*Design of Machines and Structures, Vol. 5, No. 2 (2015) pp. 17–29.*
*https://doi.org/10.32972/dms.2015.010*

# BRANCH SHAKER DESIGNING PROJECT

GERGŐ NAGY–BERNADETT SPISÁK–ATTILA SZÓJA–
ISTVÁN SZÁNTAI–JARMO JALKANEN–JARNO MATTILA–
MARIA RENTOLA–TIBOR PUSKÁS
University of Miskolc, Department of Machine and Product Design
3515 Miskolc-Egyetemváros
JAMK University of Applied Sciences
PO BOX 207, FI-40101 Jyväskylä, Finland
nagy.gergo@schaeffler.com

**Abstract:** In this paper a new hand tool designing project will be represented. The background of the project is an international co-operation between JAMK University of Applied Sciences from Finland and University of Miskolc. The main task was created by Robert Bosch Power Tool Ltd. to design a multifunctional battery operated garden hand tool. For the more effective work was organized two mixed group from Hungarian and Finnish students. The competition between the groups simulates the real life, where the companies have to create better product than the others.

***Keywords:*** *hand tool, branch shaker, project planning*

## 1. Introduction

The first and most important task – like in every project – was defining the roles of the members. It was necessary to find the suitable positions for the members in the project. The most important roles were marketing, quality, purchasing, designing and the engineering side (Figure 1).

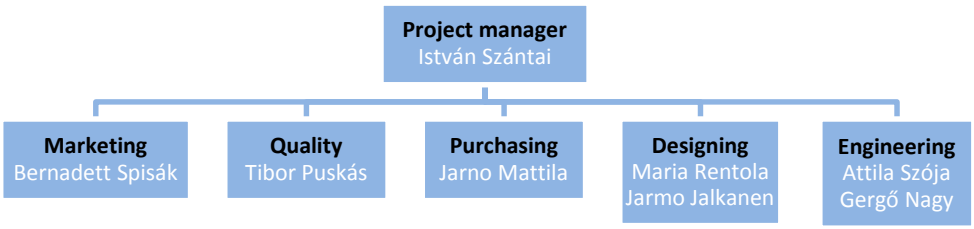



*Figure 1. Positions of the members*

Project manager was István Szántai, he leaded the team. He was responsible for finishing the project. Every team member got the assignments from him. He supervised everybody's work, organized the meetings and sent the update reports to the supervisors.

Marketing person was Bernadett Spisák. Her most important job was to keep contact with the potential customers and map the competitive products.

Quality man was Tibor Puskás. His task was to oversee that the choosing of the parts were right and economic. He observed that every part of the construction satisfy the requirements of the customers, so he reviewed those ideas that were not right. He made the connection between the engineers and the marketing person.

Purchasing was Jarno Mattila's job. He handled to find the right components, and got information about its cost. On top of that, he created a costing table. From this, he could calculate a competitive price for the product. Purchasing and marketing person worked together to find out the price customers are willing to pay.

Industrial designers and mechanical engineers had two different kinds of tasks, but their jobs were connected. Attila Szója and Gergő Nagy were the mechanical engineers and Maria Rentola, Jarmo Jalkanen were the industrial designers. Engineers designed certain parts of the product, like the motor, battery etc. Industrial designers made the conception of the house for these tool parts, which are ergonomics and comfortable for the customers.

## 2. First steps of the project – Collecting ideas

In the first step there was the hardest task to figure out a new tool. For this, the project members started brainstorming on what kind of works people can do in the garden. These works are e.g.: grass cutting, branch shaking, leaves collecting, planting, digging, fruit collecting, cleaning garden tables and chairs, root removing and so on.

After that, the group started to think about what kind of tool is not on the market yet. It was known the Bosch products are good at grass cutting and hedge trimming, so the project concentrated on the planting, digging, fruit collecting and root removing work. From these kinds of gardening jobs three possible tools were imagined for future design. These tools are: seed feeder, weed remover and branch shaker.

To find the best tool it was necessary to compare these tools in different aspects like how often used, similar products in the market, weight, size, possible price of the product.

