Smart Biowaste Machine

HAMK
UNIVERSITY OF APPLIED SCIENCES

Bachelor’s thesis

Mechanical Engineering and Production Technology

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ABSTRACT

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ABSTRACT

The background for this thesis is mechanical design related to biowaste machine design and product development process. This machine should be able to pack food waste nicely for biogas generation. The topic was reuse of biowaste and the commissioner of this thesis was Nature resources education and research centre from HAMK University of Applied Sciences.

The objective of this thesis work was: creating different ideas, an idea matrix, house of quality form making and the screening of idea method applying.

The target of this thesis was to come up with a realistic and concrete solution of smart biowaste machine from customer needs. The project contained particular explanations of idea sketches or models, a particular introduction of an idea matrix, how the idea matrix was made, why the idea matrix and how to use the idea matrix. A House of quality form was also introduced in this project, with explanations on why it is useful, and the calculations behind this form. There are two idea screening methods introduced in this thesis. Mainly the idea screening method focused on how to calculate the results and select ideas according to the results.

This thesis work is a product development process study and a process of mechanical idea generation, which are inseparable from customer needs. The final customer goal was to create a working prototype. Because of time issues, the thesis could not include a prototype, however, all the materials of this thesis work were handed out to the FUSA summer school student team as background support materials. Students from the team can use the existing ideas or upgrade the ideas and come up with better solutions. The final working prototype will be made by the summer student team.

Keywords product development process, mechanical design, sketches
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CONTENTS

1. INTRODUCTION 1
1.1 Terminology used 2
2 FEASIBILITY STUDY 2
2.1 Mechanical design feasibility study 2
2.2 Biochemical dilemma study 3
2.3 Student workshop 4
2.4 Idea processing methods 4
3 PROPOSALS 5
3.1 Idea matrix 5
3.2 Design sketches 5
3.3 House of quality 6
3.4 Idea screening 6
3.5 Manufacturing and cost estimation 6
4 CONCRETE LAY OUT DESIGNS 6
4.1 Result of idea matrix 7
4.2 Feeder device 7
4.2.1 Seal of feeder 7
4.2.2 Flow control 9
4.3 Container 10
4.3.1 Outlooks 11
4.3.2 Inside 11
4.4 Milling device 12
4.4.1 Cutting tool 12
4.4.2 Filter 14
4.4.3 Connection to bagging device 15
4.5 Bagging device 16
4.5.1 Bag position fix 16
4.5.2 Bag design 16
4.6 Sealing device 17
4.6.1 Sealing device fix 17
4.6.2 Ways of sealing 18
4.7 Oxygen control 19
4.7.1 Vacuuming 19
4.7.2 Chemical material 20
5 IDEA SCREEN METHOD AND RESULTS 21
5.1 House of quality 21
5.2 Idea screening 23

5.2.1 First Idea screening process 23
5.2.2 Second idea screening process 24

6 MANUFACTURING AND COST EVALUATION 25

7 CONCLUSIONS 37

SOURCES 38

Appendix: Idea screening methods and sub ideas catalogue

Appendix 1: Idea screening table 1
Appendix 2: Idea screening table 2
Appendix 3: Sub ideas catalogue

1. INTRODUCTION

Nowadays, environmental protection is one important topic for human beings; therefore, energy recycling and waste management come to the fore of this topic. The topic of this thesis is mechanical design and product development of a food waste managing machine. The machine can pack and seal food waste for biogas generation.

This thesis work was commissioned by HAMK, the Natural Resources Education and Research Center, the customer being a smart biowaste project group.

A food waste managing machine has the ability to mill, pack and seal food waste. There are mainly four eco-friendly ways to deal with biowaste: in landfills, by incineration, composting and anaerobic digestion. In this thesis work, the bagging and sealing solutions were mainly as to anaerobic digestion for biogas creation. For biogas creation, anaerobic digestion will take place in an oxygen free environment. In order to get a more efficient anaerobic digestion process, it is important to consider for the bagging and sealing design to keep the microbes alive in the food waste.

Customers have stated that the design of the machine needs to have following properties: low manufacturing costs, good quality, easy to assemble, easy to clean, energy saving and user friendly. This means the design needs to be considered in the manufacturing processes, material selections and have the good possibilities to work effectively in real life. The customer's future plan is to develop three different types of products for household, restaurant and food industry, therefore, it seems to be a long term project according to the entire project plan, and the time of this thesis work can not satisfy to come up with qualified designs for the three products. After discussion with the customer, this thesis went deep in household type only.

The mechanical design contains six sub-designs: feeder, container, milling, bagging, sealing and oxygen control of bagging. Milling can grind the food waste into small pieces, so it is a good way for space saving, bagging and sealing makes the food waste bag easy to store and no leak of smell

In order to in crease the quality of sub ideas, the idea matrix was made. The main aim is to put all different sub-designs into one idea matrix, assemble sub-designs form into different complete ideas. New sub ideas can also be created through idea matrix. House of quality form is part of the process in product development, it increase the practicability of sub ideas. Idea screening is the last stage in this thesis work. Two idea screening methods were used.

Component cost estimation and comparison were made for the prototype.

1.1 Terminology used

Anaerobic digestion: is a process that organics being digested by anaerobic organism under the absence of oxygen condition and suitable temperature condition to create methane and carbon dioxide.

Oxidizing reaction in food processing: microbes using oxygen to decompose the nutrients contains in the food.

Anaerobic bacteria: this is kind of bacteria which lives more active in the low oxygen contain environment than in aerobic environment. It is a very important kind of bacteria for biogas generation because some of them can generate methane. Methane is the main substance in biogas.

2 FEASIBILITY STUDY

At first, the feasibility study was around food waste managing machines. The main aim of this thesis work was to come up with sensible ideas, an idea matrix, a house of quality form and ideas screening results, so the feasibility study was conducted around these four topics.

2.1 Mechanical design feasibility study

Food waste managing machine feasibility study: The task of this thesis design work was to create a new food waste household kitchen use machine which has the ability to mill and package food waste. There are some existing products of garbage shredding machine, however their properties can not satisfy customer‘s request. Nevertheless, there are still some useful machines which could provide design ideas for this project.

Figure 1 is one kitchen garbage disposer machine, which is presented in the following:

Figure 1. InSinkErator Evolution Compact 3/4 HP Continuous Feed Garbage Disposal (The home depot 2000-2015)

This kind of garbage disposal can provide inspiration for the mechanical design of this project. The milling function properties are quite close to reach the customer needs. There is also an existing kitchen milling or food packaging machine which can provide different ideas for food waste milling and packaging for this project.

2.2 Biochemical dilemma study

In order to come up with sensible ideas, the feasibility study of biochemical dilemma was needed.

In this thesis work, the bio waste mainly refers to food waste. Food waste usually contains solids and liquids. According to customer needs, it is preferable to keep the liquid food waste because liquid waste also contains energy to generate biogas.

Food waste also contains substances which cause corrosion to the material of this machine, therefore, an extra coating was also considered. An extra coating is also an advantage to facilitate the cleaning process of this machine.

It is known to all that food waste is easily decayed starting to generate an undesirable smell. In this case the bagging process and the sealing solution are very important to prevent leakage. Besides, another challenge to consider was the next use for these food wastes while bagging and sealing food waste. As mentioned in chapter 1, the customers expect the food waste mainly to be used in creating biogases. Gasum has launched the first Nordic Ecolabelled vehicle fuel − biogas − in the Finnish market. Biogas is a local product, and the Nordic Ecolabel is only awarded to low-emission products.(The production and future of biogas in Finland, 2014) In order to make the biogas generation process more effective in the biogas plant, it is important to keep the food waste in an oxygen free environment to keep the anaerobic bacteria alive, it will make the biogas generation more effective in the biogas plant.

There are some possible solutions to prevent the oxidizing reaction, for example, vacuum could be one option. The size of the packing bag was also an important part to be considered.

2.3 Student workshop

During the ideas generation process that a student workshop for idea brainstorms was organized. The student workshop was collaborated with three students: Abass adeyinka, Avijita Kharel and Yijie Li. The meeting was hold on 7 February at 12 o'clock through Skype video chatting. The main meeting goal was to come up with bagging and sealing ideas.

Customer needs and background information were introduced before the brainstorming process. According to customer needs there should be a low oxygen level in the waste bag after sealing, in that case, a suitable living environment for anaerobic bacteria could be created, keeping anaerobic bacteria alive in the package bag make the biogas generating process more effective in the biogas plant. The outcome ideas of the workshop were vacuum pump solutions, cooling solutions and chemical material solution for bagging and sealing. It was also considered that if the liquid waste should be separated from solid waste.

2.4 Idea processing methods

There are lots of different types of idea processing methods. An idea processing method is a tool to generate more ideas. In this thesis work, three idea processing methods were used.

Idea matrix
Idea matrix making is one essential part in product development for new product selections. The bio waste machine is assembled of a few parts which have different functions. The idea matrix should present all the ideas for different parts, which can be linked together to come up with several most possible designs. There is no standard form about how this matrix should be but there are some mechanical design books has similar matrix which can be helpful in this case. To sum up, it is possible to come up with idea matrix which can present all the needed ideas.

