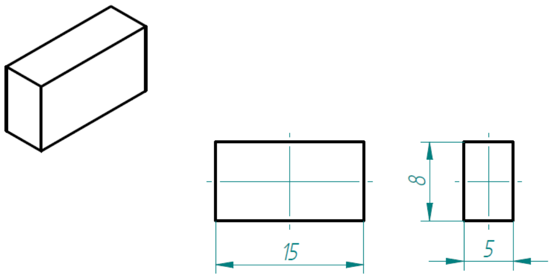

Figure 1. Examined specimen

An important consideration in determining the geometry of the specimen was that it could be quickly and easily produced and that fractions of appropriate size could be pre-set. Another aspect was to reduce the time duration of the production and to save printing material. After producing the specimens and preparing the right fractions, pictures were taken by SEM, which is shown in the *Figure 2*.

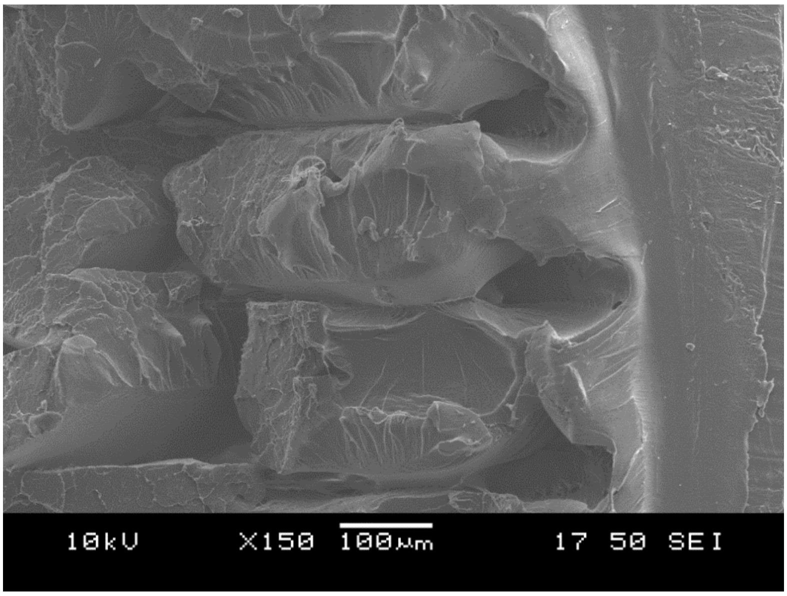

Figure 2. SEM picture (FDM technology, material: PLA)

In the *Figure 2* the layers and gaps can be observed, revealing that the connection between the filaments is not perfect, and the layers are not merged perfectly into each other. The size of the gaps has an effect on the stiffness because this way the cross section decreases as well. Despite of the good visibility this picture is not capable of further investigations because of the direction of the filaments (there are unreal sizes). For the exact numerical evaluation our study needed pictures where the filaments were perpendicular to the fraction.

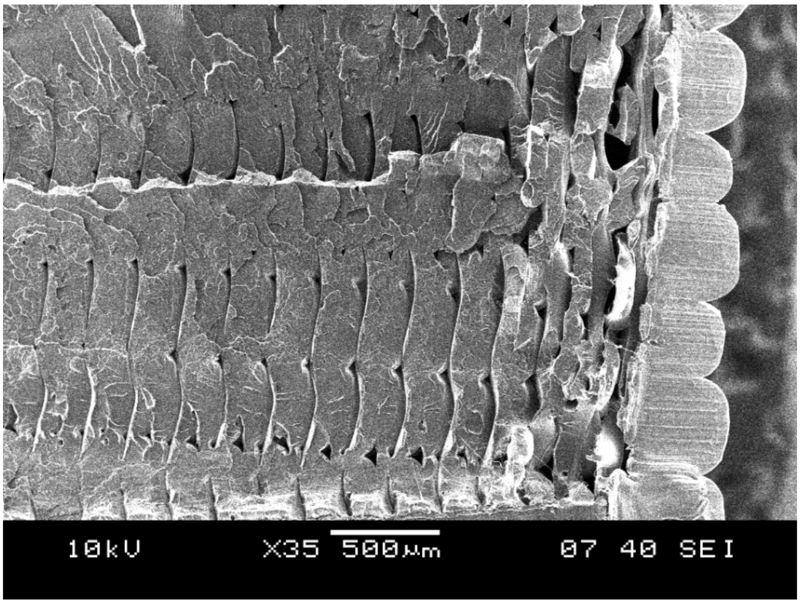

Figure 3. SEM picture, the filaments are perpendicular to the fraction (FDM technology, material: PLA, 220 °C, 0.1 mm, 20 mm/s)

In the *Figure 3* the fractured plane is in the right plane for evaluation. Unfortunately it is less spectacular than the picture in *Figure 2*, but here the inter-layer gaps can be observed on the real size. The purpose of our study is the examination of these triangle-like gaps. The size of the failures is definable with scale on the picture. Theoretically the precise side-size of the gaps is measureable with different photoshop softwares but these gaps have not got an exact shape therefore it would not be the easiest way. In the CAD software there is a function with the size of the closed curves are measureable, furthermore the CAD software are based on the NURBS (Non Uniform Rational Bezier Spline) which means these approximated curves are really well evaluated therefore we can measure the gaps like the curves enclose gaps. The pictures were evaluated with this opportunity.

The steps of the evaluation

- Paste the chosen picture to the CAD software (first a right plane has to be chosen)

- Resize the picture in accordance with scale
- Draft around the gap by NURBS curve (the curve has to be closed)
- Get the size of the gaps
- Recording of measured values, calculate the average

3. RESULTS

With these steps the exact solution can be determined. In the *Figure 4* there is a gap drawn around and its area information. The information was provided by Solid Edge CAD system.

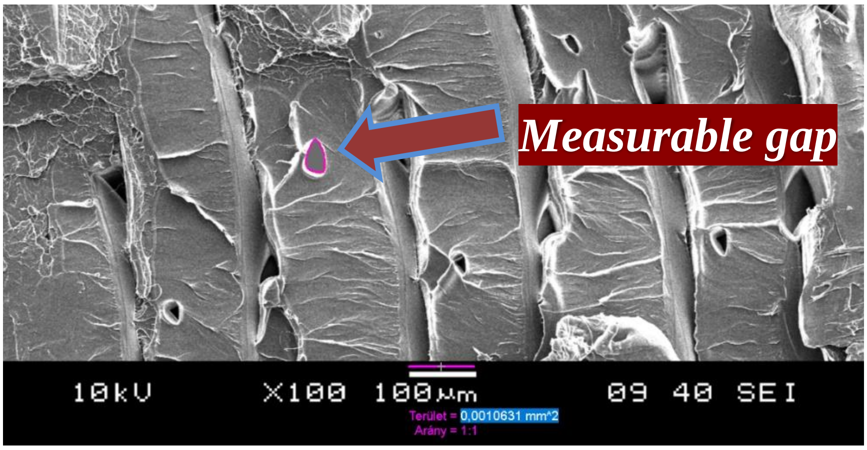

Figure 4. Determination of the gap sizes by CAD software

The average gap sizes were determined by the summarized and statistically evaluated results. The changing of the average gap size, which depends on the changing of the printing parameters, can be analysed. In the *Figure 5* there is a diagram demonstrating the change of the average gap size depending on the nozzle temperature.

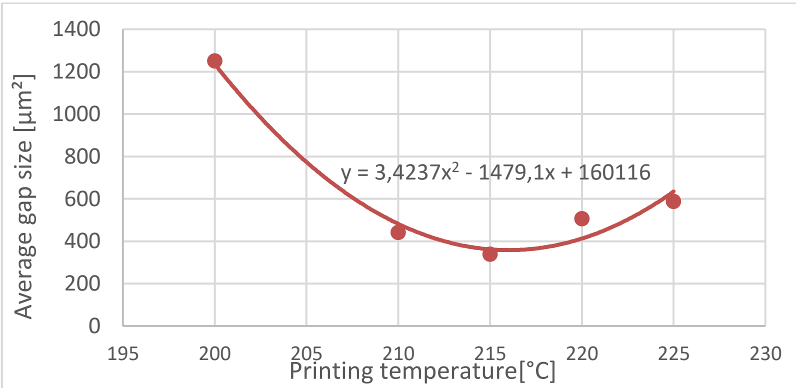

Figure 5. Average gap size depends on the printing temperature

4. Discussion

According to the *Figure 5* the smallest gap size is about 215 °C, but the exact solution can be defined by the equation of the diagram. This point is an optimum too, because this temperature is the recommendation of the material manufacturers. According to the academic literature, the mechanical optimum is about this temperature too [6].