The team thought that people are able to use the branch shaker to shake many different fruits down from the trees and they can use it for leaves shaking as well. The group did not find such branch shaker tool on the market that is operated with battery, as well as this shaker technique is used in more tools and machines for harvesting, so in this tool could work also. The branch shaker had so many advantages as it was chosen to design.

## 3. Designing the tool

### *3.1. Designing the shaker head*

Searching for patents of different head types is very important task, because stealing anybody's idea is not correct. However, the searching is useful, because we can use the old, forgotten ideas to design a new machine.

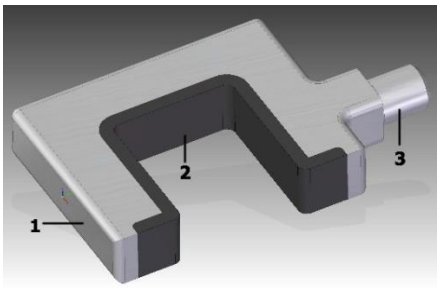



*Figure 2. Fixed head (first 3D model)*

Many conceptions were created during design. For example: fixed-, adjustable-, handle operated-, automatic head. All of these were analysed, and the most suitable was chosen.

The chosen head has fixed size (Figure 2). This is not adjustable. People can grab branches under the size of the head's mouth. If the internal size of the mouth is 40 mm, than man can grab a branch that has a diameter of 40 mm, or smaller. Some measurements were made to define the average branch diameter and shaker force than the conclusions were described. The internal size of the mouth can be maximum 60 mm. Larger mouth is unnecessary. The head part 1 material is a strong steel or aluminium alloy. Part 2 is a flexible deposit. Its material is rubber. This head can be one part with the rod, or it can be connectable to the rod in point, part 3.

Different working situations were examined and the fixed head was chosen. People can grab the branch with this type of head and it works on other tools too. Its design is easier than the others.

### *3.2. Finite element analysis of the head*

It is an important exercise because it could simulate the working situation and the group can optimize the critical parts. We made the analysis more times. Two materials were chosen, an aluminium alloy and ABS plastic material. The results of the analysis were compared with the material properties. The most important things were the deformation, and the equivalent stress in the material of the head. The analysis was made in Ansys 14 and Solid works.

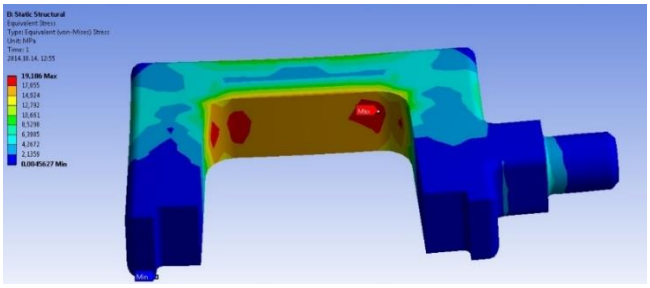


*Figure 3. Finite element analysis of the head*

Plastic material is cheaper and lighter than aluminium, but its strength would not be enough, just with larger size, that is why the material of the head has to be aluminium alloy.

Results of the analysis showed, the form of the head is not the optimal. It was necessary to make an optimization. The highest stress values were in the inner corner of the mouth. It was necessary to apply bigger radius in this corner. So the loading distributes evenly in the head. The other reason was the nicer form. It looks prettier with the modified shape (Figure 4).

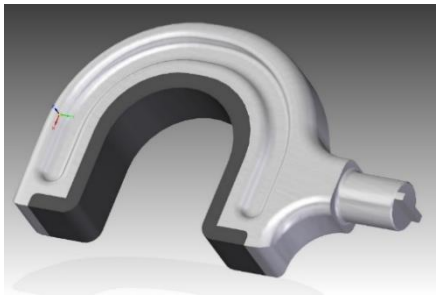


*Figure 4. New design of the head*

### *3.3. Connection between the head and the arm of the transmission*

This tool is multifunctional. First function is branch shaking; second one is branch cutting. It is necessary to change the head and the saw on this machine. Our group had to create an adapter to the arm of the transmission. This adapter is able to fix the head or the jigsaw fixer adapter.