House of quality

House of quality form is a diagram, resembling a house, used for defining the relationship between customer desires and the firm/product capabilities. (Wikipedia, 2015) It is a good tool to use during mechanical design because it can tell which part of product capability is more important to consider.

Idea analysis
Idea analysis also can be called concept selection. Concept selection is the process of evaluating concepts with respect to customer needs and other criteria, comparing the strengths and weaknesses of the concepts, and selecting one or more concepts for future investigation or development.(Ulrich & Eppinger 1995, 106) Two different concept selection method were used in this these work.

3 PROPOSALS

This chapter roughly introduces the final outcomes of this thesis work and the research work behind it.

3.1 Idea matrix

Idea matrix is a better organized and a literal version of a mind map. A mind map is a diagram used to visually organize information.(Mind map, 2015)There is no standard form of how idea matrix should be and no smart software was found to generate idea matrix, the only appropriate tool to create the idea matrix is excel. The idea matrix was created in a logical way: first of all, disassemble a completed design into few sub devices; second of all, divide sub devices into few parts, thirdly, try to find out different method of solution for each part. The idea matrix is a divergent way of thinking; the idea matrix helps with increasing the quantity of assembled ideas. It helps guide the idea generation process.

3.2 Design sketches

Design sketches were made for expressing the idea in a clear way. Sometimes picture tells better than words. Mostly 3D hand sketches were made to present the main idea; few 2D sketches were made to show the cross section of detail.

3.3 House of quality

House of quality is a very useful tool during design process; it can present the relationships between customer's need and technical feature without dimensions. There were three results from house of quality: first result was the importance percentage for each customer's need, second result was the strong/weak interference between technical features, and third result was the importance percentage for technical features. The house of quality is a simplified version in this thesis work, only the most important part was included.

3.4 Idea screening

Two idea screening method was used, first method was concept screening, few promising ideas will be selected, second method was concept scoring, the selected ideas were used as candidates for the final result. There were two selected ideas in the end.

3.5 Manufacturing and cost estimation

Few component costs estimation equations and the use guide of equations were introduced. Two selected ideas from idea screening method were used as examples to calculate the prototype cost.

4 CONCRETE LAY OUT DESIGNS

This thesis work was focused on the household type food waste managing machine. There are two types of model generated: the first one is separated from sink, and can use by mainly muscle energy; the second one is connected to the bottom of the sink, so customer can throw the food waste into the sink and sweep the food waste into the milling container through sinkhole.

4.1 Result of idea matrix

Table 1 Idea matrix

Devices	parts included in the devices	Different method for parts	Idea sketches
Feeder device	Seal of feeder	Magnet method	
		Pressiong method	
		Sliding method	
	Flow control	Rotation method	
		Pressing method	
Container	Container for milling tools and biowaste	Different shape	
		Inside design	
Milling device	Cutting tools	milling method	
		grinding method	
		Pressing method	
	Filter	Different cuttings	
	Connect to bagging device	Screw	
		Lock valve	
Bagging device	Bag position fix	Lock	
		Placing	
	Bag design	milk box/juice box	
		plastic bag	
		sausage skin	
Sealing device	Sealing device fix	screw	
		Lock value	
	Ways of sealing	heating	
		tighting	
		glue	
Oxygen control	Vacuuming	ways of vacuuming	
		Vacuum position fix	
	Chemical meterial	Chemical bag	

Table 1 showed the final result of idea matrix developing. Idea matrix can be seemed as an idea bank; it is a divergent way of idea developing tool, through this table the idea bank can be enriched. The more idea method and sketches could be made the more possible completed ideas can be assembled from idea bank and attend the idea screening system.

4.2 Feeder device

There are two problems to be considered for the feeder of the machine. First is the sealing of the feeder, second is the follow control problem for the “connect to the sink” model type.

4.2.1 Seal of feeder

Different kinds of cover were designed for the seal of feeder to prevent the unpleasant smell.

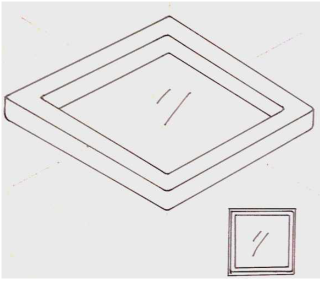


Figure 2 Sealing cover 1

This sealing design is a plastic sealing cover with concaved edges which allows the cover to be pressed in and clasp the edge of the feeder. This design used the elastic property of plastic material. In order to make the milling process safe, the top of the sealing cover is transparent, so the user can observe error of milling process easily and stop the milling process if necessary.

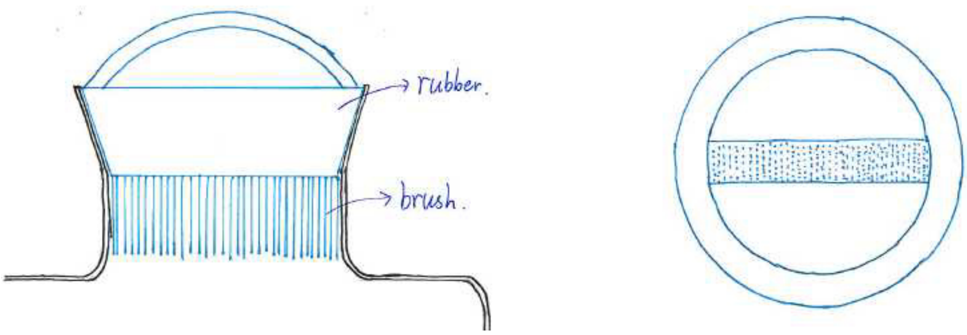


Figure 3 Sealing cover 2

Sealing cover 2 in figure 3 is made of rubber material, it is designed for connect to the sink model. It used friction forces between rubber and metal to seal the sinkhole and there is a small area with plastic brush to sweep the food waste into the milling container.

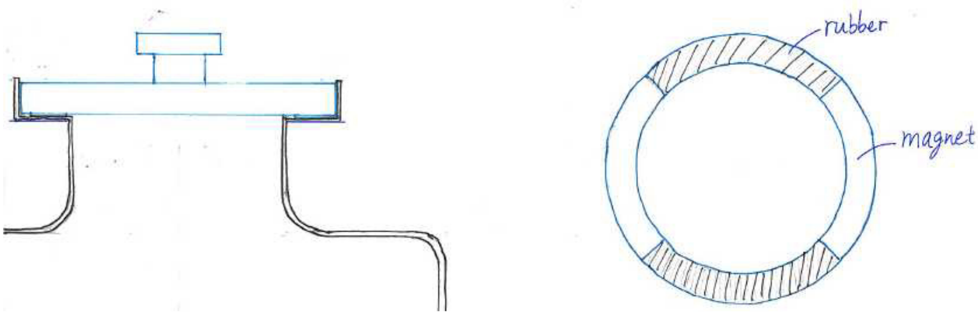


Figure 4 Sealing cover 3

Sealing cover 3 is also designed for connected to sink model. The magnet was used in sealing design and rubber loop was provided the friction force and increase the seal ability for the sinkhole.

4.2.2 Flow control

This design part is particular for connected to sink model. In order to save water and simplify the bagging process, the running water from the tap has to be separated from food waste.

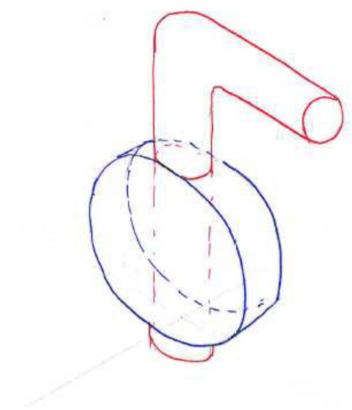


Figure 5 Flow control 1

Flow control 1 in figure 5 is a rotational valve for water flow control; it can be assembled into sink tube. When the valve is open it allows water pass through the tube, but not allow the food waste pass through and vice versa.

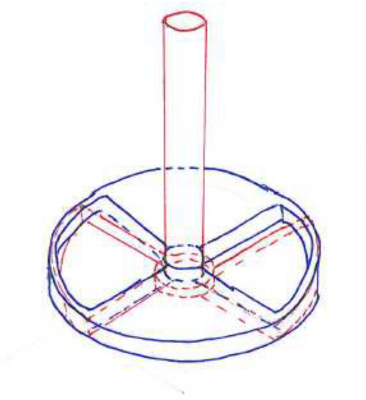


Figure 6 Flow control 2

Flow control 2 in figure 6 is also a rotational flow control valve. This valve is directly assembled in the sinkhole. The detail was showed in following figure.