Acknowledgement

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THE 'PERFECT' MIXING MACHINE

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Abstract: In the past few years the Machine and Product Design Institute of the University of Miskolc took part in an international project, called HeiBus (http://www.heibus.eu/). As a part of this project student groups had to work on different real-life problems that were given by companies like Valeo, Robert Bosch, Festool etc. The real-life problem this paper is about was given by the Festool. The task was to design a machine that helps to make the 'perfect' mix. This paper is about the idea and about the developing process. In the task inscription, there was only one statement: 'Develop the perfect mixing machine'. There were no restrictions about size, price and application, everything was up to the student team, but it was obvious that it had to be marketable.

Keywords: *smart system, mixing machine, 3D modelling, modularity*

1. BRAINSTORMING

At the beginning of the project there was an intensive week in Esslingen, Germany, where the participants took place on several programs for better understanding the task and to get to know the team members better.

There were presentations hold by university lecturers and representatives of the Festool company. We visited the company and some work sites, where a direct interaction with the consumers could be established and it was a very useful way to see what is actually needed in real life.

After we got acquainted with the challenge we had to face in the next ten and a half weeks, we got some time to talk to each other, speak our minds and put together a mock-up of our idea, in order to have something that we could discuss with the supervisors from the universities and with the professionals from the company. Our main principle for the whole process of development was modularity. We all agreed on that we should think about a quite complex machine, that can satisfy all the diverse needs of the costumers (painters, construction workers etc.). On the other hand, to keep the price low we designed modules for different functions and each module could be bought separately to fulfil the given function.

The following functions and parts were the initial idea of our concept. Nevertheless, it would have been developed and improved during the rest of the project. Some of them were refused, following the supervisor's advice, and other have been remained in the final concept of our project.

1.1. Smart system

The aim was to move automatically the tool of the mixing device on the mathematically optimized orbit and for the perfect period, calculated by the computer and dependent what are the mixing components. By this system the workers' physical health is also conserved, as nowadays used manual mixing machines often cause backpain for their users, due to company representatives. A display and a microcontroller form the smart system incorporated in our machine.

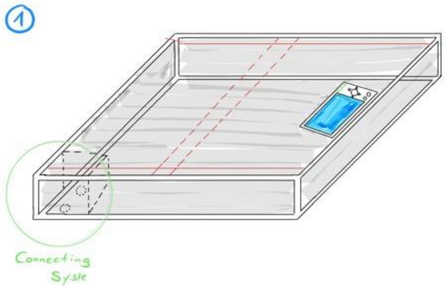

Figure 1. X-Y coordinate automatic system

1.2. Scale

The aim was to help the workers to make the perfect mix by telling them how much to put from each ingredient into the mixture.

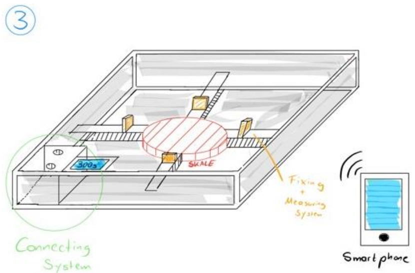

Figure 2. Scale

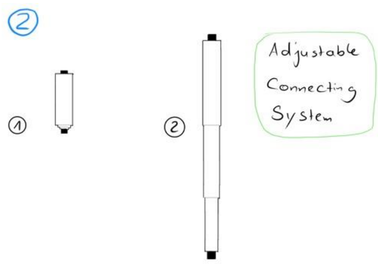

Figure 3. Connecting system

1.3. Connecting system

The conceptual design phase, in comparison with the other steps of the whole design process is barely supported by computer. The research intends to fill this gap [4], [5]. The most important aspect is to help brainstorming with an easy-to-use application on mobile devices. In the first phase of the research, the aim is that the students use the application in their own individual tasks in design methodology lessons and build concepts based on their individual ideas. A further goal is to create a version of the application that is capable of generating all the possible solution variants from functional subassemblies selected by the user and then reducing the large number of solutions based on the user-defined rule set, according to the theory in chapter 2 of this paper. The goal was to connect the upper side (axles and microcontroller) to the underside (scale) with a removable connection system to ensure stability and to be able to adjust the operating height to the workers working on it.

1.4. Cleaning system

Talking to the costumers made us to realize what a huge issue is to clean the tools and it takes surprisingly a lot of time. We found it really important to deal with this problem and to find a solution for it.

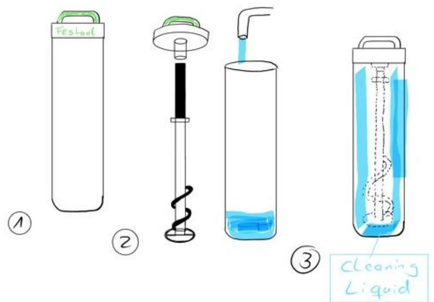

Figure 4. Cleaning system

Figure 5. Transportable device

Being aware of that most of the costumers work on-site, which means a lot of daily travel to them, transportability is crucial for them, so we kept that in mind during developing.


Figure 6. Our mock-up

2. Finalizing the concept

After the intensive week came ten weeks when continued the work individually and had weekly meetings to discuss and distribute the tasks and to talk about that we have done during that week. At the beginning, we had to finalize our concept considering the valuable pieces of information that we have received after the presentation of our mock up and that we gathered during a market research. We decided that we will not focus on the fully-automated mixing system because it might be too unpractical, too expensive and less flexible/mobile for our customers in their daily workplace.

Instead, we started designing a tripod manual mixing machine, based on the Collomix RMX's (Collomix RMX [10. 10. 2018], https://www.dalhoff.de/werkzeuge/zubehoer-fuer-elektromaschinen/ruehrkoerbe/collomix-ruehrstaender-rmx-gewicht-17-kg-abmessung-45-5x118-mm.html?utmid=nex) improved idea. Our solution was planned to be less expensive, more mobile and was meant to be complemented by useful additional modules can be seen later.

Figure 7. Collomix RMX

Keeping in mind our first idea during the intensive week, we've continued developing more ideas to improve some flaws in our design. There will be four main components, intended to work separately, but they are better if the set is complete, specially the first three ones, because the last one – the cleaning system – is a standalone useful accessory. Otherwise we create special accessories for all of our products.

- Scale: weighs the mix.
- Tripod: holds the mixer.
- The HMI: shows the GUI (Graphical User Interface) easier than a smartphone.

3. SCALE

This is one of the main components, as it is needed to achieve a perfect mix: it weighs the different materials in real-time in order to calculate the fraction of every material depending on temperature, humidity, area or volume needed (to improve efficiency). Industrial grade scales are very robust and water/dust resistant; therefore, this is a must in our idea. Most of them only have a display, but expensive ones have other wired, industrial and real-time connections, for example Profibus, Profinet, Ethernet IP, RS85 or RS232.

Those were good examples for connections in precise machines. A simpler and smaller display (e.g. 7-segment one) would be required in order to have an easy functionality. If we want to give advice to the user about the mix, we will need a stable connection with the smart system. This system can help the user with the needed quantities of water/liquids/component and warn them to stop when it has reached the perfect amount. It’s very useful, for example, when the worker is using a water hose to fill the bucket. Moreover, it weighs the bucket first and then in every stage of the process: adding components is completely guided from an easy-to-use GUI (Graphical User Interface).

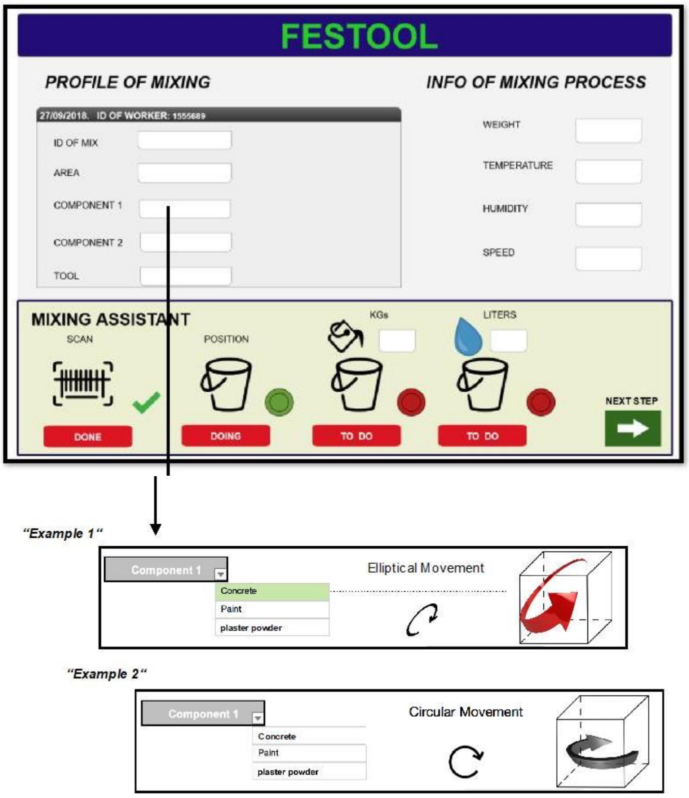

Figure 8. One possibility for the GUI, either in smartphone or display

However, the connection has to be wireless as a wire can be damaged and requires time to be mounted. We have decided to be wireless, even on the power supply side.