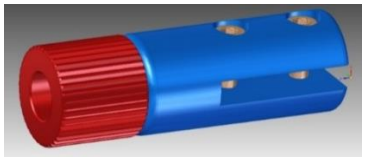


*Figure 5. Adapter for fixing the head and jigsaw adapter*

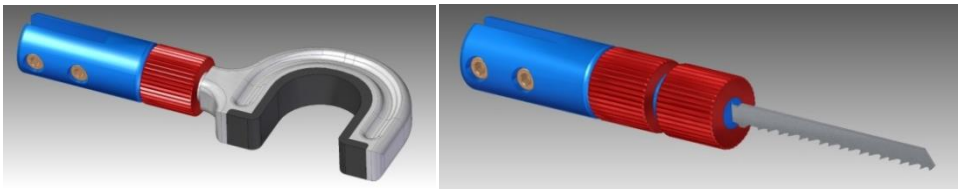


*Figure 6. Shaker head and jigsaw blade with the adapter*

### *3.4. Rod connection*

Our group found some patents for rod connection. There were connectable and telescopic too. Drusiani Franco had a great idea. He invented the telescopic rod connection for agricultural tools on the 20th June 1995. It is lapsed, so we could use it up free.

A similar solution was applied in case of the branch shaker. This connection type operates as follows. There is an outer tube and there is a threaded connection element fixed in this tube. There is an inner tube with closing element. There is a tapered clamping element next to the threaded element. There is a grip on these parts with an internally threaded element. If we turn the grip in one direction, we can release the clamping, so we can pull the inner tube to full length. If we turn the grip reverse, we can make the clamping, so the inner tube is fixed in that position (Figure 7).

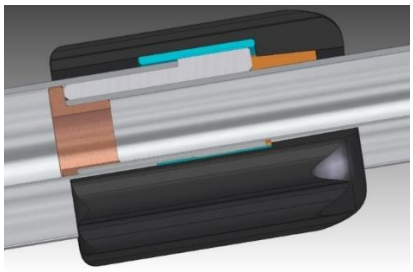


*Figure 7. Rod connection in case of branch shaker*

Finite element analysis is also important in case of the rod. It was necessary to run dynamic analysis because shaking and cutting load change in time.

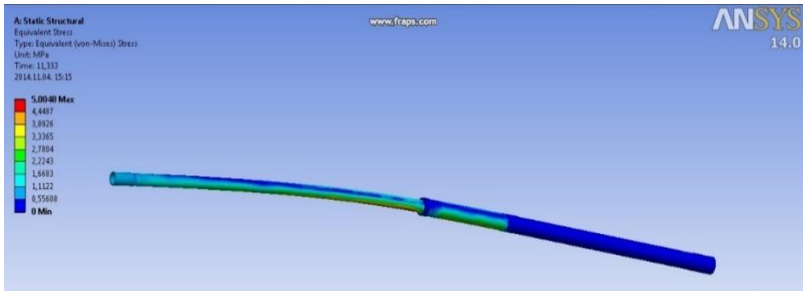



*Figure 8. Finite element analysis of the rod*

There are two fixed support on the rod, because the customer grabs the tool with two hands. The position of the electrical hand tool during the work is not horizontal, but 45° angle to the ground. There is not only one load, but there are two. These loads change in time. One of them is the weight of the motor and the head; it is about 20 N. This load is at the end of the rod and it points towards the ground. The other load is the shaker force. It is in direction of the rod. The shaker force is about 200 N,

but it is not the maximal. We have to make analysis with overload. Overload is 500 N. It simulates if the customer grabs the branch with this tool and pulls it. The standard earth gravity also takes its effect.

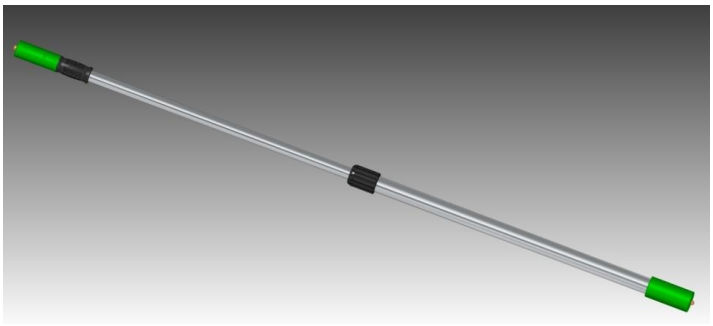


*Figure 9. Full length of the rod with shock absorbers*

Figure 9 shows the rod design. The weight of the rod without the shock absorbers is 2,77 kg.