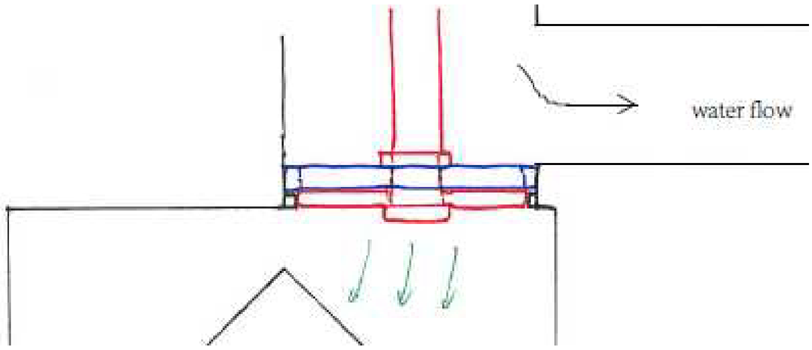


Figure 7 Detail of flow control 2

According to figure 6, the red part can rotate, when it rotates to certain angle and the circular sector is in a superposition with the blue part, it allows the food waste into the milling container; when the red part rotates back, the food waste entrance is locked and water can flow to the right side sink tube.

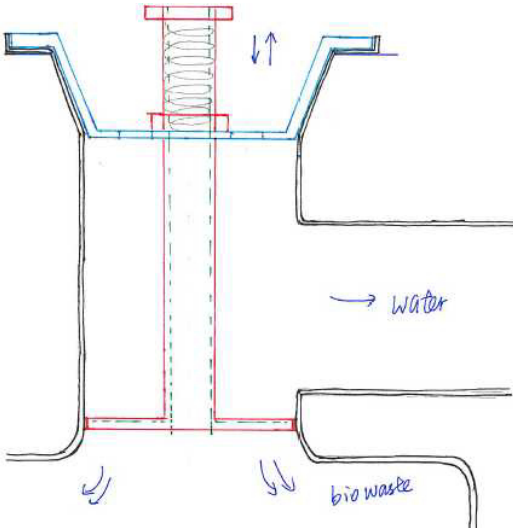


Figure 8 Flow control 3

The flow control 3 used pressing method. The original position of the design makes the milling container entrance being locked and allows water flow to the sink tube. When press the red rod down, the food waste can be threw into the milling container, press the red rod again, it jumps back to the original position.

4.3 Container

In this chapter, different outlooks of the container and the inner layer of the container are presented.

4.3.1 Outlooks

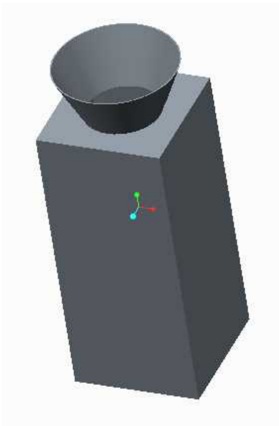


Figure 9 Outlook 1 of container

Figure 9 illustrates one of the “separated from sink model”, the outlook designed as a cube.

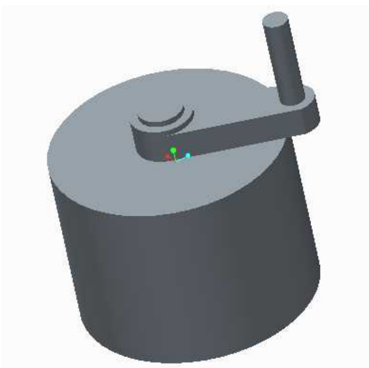


Figure 10 Outlook 2 of container

Figure 10 presents the outlook as a cylinder.

4.3.2 Inside

This chapter presents the differences between the containers’ inside wall design. For example, in figure 14, the inside wall of the container is different from the other designs, there are shape teeth planes and rough teeth in the inside wall while the inside walls of other design are smooth.

4.4 Milling device

There are three different ideas of milling method.

4.4.1 Cutting tool

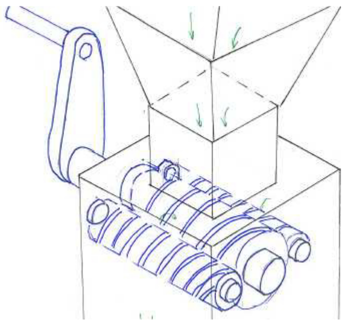


Figure 11 Cutting tool 1

Figure 11 shows the cutting by rotation of a handle, the cutting tool is a rotational cylinder mill knifes which can rotate with the handle.

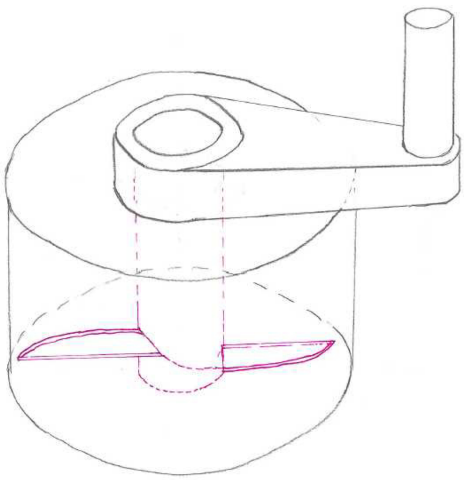


Figure 12 Cutting tool 2

Cutting tool 2 as seen in figure 12 is also a rotational cutting tool.

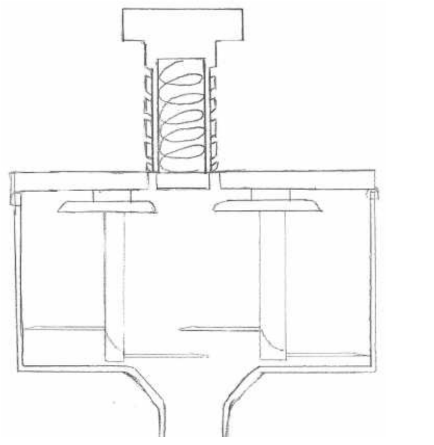


Figure 13 Cutting tool 3

The design in figure 13 uses pressing method to amplify the force and to make the two knife rods to rotate.

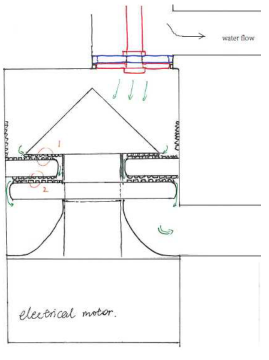


Figure 14 Cutting tool 4

In figure 14, the milling process uses high friction force to crush the food waste.

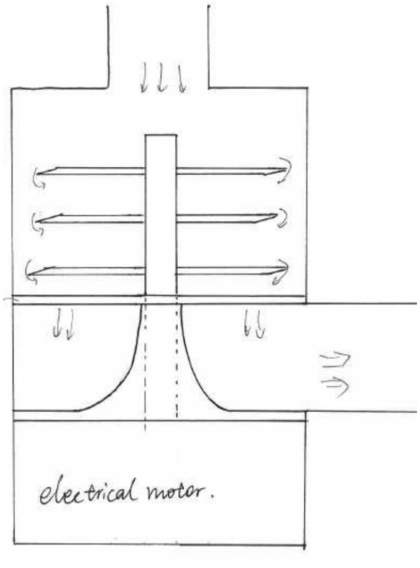


Figure 15 Cutting tool 5

Unlike the tools presented in figure 12, in figure 15 there are 3 layers of knifes, so the milling process is more effective.

4.4.2 Filter

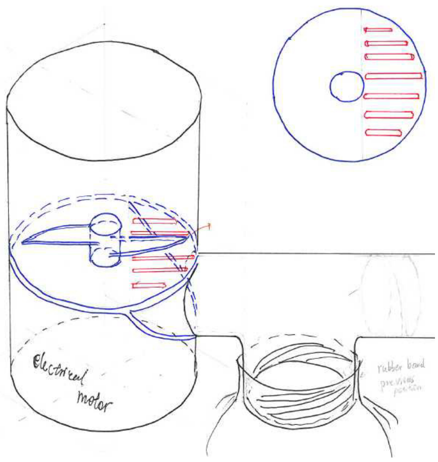


Figure 16 Filter 1

Figure 16 shows filter 1, which opens only half of the plane, so the milled food waste can flow down to the bagging device.

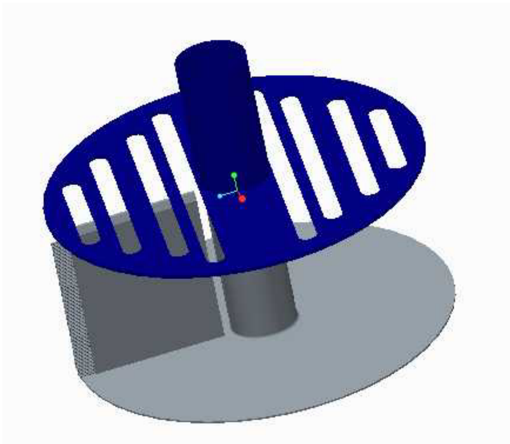


Figure 17 Filter 2

The second filter seen in figure 17 has a plastic sweeper under it, that rotates together with the milling knife. The plastic sweeper gathers and sweeps the milled food waste into the bagging device.