Finally, our scale has to fulfil the following requirements: portability, lightweight if possible, robust, IP 67 (maximum in dusty-wet environments), range up to 100 kg or less, it really depends on the application for the mixer, battery powered: lithium, wireless connection: for example Bluetooth 4.0, low-consumption (8 or 32 bit) microcontroller that can handle wireless connections, a little 7-segment display to check the weight and LEDS to update the battery level status.

This is feasible, but we need an enterprise to develop/modify current industrial scales to include lithium batteries, Bluetooth 4.0 as it has low consumption profiles, very stable connections (if the devices are nearer than 10 meters); and a little display.

3.1. Database

As mentioned above, the scale is a great help, but not the best option to achieve a perfect mix yet. That is why we have developed a smart system for the whole process. Obviously, it needs a display or a screen. The best option is using our integrated display directly on the tripod, but if the scale has to work in its own, a smartphone can be used. Here is a simple example to explain how it works:

A painter wants to paint a determined area. In our app (smartphone or display) he/she selects the size of the surface he/she wants to cover. Then, he/she has three choices:

- Scan the barcode with the camera integrated in the display,
- Scan the barcode with his/her smartphone app,
- Choose the paint already set in the app previously or from his/her own catalogue.

The system, keeping in mind the temperature and humidity with cheap sensors located in the scale, calculates the perfect quantity of each component. Beside quantity, the system also calculates the mixing time –another crucial parameter of mixing. The next step is placing the empty bucket on the scale. After that, the scale already knows the weight of the bucket. The painter pours the different components and either the display or the smartphone warns (with sound) when the calculated volume is near.

Finally, the worker can mix using a FESTOOL mixer or from any other brands. If he/her uses a FESTOOL mixer, the app can advise him/her which tool is the best one from his/her repertory and check it with RFID sticker located in the tool and a RFID scanner located in the display.

This database will improve over time, using Machine Learning Techniques and recording the user’s different mixes, helping him to do the whole process faster and better.

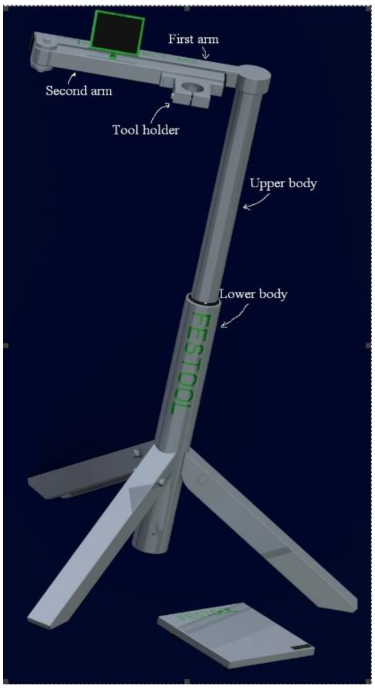

Figure 9. The tripod

4. TRIPOD

While designing our tripod, our main goal was to provide an affordable solution to anybody. To achieve this, we needed our system to be fully adjustable and cheap to produce. The gas spring provides a range of motion that spreads from 700 to 1,200 millimetres, thus making it ergonomic for workers at any height. The production costs are kept down by using as few welded connections as possible and keeping the design simple. Furthermore, the tripod is sold in an unassembled state, the buyer can assemble it in a few easy steps. This way we can keep boxing and transport costs as low as possible and it even makes it easier to keep the system clean.

The heart of the tripod is a gas spring seen on the top of *Figure 10*, that provides a constant pressure force that keeps the upper part of our system lifted, supports the weight of any attached power tool, and enables rotation. The section view of the spring can be seen on the bottom of *Figure 10*.

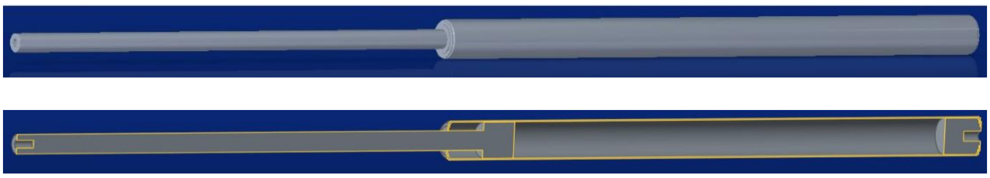

Figure 10. Gas spring

The gas spring is supported by an outer body, section view can be seen in *Figure 11*, that helps with bearing the weight of upper part, provides an easy rotating sliding surface, and keeps the dirt out with a rubber seal. Both the upper and the lower body are connected with end screws.

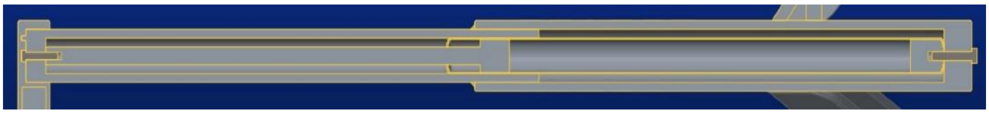

Figure 11. Outer body

The legs are held in place with the highlighted part seen in *Figure 12*, which is welded to the lower body. The screws allow them to rotate. In an open position they perfectly fit the lower body, so they stand still. While closed, the screws and mother screws provide enough support to keep them from wiggling.

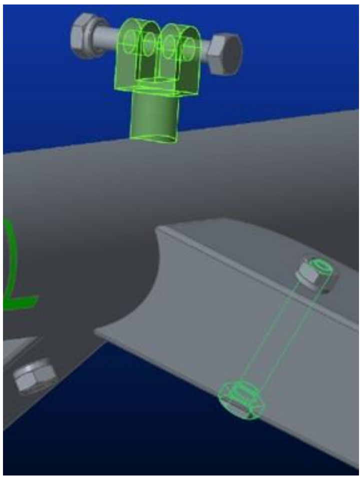

Figure 12. Leg holder

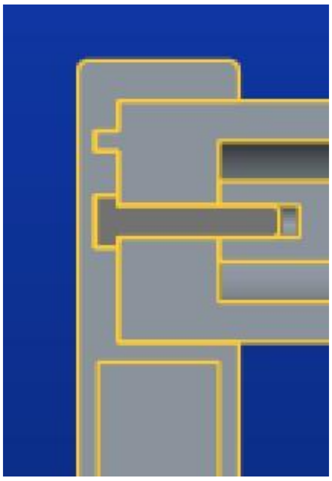

Figure 13. Upper connector

The first arm is connected to the upper body and is held in position by a positioning rod and a magnet, as it can be seen in *Figure 13*. The magnet provides enough force to keep the system together, while it is easy to detach and is not sensible to dirt.
To provide a wider range of motion, another rotation axis was needed too, it can be seen in *Figure 14*. The highlighted rotating arm can be locked in closed position with the pin, highlighted with red. The screen is held by a regular screen holder, which is connected by a screw and a positioning rod. The power tool can be inserted on the holder seen on the lower right part of the picture and can be fixed by tightening the end screw.

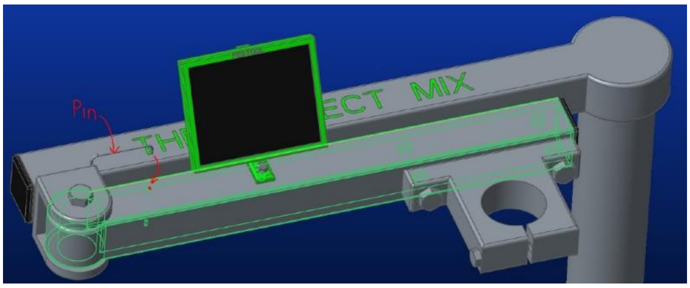

Figure 14. Upper part

The upper body has two machined slots on its bottom, as seen in *Figure 15*. With the help of these and two screws connecting to them, the tripod can be locked in a closed position by pushing it down and rotating it clockwise. Then the gas spring pushes it back up, creating a shape connection, and holding it closed.