### *3.5. Shock Absorber Unit*

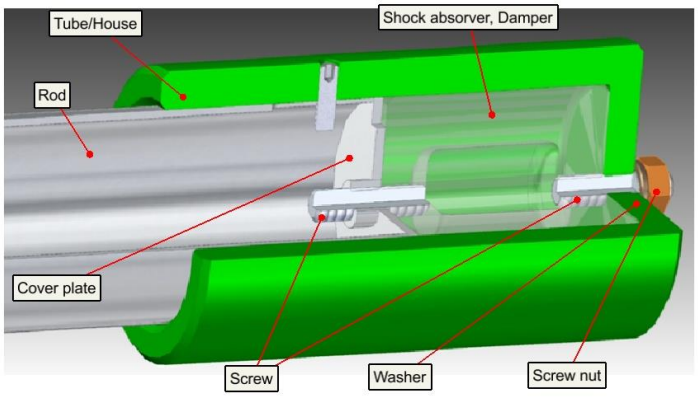



*Figure 10. Shock-absorber unit*

It was necessary to create a unit that reduces vibration of the branch shaking. It is obvious, that vibration is harmful for human's body, so vibration absorbing was an important part of engineering design. Inside and outside diameters were important, because the vibration absorber involved the bottom of the rod. Therefore, there is housing for the tube. This house is cylindrical. Since it is necessary to support the rod, the house has 75 mm support hole. In the house there is an extra place for the shock absorber. The damper is under the rod. Shock absorber consists of three main parts. One of them is the silicon cylinder that is responsible for absorbing. This is

due to the fact, that silicon has big capability for shape deformation. Other two parts are screws, one for the rod and one for the house fixing. Shock reducing process is simple. When the motor starts and the shaker is working, there is high vibration in the entire rod. Therefore, vibration causes deformation in the silicon part of damper. Silicon is hollow, so there is enough space for deformation (Figure 10).

### *3.6. Motor choosing and movement conversion*

The main part of the tool is the motor. This part is responsible for how hard the tool can push and pull the branch and how much time the tool works. A quick alternate movement was needed to the branch shaker that is why a movement converter part had to take place into the tool that changes the motor rotation to alternate moving. The easiest way for this transmission was a couple of gear and an arm part, where the bigger gear is an eccentric gear (Figure 11).

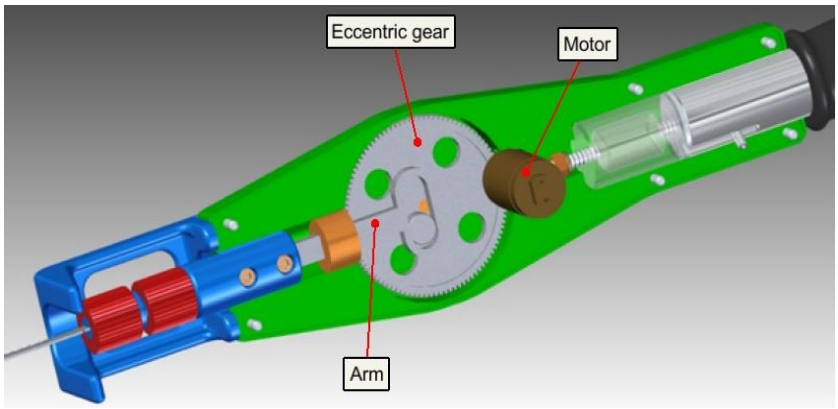



*Figure 11. Motor and gears for alternate moving*

It was necessary to determine how large force is needed for the shaking and how long the customers would like to use the tool in one time. Based on marketing surveys users do not plan to work with the tool above one an hour at once. Measurement showed that a 50 N force is enough to move thinner branch.

Estimating the working time of the tool was created in SciLab program, where more factors were needed to define previously.