4.4.3 Connection to bagging device

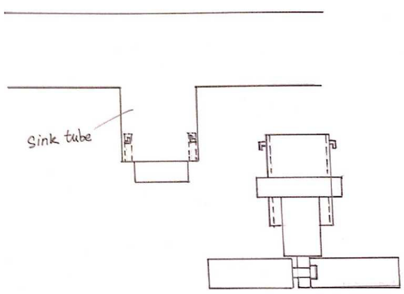


Figure 18 Bag position fix 1

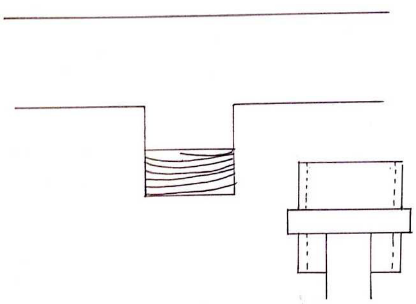


Figure 19 Bag position fix 2

As can be seen in figure 19, the bagging device was connected after milling machine by using thread method. In figure 18, it is a rotation lock device to fix the bagging device.

4.5 Bagging device

The main request of bagging device is easy to seal. The bagging material was also considered to be economical and recyclable. Bag fixed to the food waste out come and bag itself were considered in this chapter.

4.5.1 Bag position fix

Basically the bag position was locked to the outcome of milled food waste, by using rubber band with the single stand machine of the friction force.

4.5.2 Bag design

There are three ideas for bags: a milk carton, plastic bag or sausage skin..

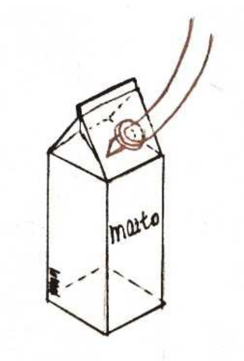


Figure 20 Milk carton

A Milk box or juice carton as seen in figure 20 is one of the bag design ideas. It is easy to use and every family has it. It is also a reusable material.

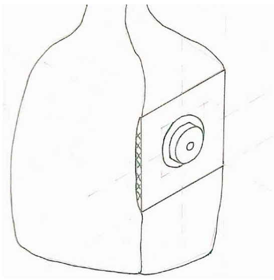


Figure 21 Plastic bag

In figure 21, a special designed plastic bag is illustrated. There is a special pad and plastic outcome on the side of the plastic bag, the pad can be filled with liquid observe material and the plastic outcome is the vacuum point.

The third idea for bag design is sausage skin. The sausage skin itself is pig intestine; it also could be a kind of plastic. After filling it with food waste it can be put into the bio gas reactor without any further processes.

4.6 Sealing device

The sealing device has to be user friendly and it should not allow for leakage of bag smell. The sealing device is fixed near to the bagging area.

4.6.1 Sealing device fix

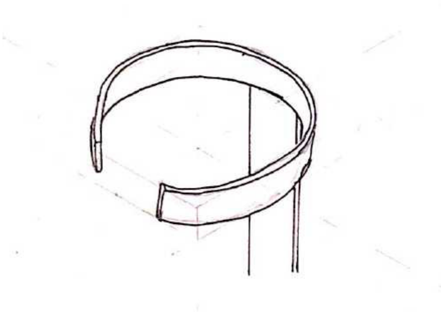


Figure 22 Sealing device position fix

Sealing device as seen in figure 22 is fixed to the final outcome tube by this idea. The material of this design has elastic abilities to fix to the food waste outcome tube.

4.6.2 Ways of sealing

There are three ideas for sealing: glue, heating and tighten with rubber band or rope.

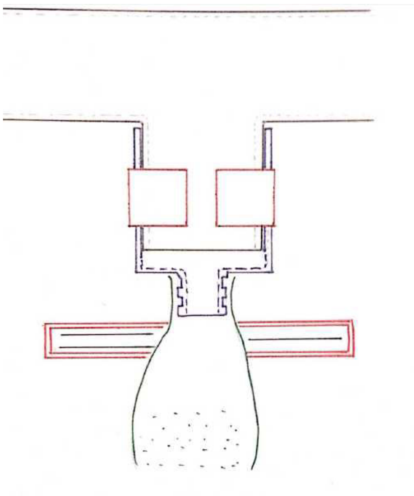


Figure 23 Sealing 1

According to figure 23, the sealing solution is to seal the bag by melting the plastic bag and pressing the melted part together before they get cold. In the figure 23, the red colour plane can generate heat by using electricity. By pressing the two red planes and stick them together the waste bag could be melted and sealed.

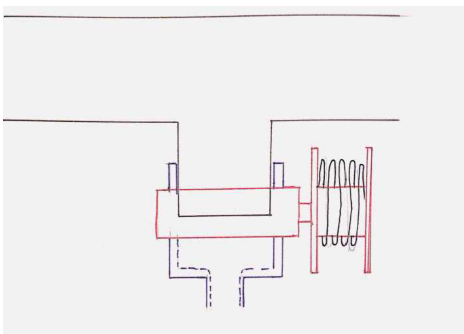


Figure 24 Sealing 2

In figure 24, the idea of sealing 2 used tightening method; there is one rope loop on the right side of the outcome tube. The rope can be pulled out and seal the plastic bag.

4.7 Oxygen control

For better efficiency of bio gas generation, the low oxygen contained in the bag is needed. Two ideas of oxygen control were presented in this chapter.

4.7.1 Vacuuming

There are different products of vacuum hand pumps. As can be seen in figure 25 and figure 26.

Figure 25. Hand pump 1 (Ailexpress, 2010-2015.)

Figure 26. Hand pump 2 (Arbor scientific, 2015.)

According to customer needs, the idea is good to be real products.

4.7.2 Chemical material

Figure 27. Oxygen absorber (Oxygen absorber, 2015)

Oxygen absorber inside the bag can be solution, as can be seen in figure 27.

5 IDEA SCREEN METHOD AND RESULTS

Different small ideas from idea matrix were assembled into sub ideas. Promising sub ideas were selected and waited for idea screen.

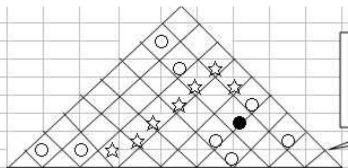
Two round of idea screening method were used. The first idea screening method is named: concept screening. Concept scoring method was use for the second round of idea selections.

All the idea screening method have their own valve system, the judgement was made according to customer's need. However, each customer's need has it own importance level. In order to distinguish the different importance of customer's need, the house of quality analysis system was used before idea screening.

5.1 House of quality

The house of quality table is presented in table 2.

Table 2 House of quality



● Strong positive relation
○ Slightly positive relation
☆ Slightly negative relation
★ Very negative relation
No relation, leave blank

△/▽ up/down, if it is the more the better.

Score 1-5 for each requirement. 5 means the most important.

Strong influence: 9
Medium influence: 3
Weak influence: 1
None, leave it blank

			▽	▽	▽	△	△	△	△	△	▽	
Customer's requirement	Score	%	Dimensions	Weight	Cost of production	Feeder sealing ability	Knife milling ability	Economical bagging soluti	Sealing ability	Engine of milling	Number of parts	
Good quality	4	14.5			9	3	3	3	3	3	1	
Cheap price	3.5	12.7			9	3	3	3	3	3	1	
Easy to assemble	3	10.9		1		3	1	1	3	3	9	
Easy to use	3.5	12.7		1		9	9	3	9	3		
No smell/leak	4	14.5	1		1	9		3	9		1	
Safety	4	14.5			1	3	9	3	3	3	1	
Easy to store	2.5	9	9	3	3	1		1	1	3	3	
Oxygen control	3	10.9			3		1	3	9		1	Total
Total	27.5		96	50,6	333,5	411,6	348,2	259,3	509,7	228,3	192,2	2428,9
			3,8	2	13,7	16,9	14,3	10,7	21	9,3	7,9	%
			8	9	4	2	3	5	1	6	7	Rank

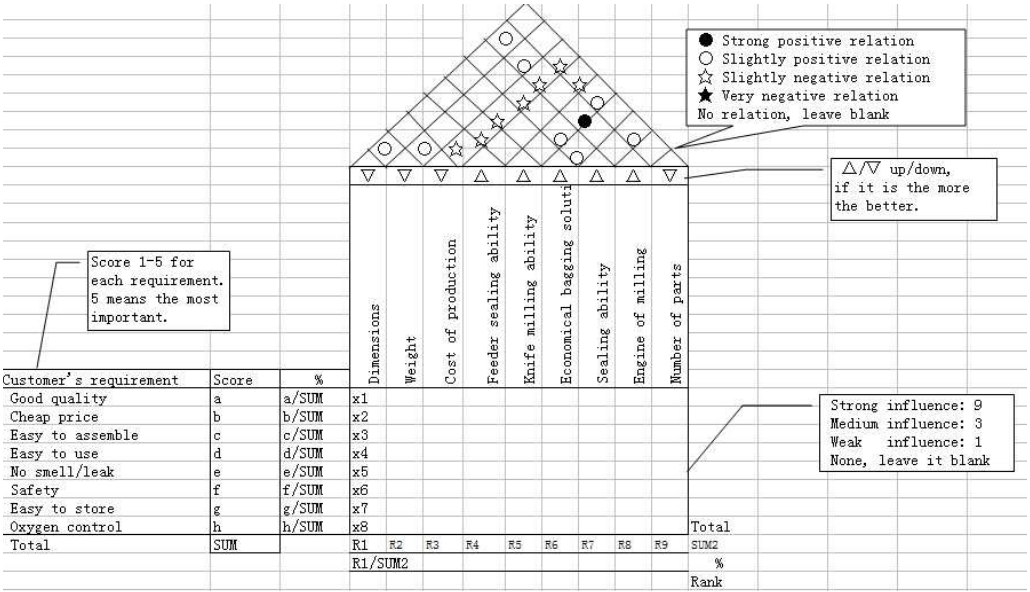
Table 2 is a simplified version of house of quality. House of quality is a tool for estimating the importance of product features according to customer's requirement. It can also estimate the most important customer's requirement and the influence between product features.