Figure 15. Upper body connecting slot

5. HMI

5.1. Microcomputer

A small and affordable computer: the Rasberry Pi 3 Model B+. It is the latest product in the Raspberry Pi 3 range. Specifications (https://www.raspberrypi.org):

- Broadcom BCM2837B0, Cortex-A53 (ARMv8) 64-bit SoC @ 1.4GHz,
- 1GB LPDDR2 SDRAM,
- 2.4 GHz and 5 GHz IEEE 802.11.b/g/n/ac wireless LAN, Bluetooth 4.2, BLE,
- Gigabit Ethernet over USB 2.0 (maximum throughput 300 Mbps),
- Extended 40-pin GPIO header,
- Full-size HDMI,
- 4 USB 2.0 ports,
- CSI camera port for connecting a Raspberry Pi camera,
- DSI display port for connecting a Raspberry Pi touchscreen display,

- 4-pole stereo output and composite video port,
- Micro SD port for loading your operating system and storing data,
- 5V/2.5A DC power input,
- Power-over-Ethernet (PoE) support (requires separate PoE HAT).

Figure 16. Rasberry Pi 3 Model B+

Figure 17. Chosen display

5.2. Display

This 7” touchscreen monitor for Raspberry Pi gives us the possibility to create our smart system device for our mixing machine. The 800 × 480 display is easily connectable to our system, which also gives the opportunity for a quick change if needed. The screen is big enough to be easily visible for the workers, so they don’t have to stop doing their job to look at it, they will be able to see everything in a glance. The smart system will provide all the necessary data to make the perfect mix and will be interactive for the workers. It could be like ‘Siri’ of Apple or ‘Cortana’ of Windows. Our device will be connected to the IoT by simply having an internet connection, so we will be able to transform data into information in real time. That will be extended by the machine learning concept, which makes the system even smarter. The smart system will represent step by step all the way the necessary data to make the perfect mix.

5.3. Camera

We have chosen the Raspberry Pi Camera Board v2 that is a high quality 8-megapixel Sony IMX219 image sensor custom designed add-on board for Raspberry Pi, featuring a fixed focus lens. It is capable of 3280 × 2464-pixel static images and also supports 1080p30, 720p60, and 640 × 480p90 video.

Figure 18. Rasberry Pi camera

Figure 19. RFID reader

5.4. RFID reader

The RFID reader reads out the tools on which an adhesive RFID tag is attached. If the right tool has been selected to match the selected program, the user will be informed by audio signal.

6. Cleaning system

The main idea of our cleaning system is to keep the tools with the stucked mixed material wet during the day – working hours plus travelling from the working site – so cleaning the tools at ‘home’ becomes much easier and faster. In order to keep the tools wet, it should be put in a tube filled with water or with a solution that does not let the mixed material dry and does not harm the tool.

Figure 20. Cleaning tubes

It has a longer lower part, in which comes the cleaning solution and the tool. It is supposed to be made of a clear/glass like material – hardened plastic: durable, no cracks, so the worker can see the type of the tools in the tubes without having to open them and check each time a tool is changed. It is connected to its cover with the screw thread. That makes the connection strong and able to lock hermetically, so with the hole on the top the tubes can be hung up or either laid. In addition, the tools are connected to the cover with the same connector as the mixing tools do with the mixing machine. This greatly increases the removal of the tools immensely.

7. ACCESSORIES

7.1. Rack

The rack is built up from 5 parts, but this takes quite a lot of space and besides being inconvenient to set up it also consumes quite a lot of time, but a perfect choice for the home workshop.

Figure 21. Rack

7.2. Holder to go

In most cases there is no need for many tools at the job sites, 3 of them are enough. This holder is built up from 3 parts to make it easier and faster to assemble or disassemble, takes less space and it is more massive then the first one. We suggest this holder for the job sites as it is easy to transport and does not take a lot of space.

Figure 22. Holder to go

Figure 23.

Figure 24. The case

7.3. Case

Storing the tubes in the case is the most evident solution, if somebody buys the case for the tripod. No extra parts, no extra weight, easy to carry.

8. Conclusion

I am glad to have the opportunity to participate in this program. I gained experiences from different fields, that I can apply either in my studies, everyday life and at my job. Going through chronologically, I have improved my organizing skills during preparing for the program – finding a way to get to Esslingen, booking room, etc. During the intensive week, my communication has improved quite a lot. It became more and more easier to express myself, to talk about my ideas in the way, that my colleagues can understand what I am talking about. My English got better, new, special words came up, that I have learnt. My listening skills have also improved, as I have been talking to a lot of people, from different countries and the 10 weeks of ‘home work’ and skype meetings helped a lot, in order to improve myself. I experienced what it is like to work hard together in a project to achieve our common goal and I really enjoyed it!

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EXAMINATION OF THE CONTACT PATTERN OF ROLLING SURFACES

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Abstract: This article provides a brief summary of the potential applications of contact pattern examinations. The examination of contact pattern is a frequently used test for gear drives, rolling bearings and checking support rollers. It is used on gear drives and support rollers to test operating conditions, whereas in the case of rolling bearings the cause of the failure has already been identified. The chapters mention the types of contact patterns, the shape and size of contact patterns. This article is an introduction to a multi-part article series that presents the computerbased capabilities of contact pattern examination.

Keywords: *gear, gear drive, rolling bearing, support rollers, tooth contact pattern, contact pattern*

1. INTRODUCTION

A commonly used method for examining the connection of rolling or sliding roller components is the contact pattern test. Most often we are looking at the resulting contact pattern for gears. In addition to gears, we can also see the problem of the contact patterns on roller bearings and support rollers. Traces of wear on the treads of automotive tires can also be interpreted as a contact pattern that indicates the correct alignment of the chassis or the correct tire pressure applied *(Figure 1)*.

a) b)

Figure 1. Contact pattern (wear) on the tire, (a) as a result of incorrect chassis alignment, (b) excessive tire pressure [9]

Contact print illustrates contact zones between contact elements. The shape, size and position of the zones can be inferred from a structure-specific property. In the following chapters, the article provides a brief literature review on how to make a contact pattern scan, its conditions and how to use the result.

2. ABOUT CONTACT PATTERN EXAMINATIONS IN GENERALLY

The load-bearing tests can be divided into two distinct groups according to the applied load. One group where the test should be conducted under operational conditions and the other group when the test is performed with minimal load. In the case of a contact pattern making, one of the contacting pairs of surfaces should be coated with paint (painted element) and the other left clean (clean element). By touching the elements, the ink is pressed onto the clean element and creates a pattern there. The resulting pattern is called a contact pattern. In order to keep the paint on the surfaces from the contact elements, the lubricant must be removed and degreased. The material of the paint will not adhere to dirty surfaces, thus preventing the wear image from forming on the clean element. Alternatively, the entire tooth is painted, and the paint is removed from the contact points to create a wear pattern *(Figure 2)*. From what has been described so far, it seems simple to carry out the test, but in many cases, it is not or only difficult to carry out under operational conditions.

Figure 2. The formed contact pattern on the tooth surface (the worn area) [10]

2.1. Minimum load test

The contact pattern test shall be carried out with a minimum load where it is possible. The load must reach the value at which the associated surfaces remain in contact during the connection process, without separation and re-contact. For gear drives this is achieved by turning the gear unit at low torque (often manual force) and applying slight braking on the driven wheel. Most often the load from the inertia of the rotating parts of the gear unit is enough to carry out the test. The contact pattern formed in this case may vary greatly (and often deviate) from the load condition. Special testing equipment is often used for testing unloaded carriers (e.g. cone wheels). Low load tests can be organized into two further groups. These are called snapshots and totals. In the case of a snapshot, the large gear of the assembled gear rotates only one, while in the case of a total, the gear is rotated for a longer period.

2.2. Workload test

In the case of tests under operational load, it shall be expected that depending on the degree of loading, the contact surfaces will suffer elastic deformation. Deformation may cause the paint applied between the two surfaces to be pushed out of the surfaces at higher surface pressures. In terms of the consistency (density, viscosity) of the paint used, it is a paste rather than a conventional ink.

3. Support roller bearings and its inspection

A useful method of adjusting the support rollers is to examine the contact pattern image. For example, when testing castor furnace support rollers (or otherwise running rollers), a no-load test is practically impossible. *Figure 3* shows the support roller of a drum furnace.