It was very important to define the mass moving by the motor. The mass of the rod would weight too much for the motor to move that is why the motor house is at the top of the rod, so in this case the motor has to move just the mass of the head and arm parts.

Other essential elements of the tool were the transmission of the gears and the eccentricity. These numbers were taken from a Bosch hedge trimmer's parameters.

The third factor was the motor that was chosen for big stall torque, big no load speed and a suitable battery capacity.

The program tested the designed tool according to these chosen parameters and we found that the tool can work between 20–30 minutes if the shaking force is between 50–80 N. Consequently if we have two battery packs we could reach the 60 minutes working time with the tool.

## 4. FMEA – Failure mode and effect analysing

Risk analysis tools are used to identify possible risks of the process or a target. It shows in what way the product does not fulfil customers' requirements and what are the effects of the risk to the customer. Design FMEA is a great tool to help designing and quality personnel to detect the highest risks of the new product before the process has gone too far. This way it is easier to take note of the biggest issues when you are designing the product and you do not have to make big critical changes later. It is important to find out all the risks that are harmful or dangerous to the final user of the product. During engineering design of the product you must pay attention to all of these risks and figure out the best solutions to prevent these harmful things to come true in the final product.

At the beginning of this project-FMEA our group started to list all different kind of risks from as many different aspects as possible. Group wanted to find risks that especially concerns about user safety and satisfaction of using the product. Listed risks were collected to an Excel template. After this the risks were valuated from 1÷10 according to three different factors: severity (SEV), occurrence (OCC) and detection (DET). After valuing the risks these three factors were multiplied together to get the Risk Priority Number (RPN=1÷1000). Group wanted to keep the RPN below 100 to ensure that the risk is low enough because most of the risks concerned about user safety.

Highest risks that were found and needed actions were the shaking of the tool, weight of the tool, protection against water and accidental starting of the product. Shaking can be reduced by anti-vibration solutions in handles and rod connections. For the weight of the tool it is important to use light materials. Water proofing is necessary for this tool because it is used outside and it can get in touch with water. Accidental starting of the product can be minimized with two-button start.

## 5. Purchasing

There was one main task for purchasing. Calculate the final product price with materials choosing, which satisfy the quality requirements. Besides it was decided that gross margin profit has to be over 40%.

Calculating material costs was a little hard because distributors do not always show prices for materials in websites. After investigation, it was the best way to use Alibaba.com for searching the materials and prices. At this point we could only use material costs because we did not know the shipping costs. Because of that prices, which are used in calculation, are a bit higher than in distributor sites. Excel table is used for material cost calculation and weight of the product calculation also. A part of this table can be seen in Table 1.

Table 1
Purchasing chart

| **Part** | **Quantity** | **Price/piece (€)** | **Total price (€)** | **Mass (kg)** |
|---|---|---|---|---|
| Battery cell | 2*10 | 1,25 | 25 | 0,38 |
| Battery housing | 1 | 0,5 | 0,5 | 0,08 |
| Lower house | 1 | 1,2 | 1,2 | 0,3 |
| Lower rod | 1 | 4 | 4 | 1 |
| Upper rod | 1 | 4 | 4 | 0,82 |
| Motor | 1 | 1,65 | 1,65 | 0,34 |
| …. | …. | …. | …. | …. |
| Total material cost per product: | 59,11 € | | total mass: | 6 kg |

### *5.1. Labour cost*

Labour cost per product is needed to know also for the total manufacturing price. Formula is: $x = (w * p)/(d * s)$, where x is labor cost per product, w is monthly wage, p is people per shift, d is working days per month and s is products per shift. Values which were used:

- 500 € monthly wage
- 7 people per shift
- 21,7 working days per month
- 1000 products per shift

With these values labour cost per product is only 0,16 €.

### *5.2. Market price*

Formula for gross margin profit is $g = (t - m)/t$, where g is gross margin profit, m is manufacturing price and t is total market price. Converting this formula to this form $t = m/(1 - g)$. For manufacturing price sum from labor cost and material cost are used and it is 59.27€. Gross margin profit is 40%. With these values market price is 98.79€. Because it is much lower price than competitive products, 125 € is the final market price for our product.