The main row in table 2 was filled with different product feature without dimensions. The main column was filled with different customer's requirement. Each importance of customer's requirement can be calculated according to the rating score and be presented as percentage.

For example, score 1-5 was used, "5" means "the most important", and "1" means "the least important". After objective judgements and writing down score for each customer's requirement, a sum was calculated for each customers needs. Each score of customer's requirement divide the sum got a decimal, turn the decimal into percentage form got the final important percentage, it can also be called "weight".

The importance estimating of product feature was calculated in a different way. According to table 2, there were four different magnitudes for represent the influences between customer's need and product features. Fill the magnitudes according to objective judgements and then calculate the importance of each product feature according to following figure and equations.

Table 3 House of quality calculation



According to table 3, only the example of dimensions' importance calculation was presented, real dates were represented by letters.

The calculation of the influence equation was presented in below:

$$R_1 := \left(x_1 \cdot \frac{a}{SUM} \right) + \left(x_2 \cdot \frac{b}{SUM} \right) + \ldots\ldots + \left(x_8 \cdot \frac{h}{SUM} \right) \quad (1)$$

In equation 1, "x1" to "x8" represented different influence between customer's need and dimensions of the product. "R1" is the total result of each customer's need influence. Letter "a" to "h" means different score from "1" to "5". "a/sum" is the weight of each customer needs.

According to table 2, it can be observed that: quality, no smell and safety are the most important things to consider during the development process. For the product feature, the "sealing ability" is the most important thing to consider during design and idea analysis process.

The triangle of table 2 and table 3 is the result of the positive or negative influence between product features. It is an analysis of the conflict between product features. The product can not be strong in ever product features, there are some sacrifices need to be made. It is good to have those conflicts under control.

5.2 Idea screening

The promotion system was used in this idea analysis process and idea screening method was different in each round.

5.2.1 First Idea screening process

All the assembled sub-ideas were candidates for the first idea screening.

Table 4 Idea screening 1 (Appendix 1)

					Connected to sink																					
	Muscle energy				Idea 1-5				Idea 2-5				Idea 3-5				bagging device		Bag selection			Sealing selection			oxygen control	
Customer's need/ideas	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	bagging device lock fix	bagging device screw fix	milk boxes	plastic bag	sausage skin	glue	heating	tighting	vacumm	chemical
Good quality	-	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	-	+	+	0	0	0	0	-	blank	blank
Cheap price	+	+	+	-	+	+	+	+	0	0	0	0	-	-	-	-	+	0	+	0	0	-	-	+	-	-
Easy to assemble	+	+	+	-	0	0	0	0	0	0	+	+	-	-	-	-	+	+	+	+	+	blank	blank	blank	blank	blank
Effective	+	-	0	0	-	-	0	-	+	+	+	+	+	+	+	+	0	+	+	+	+	0	+	-	0	+
Easy to clean	0	0	0	0	0	0	0	0	0	0	+	0	-	-	-	-	+	0	blank	blank	blank	blank	blank	blank	blank	blank
Easy to use	+	-	0	+	+	-	-	+	0	0	0	0	0	0	0	0	+	-	+	-	+	0	+	-	+	-
No smell/leak	-	-	-	0	+	0	+	+	0	0	+	+	0	-	+	+	-	+	0	0	0	0	+	+	-	-
Safety	0	0	0	+	+	+	+	+	-	0	0	0	+	+	+	+	0	+	+	0	0	-	-	0	0	-
Easy to store	0	0	0	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	blank	blank	blank	blank	blank
Bagging oxygen control	-	-	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-	0	+	0	0	-	+	+
Sum +	4	2	2	2	5	3	4	5	1	2	5	4	3	3	4	4	5	6	7	3	5	0	3	2	2	2
Sum 0	3	3	5	4	3	5	5	4	8	8	5	6	4	3	3	3	3	3	1	5	4	5	2	1	2	0
Sum -	3	5	3	4	2	2	1	1	1	0	0	0	3	4	3	3	2	1	1	1	0	2	2	4	2	4
Net Score	1	-3	-1	-2	3	1	3	4	0	2	5	4	0	-1	1	1	3	5	6	2	5	-2	1	-2	0	-2
Rank	1	4	2	3	3	5	3	2	6	4	1	2	6	7	5	5	2	1	1	3	2	2	1	2	1	2
Continue?	YES	NO	NO	YES	No	No	No	YES	No	No	YES	No	No	No	No	YES	No	YES	YES	No	YES	No	Yes	YES	YES	No

The first idea screening method is concept screening, this method can narrow down the concepts effectively and improve potential concept according to customer's need. There are 26 sub-ideas for idea screening 1. (Appendix 3)

Table 5 Part enlarged idea screening 1

					Connected to sink											
	Muscle energy				Idea 1-S				Idea 2-S				Idea 3-S			
Customer's need/ideas	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Good quality	-	-	-	0	0	0	0	0	0	0	0	0	0	0	0	0
Cheap price	+	+	+	-	+	+	+	+	0	0	0	0	-	-	-	-
Easy to assemble	+	+	+	-	0	0	0	0	0	0	+	+	-	-	-	-
Effective	+	-	0	0	-	-	0	-	+	+	+	+	+	+	+	+
Easy to clean	0	0	0	0	0	0	0	0	0	0	+	0	-	-	-	-
Easy to use	+	-	0	+	+	-	-	+	0	0	0	0	0	0	0	0
No smell/leak	-	-	-	0	+	0	+	+	0	0	+	+	0	-	+	+
Safety	0	0	0	+	+	+	+	+	-	0	0	0	+	+	+	+
Easy to store	0	0	0	-	+	+	+	+	+	+	+	+	+	+	+	+
Bagging oxygen control	-	-	-	-	0	0	0	0	0	0	0	0	0	0	0	0
Sum +	4	2	2	2	5	3	4	5	1	2	5	4	3	3	4	4
Sum 0	3	3	5	4	3	5	5	4	8	8	5	6	4	3	3	3
Sum -	3	5	3	4	2	2	1	1	1	0	0	0	3	4	3	3
Net Score	1	-3	-1	-2	3	1	3	4	0	2	5	4	0	-1	1	1
Rank	1	4	2	3	3	5	3	2	6	4	1	2	6	7	5	5
Continue?	YES	NO	NO	YES	No	No	No	YES	No	No	YES	No	No	No	No	YES

Table 5 is partial enlarged figure of table 4. Eligible ideas were selected according to left column customer needs. House of quality and two idea screening method used same customer needs list.

There are three evaluation mark in this method: "+", " − " and "0". "+" means "better than", when compare with other sub ideas. " − " means "worse than". "0" means "same as". After marking all the customer needs, calculate individually the sum of each evaluation mark. Use "Sum +" minus "Sum − " get the "Net score". Compare the "Net score" from each sub ideas and rank them. The row of "continue" means the question: will these sub-ideas be selected into the next idea screening round?

In some situations, it is not easy to give those marks objectively, so this method works better in group works.

According to the results, there are five sub ideas being selected into the second round.

5.2.2 Second ides screening process

Table 6 Idea screening 2 (Appendix 2)

		Muscle Energy				Connected to sink					
		Idea 1		Idea 4		Idea 8		Idea 11		Idea 16	
Customer's need/ideas	Weight %	Rating	Weighted score	Rating	Weighted score	Rating	Weighted score	Rating	Weighted score	Rating	Weighted score
Good quality	14.5	3	0.435	3	0.435	4	0.58	4	0.58	4	0.58
Cheap price	12.7	4	0.508	2	0.254	3	0.381	3	0.381	2	0.254
Easy to assemble	10.9	3	0.327	3	0.327	4	0.436	3	0.327	3	0.327
Easy to use	12.7	3	0.381	4	0.508	3	0.381	4	0.508	4	0.508
No smell/leak	14.5	3	0.435	4	0.58	4	0.58	4	0.58	4	0.58
Safety	14.5	4	0.58	4	0.58	4	0.58	4	0.58	4	0.58
Easy to store	9	4	0.36	2	0.18	4	0.36	4	0.36	4	0.36
Bagggin oxygen control	10.9	3	0.327	3	0.327	3	0.327	4	0.436	4	0.436
Total Score			3.353		3.191		3.625		3.752		3.625
Rank			1		2		2		1		2
Continue?		YES		NO		NO		YES		NO	

Second idea screen method is concept scoring.