Figure 3. Support/running roller for drum furnace

The load on the support/running rollers of the drum furnaces is primarily not the material fed to the furnace, but the furnace body (shield, masonry), which means that the own weight of the structure can place a very heavy load on the rollers. Often the material fed into the furnace is not counted when the rollers are loaded. Since it is only possible (and meaningful) to test the contact pattern of the drum furnace rollers under operating conditions, the test instrument should also be chosen accordingly. In general, operating conditions are often characterized by high temperatures and slow rotation speeds. Most paint materials are no longer usable at high temperatures, their flash point may be below the process temperature, which can lead to serious accidents. In such cases, lead wire testing is usually used. Lead is a very soft metal that easily deforms between the rolls. The lead wire is guided between the support rollers parallel to the axis of the rollers. The wire undergoes a large amount of permanent deformation due to the forces. The degree of papulose depends on the force applied to the lead wire. In the part of the rollers where greater force is transmitted, the degree of papulose will be greater. If the lead wire has suffered approximately the same amount of deformation along its length, the roller alignment can be said to be good, i.e. the axes of the contact rollers are nearly parallel to each other.

4. CONTAC PATTERN OF ROLLING BEARINGS

In the case of rolling bearings, as with all rolling pairs, we can speak of contact pattern. Because of the very limited insight into the running surfaces of rolling bearings, the contact pattern of the bearings can be examined in disassembled condition. Most of the tests are done because of some kind of failure. For many types of bearings, the roller bearings can only be disassembled with destruction, thus rebuilding the bearing is no longer possible. The correct bearing pattern of the bearings cannot be directly investigated; it is the installation, operation and design of the used structure, which can influence the wear image and thus the life expectancy based on the calculations. The rolling bearings manufacturer’s catalogs state what technical parameters (size tolerance, position tolerance, shape tolerance, surface roughness, hardness, stiffness) the bearing elements (seat, bushing) must have. This way the bearings will work with the desired bearing pattern. By inspecting the rolling surfaces of the removed bearings, it is possible to determine whether the load pattern was optimal and based on the differences to determine the cause of the error. Refer to [7] and [8] for a detailed discussion of each rolling surfaces lesion and its causes.

5. TOOTH CONTACT PATTERNS OF GEARS

Tooth contact pattern testing is the most widespread and commonly used in gear drives. There are two types of gear contact patterns. One is the full contact pattern and the other is the localized contact pattern. The contact pattern of a gear drive depends on many factors (e.g. load size, load change, rotation direction, shaft stiffness, bearing stiffness, manufacturing and mounting accuracy, etc.). The size of the contact pattern is expressed as a percentage of the size of the tooth surface, the *Equations (1)* and *(2)* being represented by the notations in *Figure 4*.

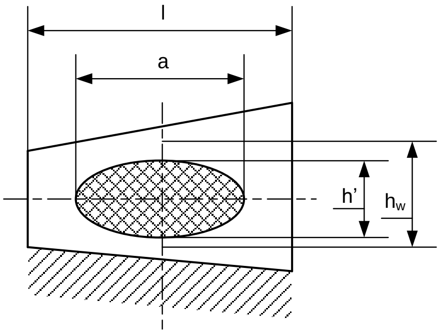

Figure 4. Interpretation of the size of the contact pattern on the tooth surface [2]

Toward the length of the tooth:

$$s_l = \frac{a}{l} \cdot 100\% \quad (1)$$

Toward the height of the tooth:

$$s_h = \frac{h'}{h_w} \cdot 100\% \quad (2)$$

where:

- a: the length of the tooth contact pattern,
- l: tooth width,
- h': the height of the tooth contact pattern,
- h_w: working tooth height.

The full load profile is used for gear units in subordinate positions, or for very precise manufacturing and rigid bearings, or for kinematic drives. Localized portraits are expensive to produce and are therefore only used in demanding applications (e.g. automotive). Due to tooth misalignment, due to manufacturing and assembly errors, wheelbase error or axle angle error, the localized tooth contact pattern determined during design may be shifted from the ideal position on the tooth surface. If part of the contact zone is removed from the tooth surface, the remaining contact area is less than necessary. The disadvantage of reducing the surface area is that the stress will increase because the same load has to be transmitted on a smaller surface. In the most severe cases, increased tension causes tooth fracture.

6. Summary

Based on the previous chapters, it can be stated that contact pattern testing is a testing tool that carries a lot of information, whether we are thinking of gear drives, roller bearings or support rollers. The location of the contact pattern is greatly influenced by the accuracy of alignment of the axes of the associated elements. There are several standards that deal with the shape of the resulting portrayal and the types of axis defects that are created [3], [4]. Knowing these, the necessary action can be taken on the drives. The extent of the intervention is more difficult to determine and here the experiment is the solution to achieve the desired contact pattern image. In order to reduce the cost of the experiments, one possible method is the finite element method, which can determine the resulting contact pattern image taking into account the deformation of each element. The next part of this article will analyze the finite element testing capabilities for contact pattern with several different drive types.

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TESTING ACCELERATED LIFE DATA OF MICRO SWITCHES

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Abstract: The aim of this paper is to introduce a testing method for accelerated lifetime testing applicable for micro switches. To predict the lifetime the operating environment in the test device is designed to accelerate the switches' failure. The design of experiments is prepared with using the Taguchi method for different productions of micro switches applying different switching speed and different humidity values in the workbench.

Keywords: *Taguchi method, thermal camera, micro switches, accelerated life testing, switching cycle, orthogonal arrays*

1. INTRODUCTION

Our aim is to obtain reliable test results for determining the product's life cycle of micro switches widely used in garden tools. The requirement producing products with high reliability have increased the need for testing of systems, components and materials. Systems generally require system components having predetermined reliability during a determined time. It is difficult to assess reliability with traditional life tests recording only failure times. A relationship between component failure and operational conditions makes it possible to use accelerated models and to predict failure-time distribution.

Nowadays, the products are designed for years. In tests performed at normal conditions a few units will fail. Therefore, accelerated tests are widely used to obtain information on reliability of product components. In accelerated methods the main objective of these methods is to induce failures of the, units in a much shorter time and to use the failure data at the accelerated conditions (use rate, temperature or pressure) to estimate the reliability at normal operating conditions. There are several reliability models that correspond to physical-failure mechanisms [9]. These results are used to demonstrate the reliability of components, to certify the components or to compare components produced by different manufacturers.

The most common failures of micro switches have been considered in papers [4, 5]. The mathematical models applicable for analysing test results have been examined which can be used after collecting the results of the series of tests. Various test methods have been reviewed that can be used to estimate the expected life of products [6–8]. Here the initial steps in designing equipment to test structural elements is presented.

The test workbench has been planned and built. Testing the micro switch samples are implemented at the first prototype of the test workbench which is capable for testing four switches at the same time. Furthermore, we can follow the number of switches with the help of a PLC program. The aim of our research is to examine different types of switches according to a predefined method. During and after the measurements, we specify the operating conditions which provide a higher load than the normal load on the equipment. Our aim is to draw conclusions from the results of the measurements regarding the lifetime of the micro switches.

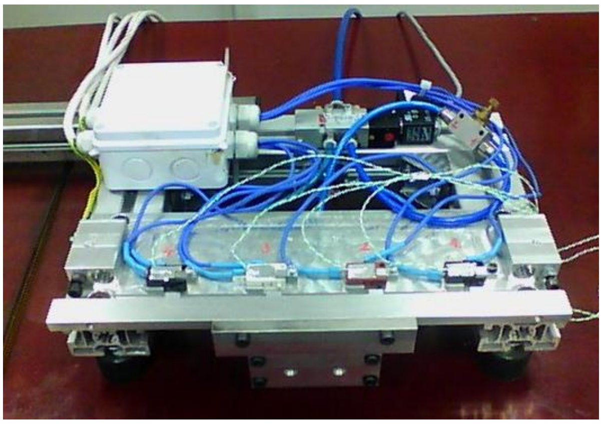

Figure 1. The test workbench

Taguchi's method will be used to design the experiments, which allows to create a well-designed measurement system. Here, the Taguchi method is introduced, and its applicability is examined on the base of previous articles [7–8]. How we can apply it to our experiments? Testing of micro switches would require multiple stress tests, results, which would mean running high number of tests. However, using the Taguchi method, the number of experiments that required, could be significantly reduced in this way.

2. DEVELOPMENT OF A METHODLOGICAL MEASURMENT SYSTEM BASED ON TAGUCHI METHOD

Taguchi, a Japanese engineer at Electrical Communication Laboratories, concluded that traditional tools for quality control and experiment design no longer met the demands of the modern age [1, 2]. Taguchi developed a new method for which he received a state award in 1960. In 1980 he introduced the experimental design in the Bell Laboratory, which has been known worldwide. Taguchi philosophy has revolutionized the industrial quality control method.