## 6. Marketing

### *6.1. Similar products*

At the beginning of the project, marketing job was to find similar products. It was necessary because this way we were able to collect ideas for our tool. On the internet, there were some items, which had the same function to shake the branches. They were compared in different aspects. Three out of five works with fuel, which makes the tool expensive, but the effectiveness of them is very good. They are heavy so the using of them is hard for elderly people. The other two items work with battery and electricity. At the end of the rod there is a rake which is moveable. These ones are

used only for olive shaking. They are light so they can be used easily. We tried to combine these tools.

### *6.2. Survey*

Another important job of the marketing person was to keep contact with the potential customers. So she made a survey. Making a questionnaire is a basic task of a product design, as we can measure the future customers' needs. With a questionnaire, we are able to collect large number of anonymous reviews. It is easily processed, and we can make statistical analysis of the data. However, we have to pay attention, because if the question is not properly provided, then a problem may arise later.

### *6.3. Making the survey*

We had to make a short, essential survey. Many questions were collected, which should be asked from the customers. The most important questions were chosen. That is how we got the following ones:

1. What is your gender?
2. What is your age?
3. Which is your country?
4. Do you have fruit trees or bushes at home?
5. What kind of fruit tree/ trees do you have?
6. How do you harvest your fruit tree?
7. Would you use a tool that helps you shake the fruits down?
8. If you have a fruit shaker tool with cutting head would you use it for branch cutting?
9. Would you use this branch shaker tool to shake the leaves down?
10. How much time would you use this branch shaker tool for one occasion?
11. How much would you pay for a tree shaker?
12. How important would be for you the weight of the tool?
13. How important would be for you the shape of the tool?
14. How important would be for you the size of place taking of the tool?

There are two different kinds of question. It can be seen that the first three questions are ordinary ones. It is important to know, who is the answerer, because with this it can be predicted, who are the future users. There were specific questions too; here we asked important things about our tool. They were needed because this way we could conclude, which are the most relevant things of our tool. It was necessary to know what kind of trees the future users have, because this way we could estimate how much force is needed to move a branch of the given tree. Our job was to make a multifunction tool. Our idea was to use it for branch cutting beside the branch shaking. From all of these the most important is, if the customer will use this tool. Another one is how much the users would pay for it.