Concept scoring is used when increased resolution will better differentiate among competing concepts. In this stage, the team weights the relative importance of the selection criteria and focuses on more refined comparisons with sum of the ratings. (Ulrich & Eppinger 1995, 117)

According to table 6, there is one “weight” row beside the “customer‘s need”, the number of weight was calculated from House of quality. There is one “rating” row under each idea, there are “one” to “five” rating numbers filled into each column according to customer’s need. Usually, there is a reference concept to be compared with each idea. The reference concept can be some commercial product; however this thesis work is inventing a new product, therefore, no reference concept could be found. The rating process was made compare each idea.

The rating number “1” means “much worse than”. “2” means “worse than”. “3” means “same as”. “4” means “better than”. “5” means “much better than”.

After filled rating rows, the total score was calculated according to following equation:

$$s_j := \sum_{i=1}^{m} \left(r_{ij} \cdot w_i\right) \qquad (2)$$

Where m: number of customer’s need

r_{ij}: rating number of idea j according to ith customer’s need

w_i: weighting for ith customer’s need

s_j: total score for idea j

After calculation and compare the total scores, two ideas were selected based on the rank result.

6 MANUFACTURING AND COST EVALUATION

Cost estimates are needed to determine the viability of projects and to minimize project and product cost. (Swift & Booker 2003, 249.)

In this chapter, the two selected ideas were evaluated as a prototype in component cost. Some of the parts could be manufactured; some of the parts can be purchased. Item sources were included as one factor in the evaluation. The sub ideas of each selected idea with same function were compared.

The rough component cost of two selected ideas was calculated. Following four equations were used:

$$M_i := V \cdot C_{mt} + R_c \cdot P_c \qquad (3)$$

Where:

M_i: a single process model for manufacturing
V : volume of material required to produce the component
C_{mt}: the cost of the material per unit
R_c : relative cost coefficient
P_c : basic processing cost

When Volume of material is unknown, follow equation 4 was used:

$$V := V_t \cdot W_c \qquad (4)$$

Where:

V_t: finished volume of component
W_c: waste coefficient

$$R_c := C_{mp} \cdot C_c \cdot C_s \cdot C_{ft} \qquad (5)$$

$$C_{ft} := C_t \text{ or } C_f \qquad (6)$$

Where:

C_{mp}: material to process suitability
C_c: shape complexity
C_s: Section coefficient
C_t: tolerance coefficient
C_f: surface finish coefficient

Equation 6 means the C_{ft} takes whatever bigger value of C_t or C_f.

Almost all the unknown numbers from equation 3,4,5,6 could be found from following figures. Unknown numbers were found according to different manufacturing methods; therefore, only related figures were presented in the following. Sheet metal work and manual machining were selected manufacturing process.

For P_c value:

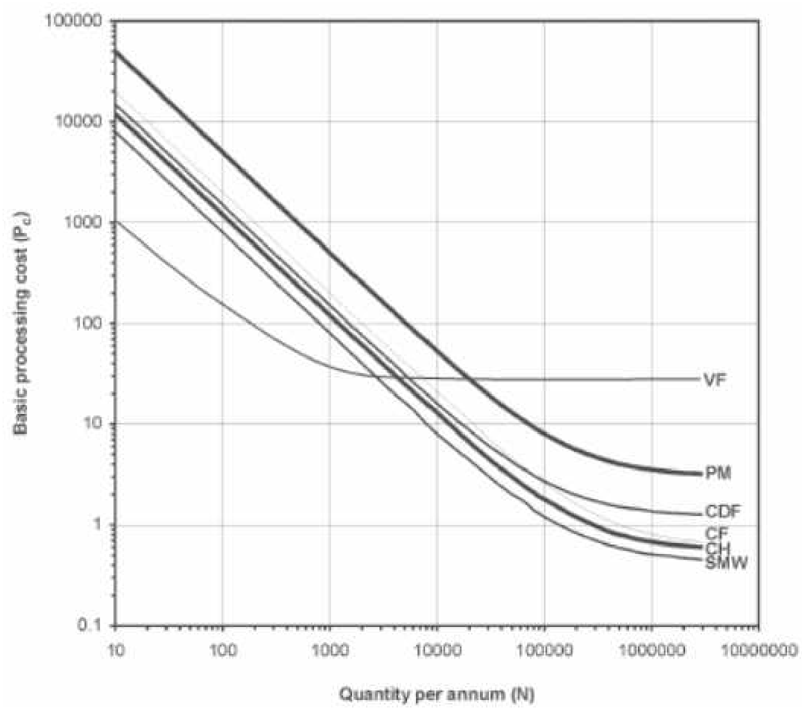


Figure 28 Basic processing cost against annual production quantity of SMW (Swift & Booker 2003, 253.)

Assume the quantity per annum is 10 for all the P_c values.

SMW is the capital initial of sheet metal work. P_c value of sheet metal could be found from figure 28.

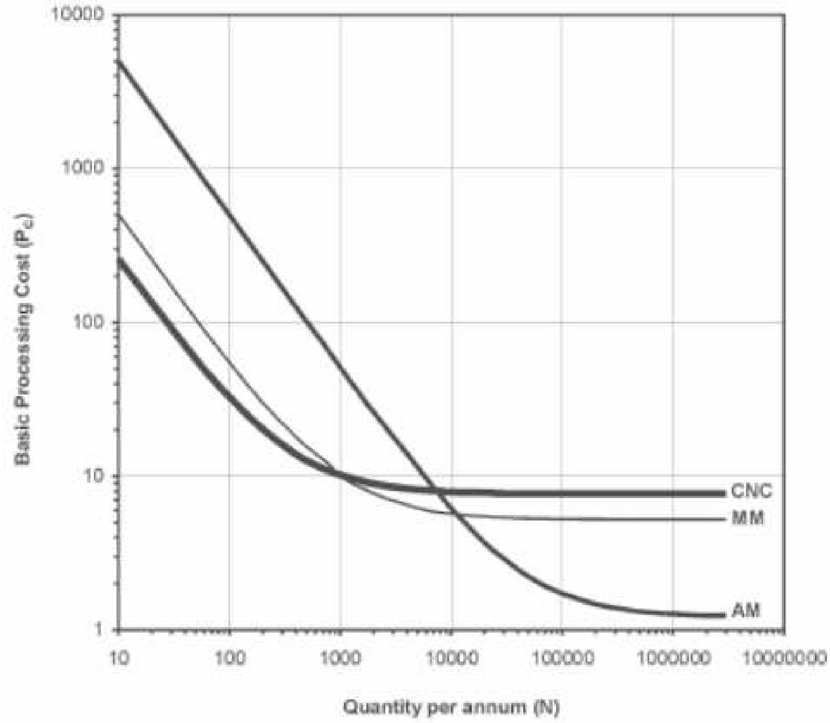


Figure 29 Basic processing cost against annual production quantity of MM (Swift & Booker 2003, 254.)

MM is the capital initial of manual machining. P_c value of manual machining could be found from figure 29.

In order to calculate R_c relative cost coefficient, four more coefficients needs to be found from following tables and figures.

For C_{mp} value:

Table 7 Relative cost data for material processing suitability (Swift & Booker 2003, 258.)

Material \ Process	AM	CCEM	CDF	CEP	CF	CH	CM2.5	CM5	CMC	CNC	CPM	GDC	HCEM	IC	IM	MM	PDC	PM	SM	SC	SMW	VF
Cast Iron	1.2						1	1	1	1.2				1		1.2		1.6	1	1		
Low Carbon Steel	1.4	1.3	1		1.3	1.3	1	1	1.2	1.4			1.3	1		1.4		1.2	1.2	1.2	1.2	
Alloy Steel	2.5	2	2		2	2	1	1	1.3	2.5			2	1		2.5		1.1	1.3	1.3	1.5	
Stainless Steel	4	2	2		2	2	1	1	1.5	4			2	1		4		1.1	1.5	1.5	1.5	
Copper Alloy	1.1	1.1	1		1	1			1	1.1			1	1		1.1	3	1	1	1	1	
Aluminium Alloy	1	1.1	1		1	1			1	1		1.5	1.1	1		1	1.5	1	1	1	1	
Zinc Alloy	1.1	1	1		1	1			1	1.1		1.2	1	1		1.1	1.2	1	1	1	1	
Thermoplastic	1.1			1						1.1	1.2				1	1.1						1
Thermoset	1.2			1.2						1.2	1				1	1.2						
Elastomer	1.1			1.5						1.1	1.5				1.5	1.1						

The same initials were used in table 7. C_{mp} value of sheet metal work and manual machining could be found from table 7.

For C_c shape complexity coefficient, there was one figure of shape classification categories used. The figure of category was used as index to find value of C_c.