Table 1
Complete factorial experiment

	Name of the object						
	A	B	C	D	E	F	G
	Number of experiments	1	2	3	4	5	6
T-1	1	1	1	1	1	1	1
T-2	1	1	1	2	2	2	2
T-3	1	2	2	1	1	2	2
T-4	1	2	2	2	2	1	1
T-5	2	1	2	1	2	1	2
T-6	2	1	2	2	1	2	1
T-7	2	2	1	1	2	2	1
T-8	2	2	1	2	1	1	2

Three basic principles of this method are known [1–3]:

1. The quality of the product does not need to be retrospectively verified but it is designed into the product ("quality design").
2. The quality will be the best if we minimize the deviation from the target. The product must be designed to be insensitive to uncontrollable environmental influences ("robust design").
3. Depending on the deviation from the standard, the required "cost" of quality must be defined. Actual cost has to be regularly measured throughout the production process ("cost of quality").

The advantage of the Taguchi method is that it prefers practical and experimental design methods rather than mathematical formulas for experimental design. This method has been more successful than previous methods.

The previously applied method, the factorial experiment design method, helped the experimenter find the most important factors affecting the experimental result and all possible combinations of these. Their effect on the experimental result is important and also how to find the optimal combination of factors. However, these factorial designs become too complex in many cases and require extremely many experiments.

In the design of partial factorial experiments can still be well designed in terms of effect mixing due to missed interactions, but replication of eighth or even higher is already very difficult. By reducing the number of attempts to reach the optimum and increasing the number of factors and interactions that are relatively easy to examine, Taguchi has created experimental designs for some common tasks. He developed orthogonal tables for the experiment plans.

In these orthogonal tables ("orthogonal arrays"), Taguchi developed the most commonly known factor combinations and determined how to place the more important and less important effects and interactions in them. These tables are called Taguchi's "cookbook". The advantage of this cookbook is that the user does not have to think through all possible versions of all effects and interactions.

The experiment can be completed in three steps:

1. The characteristics of the quality, the main factors to be considered in the experiment and the possible value of their levels should be determined. In our case, these factors are switching speed and relative humidity. These values are recorded in *Table 2*.
2. Design and run the experiments according to a recipe in the Taguchi Cookbook.
3. Run a validation experiment under optimal conditions [1–3].

3. MEASUREMENST AND RESULTS

In our measurements that a total of four types of micro switches are tested, with two different switching speeds of 0.3 s and 0.25 s, with two relative humidity setting 60% and 80%. *Table 2* shows the failure cycles of the already ran switches.

Table 2
Database with failure result used Taguchi's method

Exp.No.	**Switch type**	**Switch speed [s]**	**Humidity [%]**	**Number of tests 1**	**2**	**3**	**4**
1	D.1	0.3	60	143,213	129,171	171,711	168,082
2	D.1	0.3	80				
3	D.1	0.25	60				
4	D.1	0.25	80				
5	D.2	0.3	60	180,230	191,019	182,428	196,031
6	D.2	0.3	80				
7	D.2	0.25	60	182,918	170,965	205,622	225,077
8	D.2	0.25	80				
9	K.1	0.3	60	189,966	197,341	197,917	201,465
10	K.1	0.3	80				
11	K.1	0.25	60	138,767	217,426	99,140	185,672
12	K.1	0.25	80				
13	K.2	0.3	60	180,235	212,592	209,829	209,829
14	K.2	0.3	80				
15	K.2	0.25	60	196,937	217,426	91,820	154,036
16	K.2	0.25	80				

The temperature distribution is measured during the tests. The horizontal axis in *Figure 2* represents the time of the test and the other axis show the temperature for a switch, as an example. The red curve indicates that the second micro switch sample's temperature suddenly rises to 133.8 °C, at this point it goes to failure. *Figure 2* presents the switch that showed the highest warm-up in the earlier stages of the test, it was not the fastest to break, but it is worked relatively moderately.

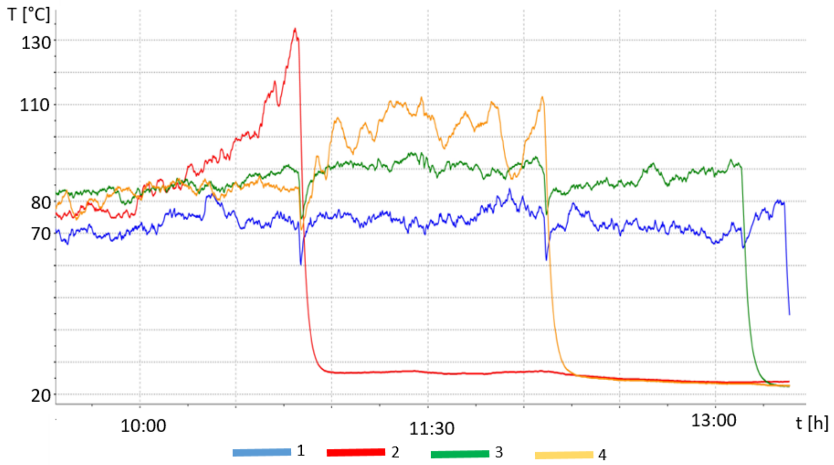

Figure 2. Temperature- time diagram

During the tests the heat impact are checked in several ways. Every switch has a temperature sensor and at the same time a special thermal camera is monitoring the temperature rise. The heat map shows that red areas are critical *(*see *Figures 3–4).*

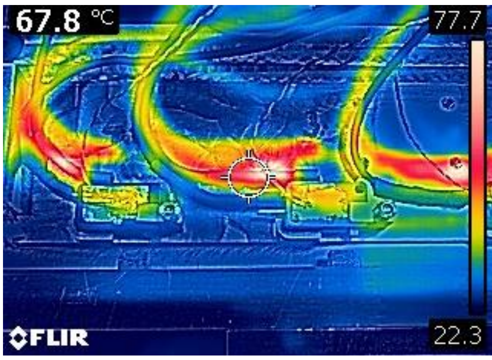

Figure 3. Photos taken by a thermal camera for two units

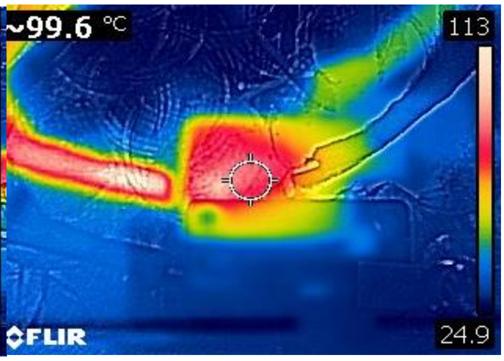

Figure 4. Photos taken by a thermal camera for one unit

The data logger records the test values in every 10 seconds, which is displayed on a spectacular temperature-time diagram. At the end of the measurements, the values recorded by the camera are the same as those have been measured by the temperature logger.

4. SUMMARY

In this paper a micro switch test workbench is introduced for measuring lifecycle of switches under accelerated operational conditions. The failure of the components of units is implemented according to measurement procedure based on the Taguchi method. The database *(Table 2)* with operation conditions data can be extended. Simulations can be performed for predicting lifetime data.

The tests are performed sequentially, by setting different statistical humidity levels. After completing appropriate number of tests, the test results can be used to develop a method that could be forecast the life expectancy of micro switches and make design and manufacturing recommendations that will influence the products lifetime.

Finally, a mathematical procedure that can validate the effect of several influencing factors on the life expectancy can be developed [9].

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IMPROVED ACCURACY GEAR TOOTH CAD MODELLING

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Abstract: The paper deals with a possible improvement of gear tooth profiles by using exact calculations for generating 2D curves instead of approximation processes. This method can be applied in almost all CAD software and gives a far superior result in profile precision.

Keywords: *gear design, CAD modelling, gear optimization*

1. INTRODUCTION

In this days, optimization of different machine parts plays a huge role in the designing process. The optimization process can take place in different stages of the designing process. The necessary changes mostly begin to surface after the first design is ready for testing. All prototype and finished product modelling and the necessary FEM analysis can benefit from a more accurate CAD model so we can make a more realistic simulation and predict the outcome of the final product. Most CAD software manufacturers provide different tools and downloadable modules to improve the ability of their software. Aside from the differences of the user interface all professional CAD system has multiple tool for a given sollution like curve design. These solutions mostly based on the same principles, so a generalised idea can be used on all system without limitations regardless of the manufacturer.
According to the biggest CAD software developers manuals [1–4] all system capable of high precision modelling.

2. CURVE MODELLING IN CAD SYSTEMS

Most of the modern CAD modelling software are capable of making full or partial gear designs from given parameters. This helpful modules greatly reduce the necessary time of making new gear designs as need arise.