### *6.4. Some results of the survey on diagram*

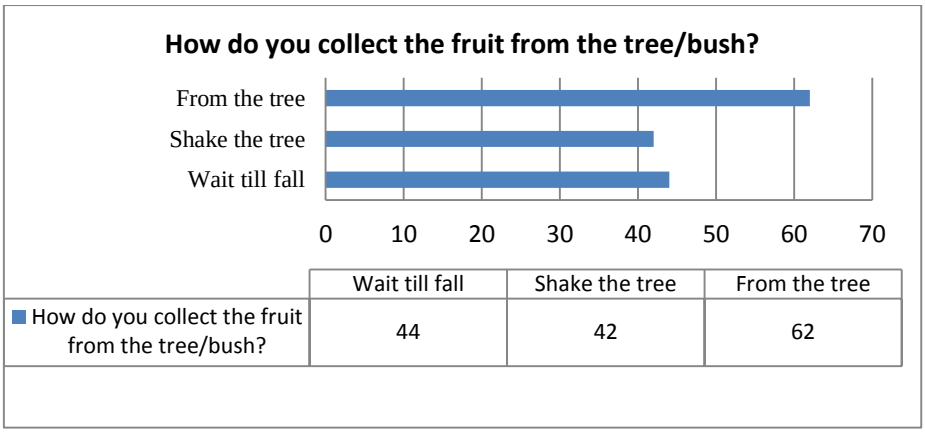



*Figure 12. Fruit collecting method*

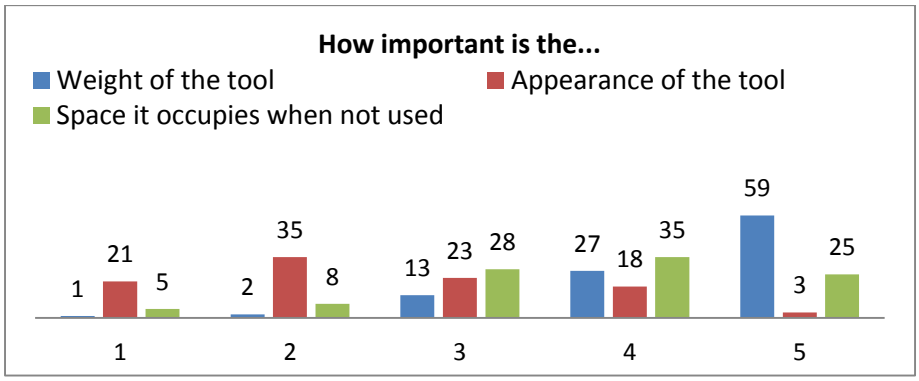



*Figure 13. Importance of aspects (1 – not important, 5 – important,)*

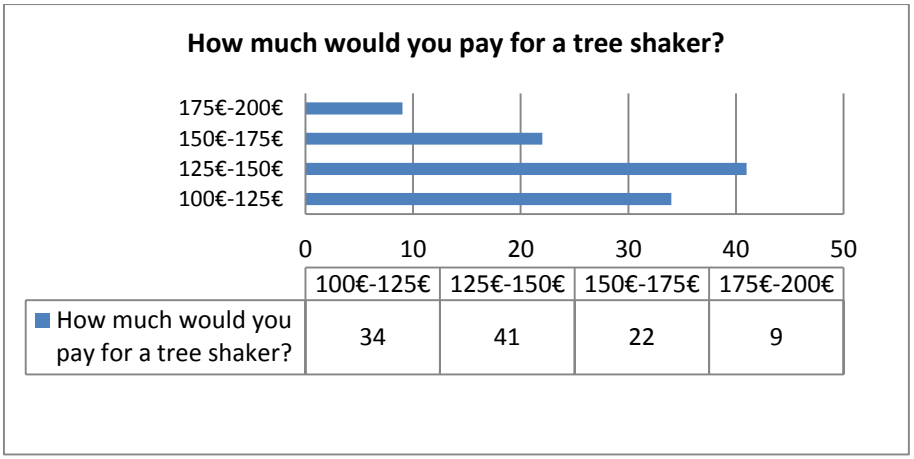



*Figure 14. Selling price*

## 7. Quality

Quality manager oversaw every parts of the tool: how much safe they are, are they satisfy the customer's requirements, etc. That is why quality manager kept connection between marketing manager and engineering designers. During the project it was suggested by the quality that battery should be built from lithium ion cells instead of buying a battery rack, because this way is cheaper and could be more ergonomic. Another suggestion was the frequency changer that helps to control the velocity of the head and the fixed head conception that is more affordable and reliable than the adjustable head. It was given tips for rod material and defined the maximum weight of the tool. Determine the maximum length of the opened and closed tool was important for carrying the tool and based on the questionnaire the price of the tool was calculated.

## 8. Summary

The tool was named Bosch Python, it could be a good name because the customer can memorize easily and it refers that our tool is strong.

Everybody from our group studied new technics on how to work in a group. All of the members got a lot of experience during project working, how to build-up a project, planning the steps of the project, execute the assignments and these experiences could be applied in the future works. Because of these lots of experience we would like to say thanks to the supervisors, who made this project realised. We got a bunch of suggestions and help so thanks for their work and enthusiasm.

Our group made the whole 3D model of this tool in this project work and finally you can see some pictures from the Bosch Python.



*Figure 15. Bosch Python with jigsaw blade*



*Figure 16. Bosch Python with shaker head*

## 9. References

[1] ZSÁRY, Á.: *Gépelemek I–II.* Tankönyvkiadó, Budapest, 1989.
[2] TERPLÁN, Z.: *Gépelemek I–II.* Nemzeti Tankönyvkiadó, Budapest.
[3] PÉTER, J.: *Géptervezés alapjai*. Miskolci Egyetemi Kiadó, Miskolc, 2008.
[4] KAMONDI, L.–SARKA, F.–TAKÁCS, Á.: *Fejlesztés-módszertani ismeretek.* Elektronikus jegyzet. TÁMOP-4.1.2-08/1/a-2009-0001, Miskolc, 2011.
[5] http://www.isixsigma.com/tools-templates/fmea/