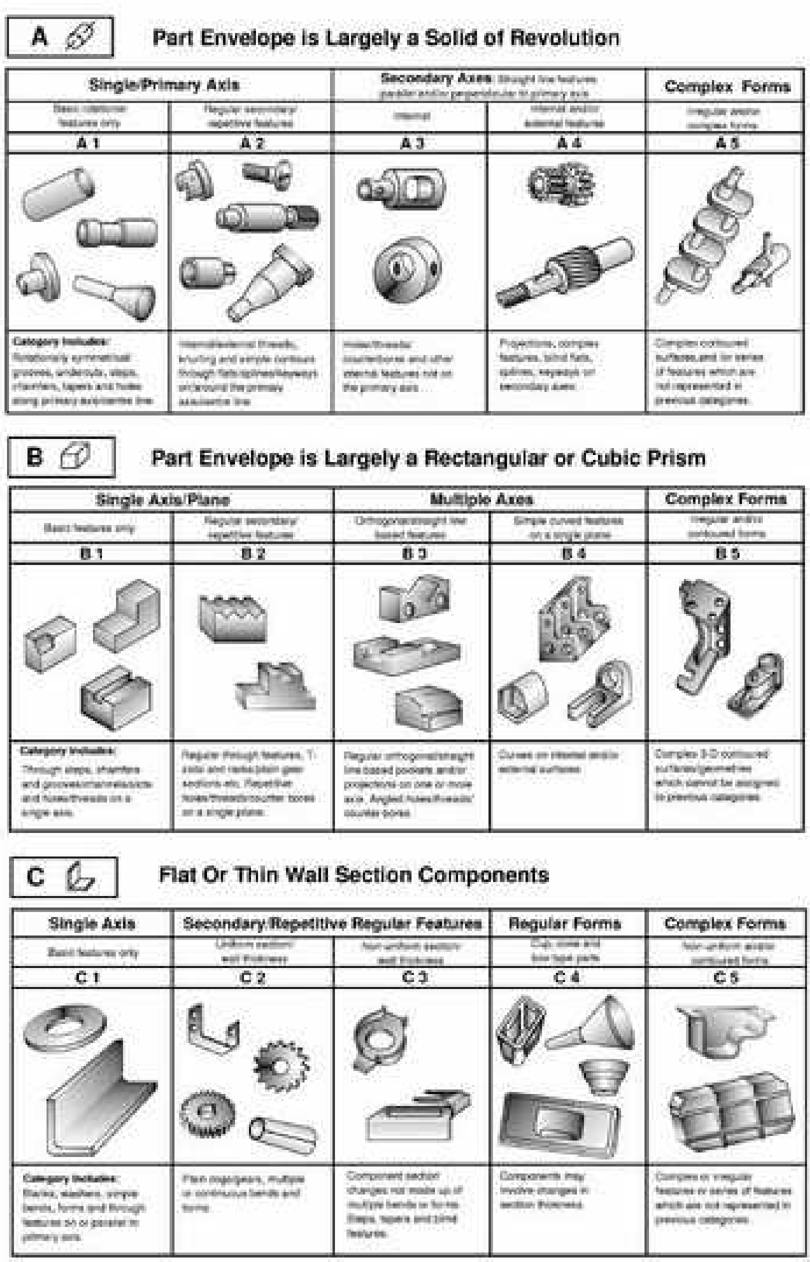


Figure 30 Shape classification categories used in the determination of C_c (Swift & Booker 2003, 259.)

According to figure 30, category table A and table C are the most suitable index to find C_c value.

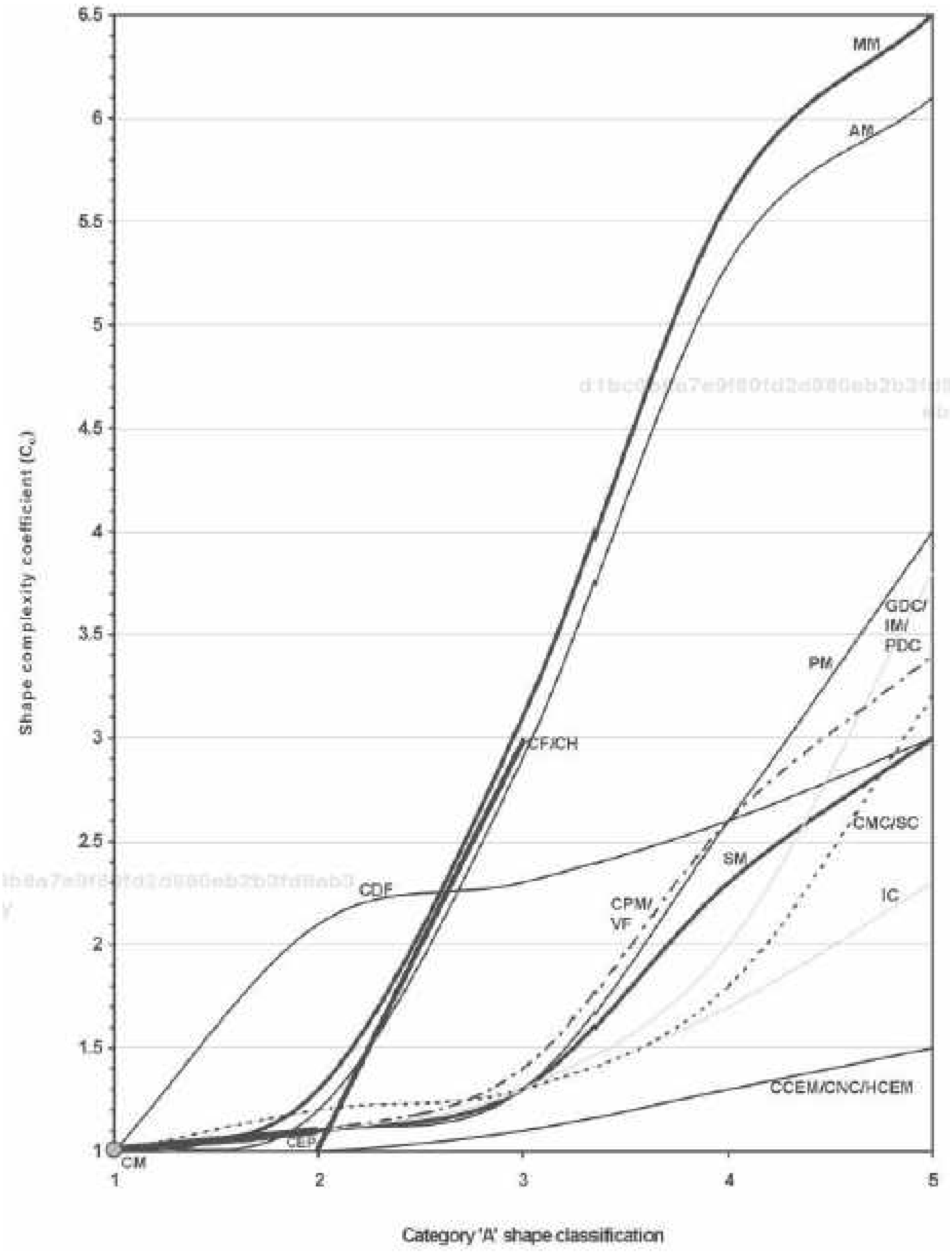


Figure 31 Determination of shape complexity coefficient- category A shape classification (Swift & Booker 2003, 260.)

According to figure 31, C_c value of category A shape, used sheet metal work or manual machining process could be found.