The bottleneck of these modules is the precision. Mostly they are adequate for supplying 3D CAD models directly for low or low-mid quality gear production but it is unusable if high precision is needed. In this case there are specialised software capable of making high and ultra high precision gears, but they have a huge cost that makes their usability very limited.

The other more convenient way is to use our already existing CAD software capabilities for this purpose.

We shall show a method in FREECAD 2D-3D software that can make a high precision evolvent to create a gear tooth profile and the differences of the approximation and precision concerning the two methods.

The main method for making an evolvent in CAD system is by making a spline from a few already calculated point [5].

Advantages:

- only a few coordinate point is necessary,
- low end PC-s can handle the graphical needs of the designer,
- fast solution that can be applied with few clics.

Disadvantages:

- limited use only in low and low – mid quality gears can be made by this method,
- spline has inflection points so they can't provide a profile that can be made into a smooth tooth surface (wavy surface),
- not suitable to provide good 3D models for FEM analysis,
- third party software or serious post processing is required to make a high precision model with this method.

It is evident from the above mentioned drawbacks that a better solution may be beneficial if we want to keep the original CAD software useful for gear design purposes.

The other solution is called in a lot of name depending on the software we use, but they are more or less the same procedures that makes curves from exact equations.

Advantages:

- this method is calculating the exact points coordinates,
- precision is adjustable by user via defining the number of calculated points,
- precision is only depend on the capabilities of the hardware and the number of calculated points the user define,
- possible to make higher precision tooth surface that can be manufactured,
- the method can be used with any approximation type for making curves,
- no specialised software or knowledge required.

Disadvantages:

- stronger hardware required for high precision gear designer,
- depending on the CAD software in a few case it can be more time consuming than the approximation method.

After we review the main differences of the two method let's have some thought about the equation driven method. This can be done by supplying a parametric equation of the curve and giving the number of points or steps we needed to calculate. An example can be seen in the next figure.

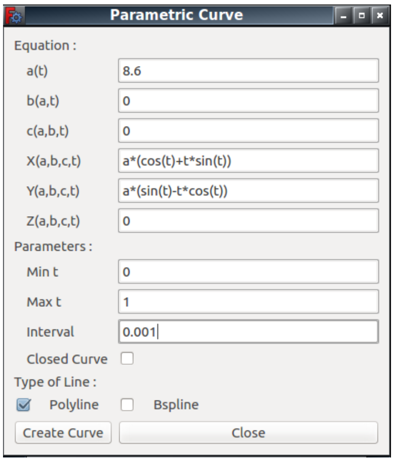

Figure 1. Equations for gear with evolvent profile with tooth number F = 11 and module m = 2

Figure 1 shows the first experimental evolvent equations made by the procedure. The method for making a continuous line is by applying polyline for the calculated points. In this way the inflection points can be avoided entirely. The comparison of the approximation and the equation method can be seen in the next figure.

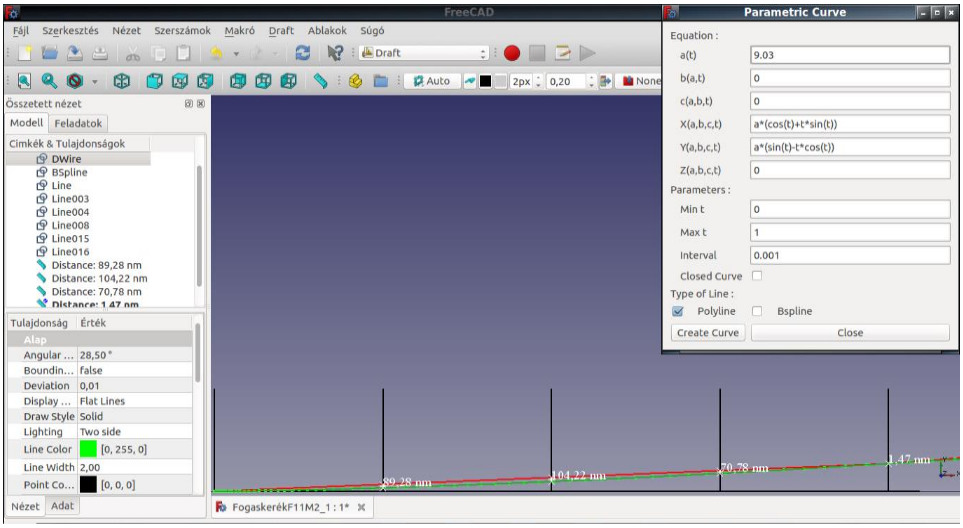

Figure 2. Spline (red) and equation curve (green)

In *Figure 2* the red line is the original spline approximation and the green line represents the equation driven method. The Min t and Max t parameters are the starting and finishing degrees in radian for the calculation of the curve. Interval is the number of steps of number of points we want to have for creating the spline. With numerous trial and error I find that the most practical interval range is between 0.01 and 0.0001. The best result hardware wise was with 0.001. Precision is decreasing as the process approaches the head of the tooth, but it is still much better than the spline version. *Figure 2* clearly shows the inflection point of the spline and the highest deviation from the real curve. The highest deviation is 104.22 nm in this design example. If we make other designs similar to this and only changing the module for a new one the difference is rising between the approximated and equation driven solutions.

Figure 3 is a summary of the degrading accuracy of the spline method compared to the equation driven one. The red line is the spline approximation the green line represents the equation one.

The tooth number F is fixed for 11 and from top to down the module is increasing as follows: 2; 2.1; 2.5.

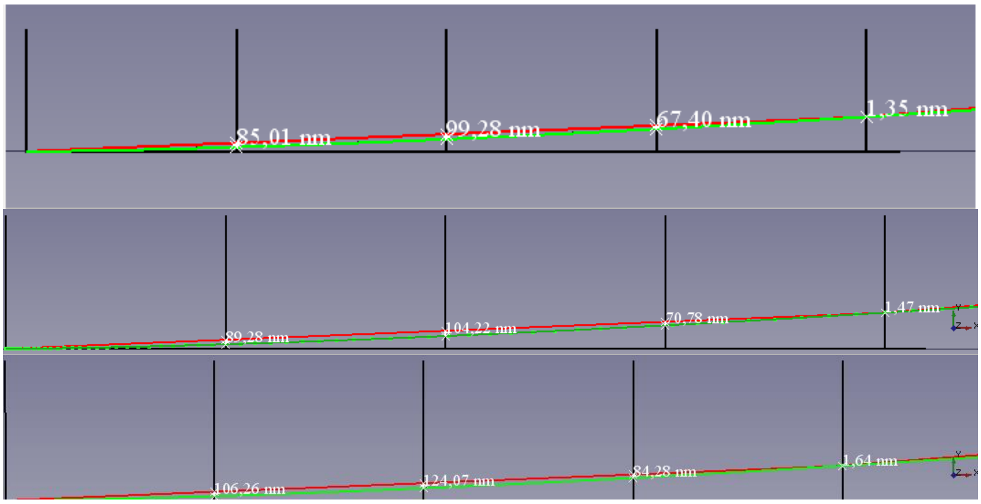

Figure 3. Error increase in the approximation

As it can be seen in *Figure 3* the approximation error is gradually rising with the rise of the module applied.

3. Summary

The equation driven method for making curves has a high potential in industrial use since it allow manufacturers to produce high quality gears without any

specialised software. The method has proven superior in almost any respect compared to the widely used spline approximation method.
Future automation of this method is possible by making program modules based on equations instead of spline approximation.

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DEVELOPMENT OF A GEAR DRIVE DESIGNER SOFTWARE

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Abstract: The paper deals with the programming and introducing the function of a new program for designing gear drives. The main goal of the program is to provide the exact machine setting parameters for producing a given gear drive. The software is a multi purpose tool for fast industrial calculations and pre-analysis.

Keywords: *gear design, gear calculation, gear design*

1. INTRODUCTION

Due to the modern industrial machining tools and automated production chains, new product manufacturing requires less manual intervention. Although it is a more convenient and productive approach than making all adjustment manually but fine tuning a product becomes much harder. The main reason behind this fact is that the machinery manufacturers try to hide the exact calculation methods and settings from the customers as a trade secret, only letting a limited setting option for the end user. Our program aims several goals. The most important of all is to help the designer and production staff with actual data about the future product in all production phase. To reach this goal the new designer program will be a multipurpose tool. The base program can already make the necessary geometrical calculations of a one step gear drive and provides a few machine settings necessary for manufacturing the gears. The functionality of the program can be extended by further calculation, graphical or analytical modules as needed.

2. BASIC CONSIDERATIONS

With the spread of smart devices, platform independence and efficient resource management in programming is a pressing issue. For this matter our program has been written in pure C language using GTK3 module to create a fast and efficient graphical user interface. By using only standardized programming functions there is a possibility to compile the program to all operating system with small or no modification.

All calculation is based on the ANSI/AGMA 2005-D3 Standards [3] that contains the necessary equations the program is using.

Our future goals are:

– to create a module that is able to calculate the necessary machine settings from the basic geometry data

– to make a graphical module to show the tooth surface changes based on the modification of the machining parameters
– to create a calculation for defining the connection line or point where the 2 gears tooth surface connect.

The main program provides the geometrical data of a hypoid gear drive with two connecting gear.

3. ABOUT GTK3

GTK3 [1] is a code and function collection for creating a graphical user interface for any type of programs. It was originally designed for Linux operating systems to help support the software developers to create fast and efficient desktop environments. But it has become an all around tool for graphical interface programming.

The main advantage of GTK3 is the fact, that we can create a low resource requirement and fast system without compromising on the user interface capabilities. This has been achieved by low memory usage and CPU use.

Transition between Linux and Windows or any other operating systems is possible since GTK3 functions are using only standard C code, therefore it can be compiled to any system without any problem.

There are two reasons for making this program for Linux at first. Nowadays, Linux is the fastest OS than can be used on computers so any calculation takes the least possible time on this systems. The second reason is that most modern operating systems are using some element of Linux. Android is based on stable Linux kernel with modifications. Windows and MacOS also has Linux modules used in their systems.

4. THE PROGRAM

Figure 1 shows the main program view.

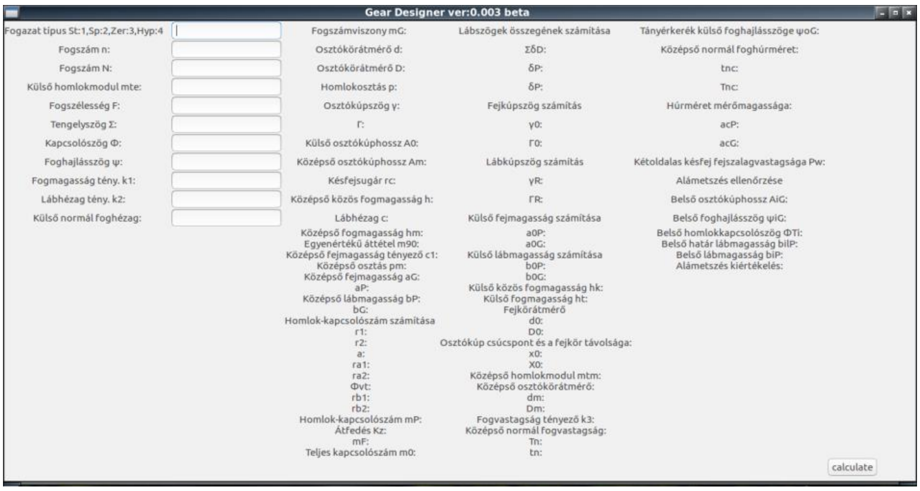

Figure 1. Main program view

The first column contains the necessary input data fields for the calculations.

The system is semi automatic at the moment, i.e, some constants have to be supplied manually as input data but in a few case the program can handle constants automatically based on the other input data without user intervention. One of the future goals is to make the system fully automated, eliminating the need for manually giving the required constants. The whole calculation process is flexible. The program keeps all supplied input data until exit so the users can make new calculations by modifying only the input data of their choosing and press calculate button. Every unmodified input field will keep the original data. There is also the possibility to make partial calculations if the user only need specific geometrical data not a whole calculation. The program will always calculate every viable equation it has adequate data for. The main reason for keeping the original data after the calculation is to speed up the process to create new variants of an already existing drive and analyse de impact of modifications on the original design directly. In this way we can make basic optimisation right after the first calculations.

5. PROGRAM STRUCTURE

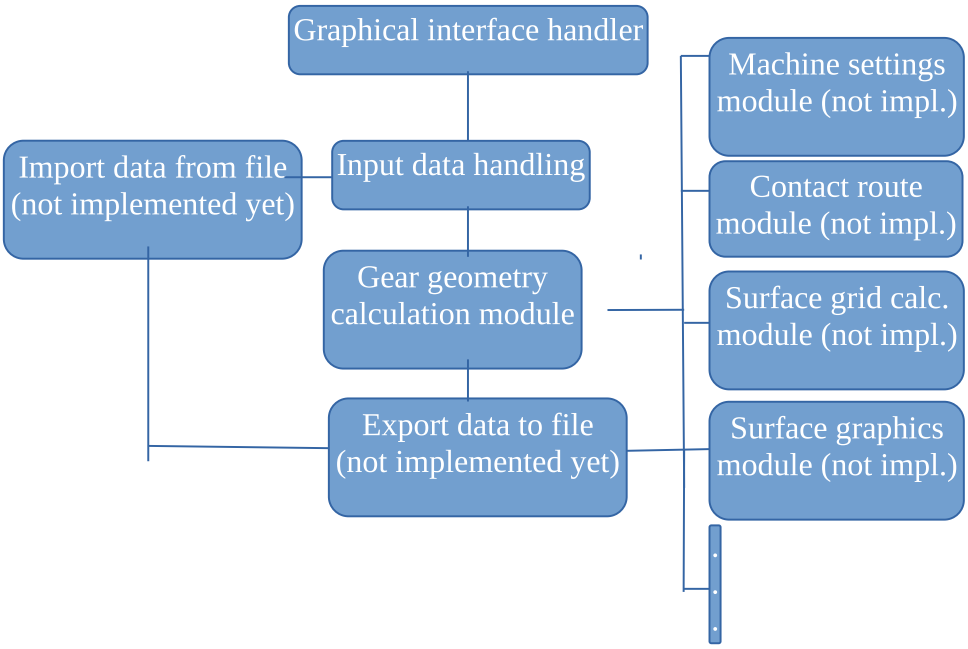

Figure 2. Existing and planned program structure

As *Figure 2* shows, the program has a lot of potential upgrade possibility. Lets us see the test run of the program with a verified input data collection. Currently, only Hungarian user interface is available for the program.

Figure 3. Test input parameters for the program

In *Figure 3* the following parameters can be seen:

- n, N: number of tooth for pinion and gear,
- mte: outer face module,
- F: tooth width,
- Σ: shaft angle,
- Φ: pressure angle,
- ψ: spiral angle,
- k1, k2, B constants from ANSI/AGMA 2005-D3 Standards based on the above mentioned parameters.

The program gives the same results as the manual calculations but precision has been increased for, higher precision calculation purposes. The next figure shows the final test calculations of the test run.

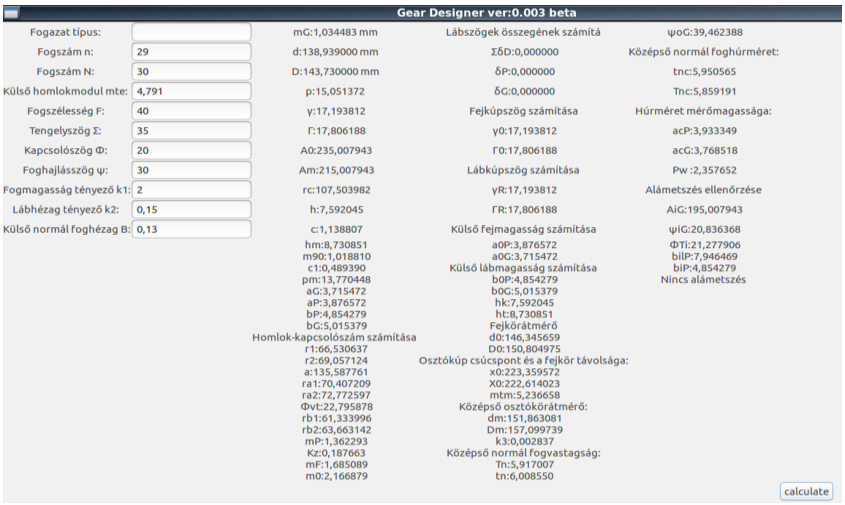

Figure 4. Final test results

The first data field is not an implemented option yet, but it will allow users in the future to choose from different gear tooth types.

6. SUMMARY

Applying the new designer software a lot of viable geometrical variation can be created in a short amount of time. This tool is platform and software independent so no additional tool is required to use it. This feature and the future integration with possible analytical modules makes this program a versatile tool for gear research and optimization problem solving.

The precision of the calculations can be further increased without any negative effect on performance.

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