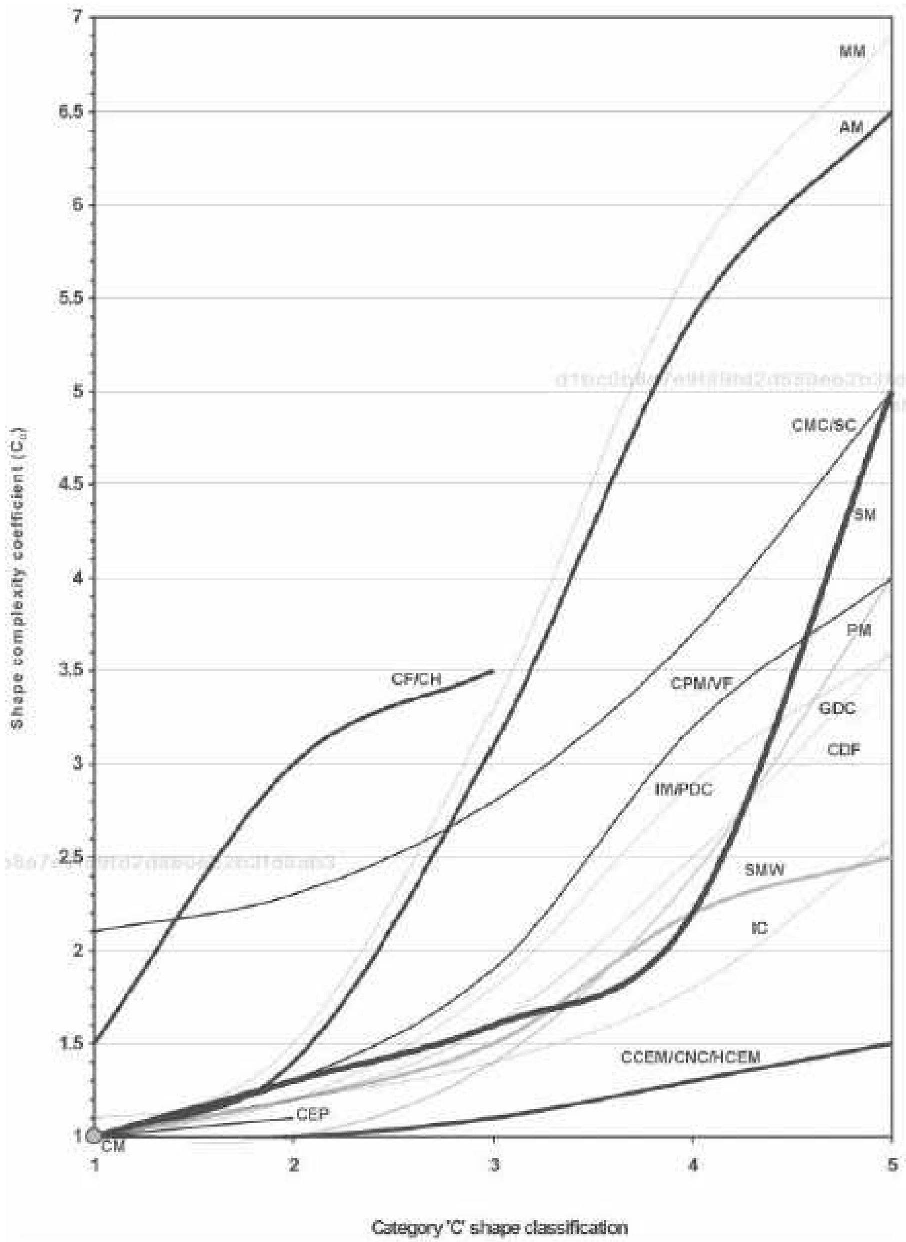


Figure 32 Determination of shape complexity coefficient – category C shape classification (Swift & Booker 2003, 262.)

According to figure 32, C_c value of category C shape, used sheet metal work or manual machining process could be found.

For C_s value, section coefficient could be found from following figure 33:

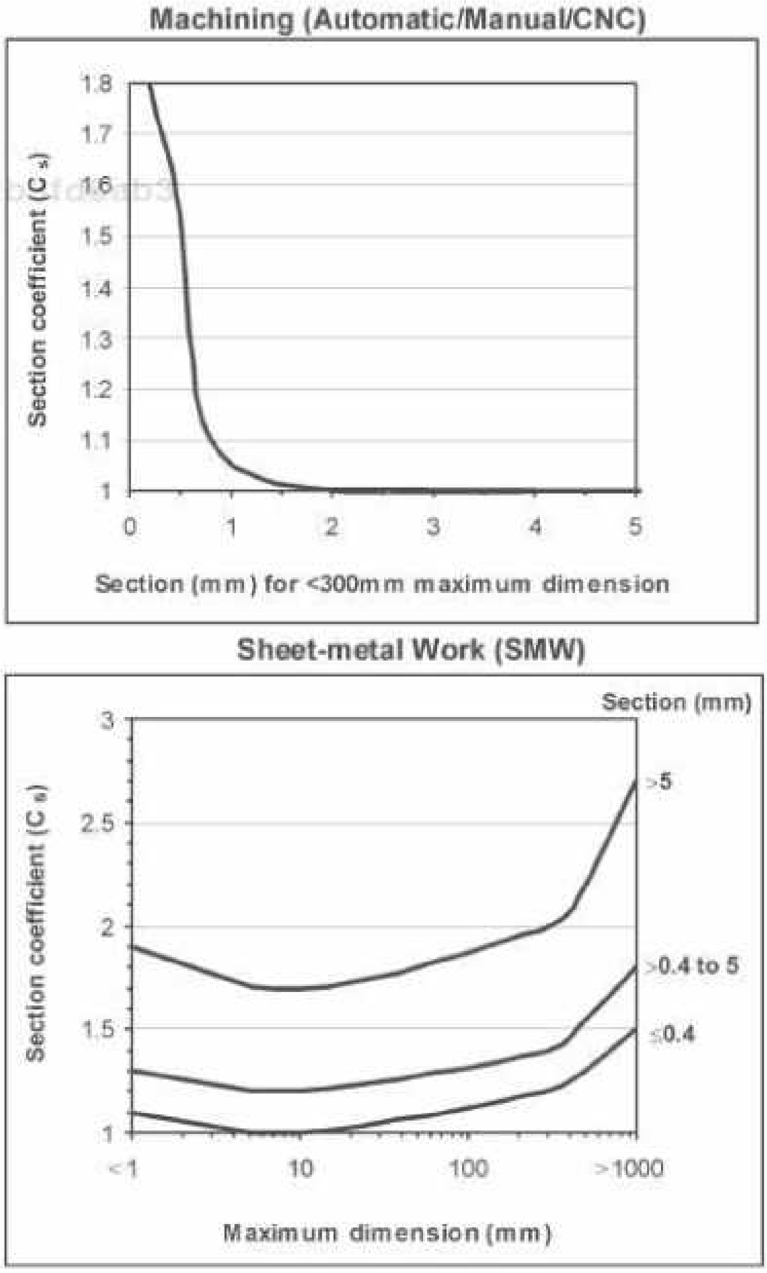


Figure 33 Determination of section coefficient for manual machining and sheet metal work (Swift & Booker 2003, 264-265.)

The X axis of Figure 33 represents the maximum dimension where the section acts, the Y axis in the right is the specified section size. The C_s value could be found according to X and Y axis.

For C_t tolerance coefficient and C_f surface finish coefficient value can be found in following figure 34 and figure 35:

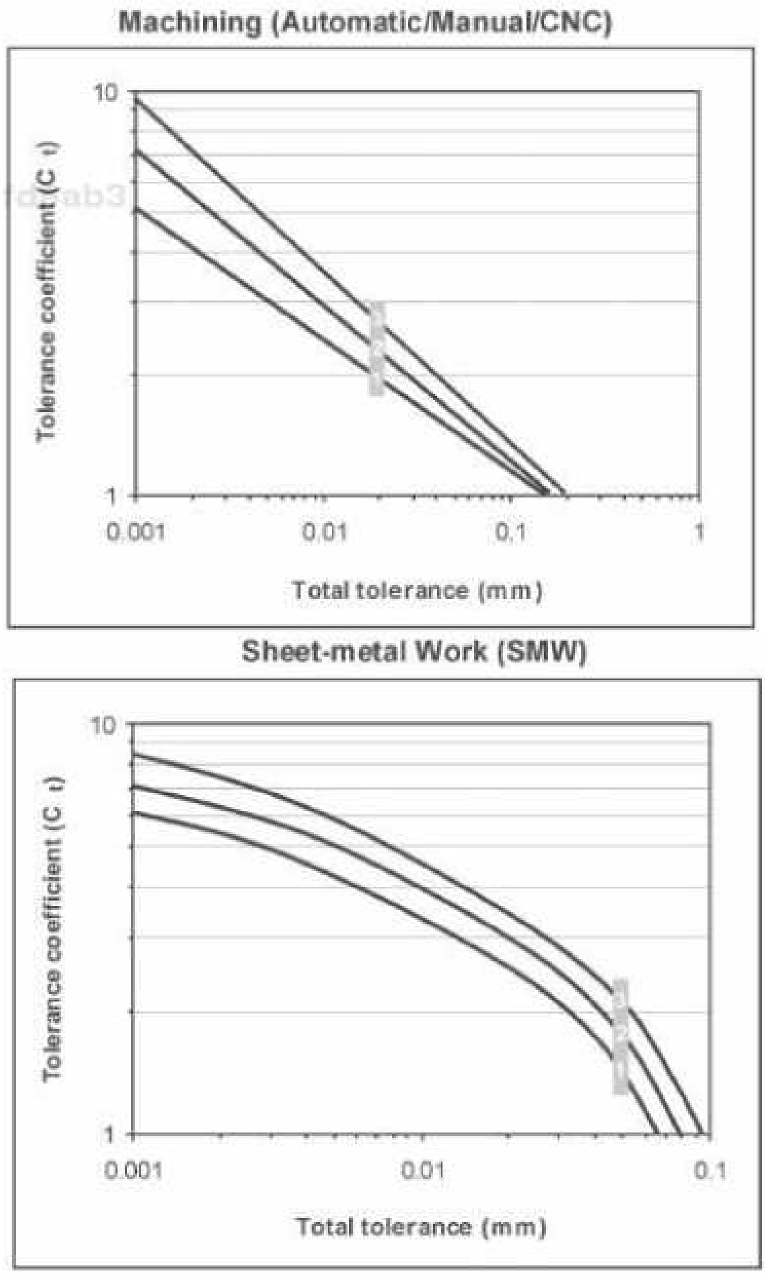


Figure 34 Determination of the tolerance coefficient C_t for sheet metal work and manual machining (Swift & Booker 2003, 267-268.)

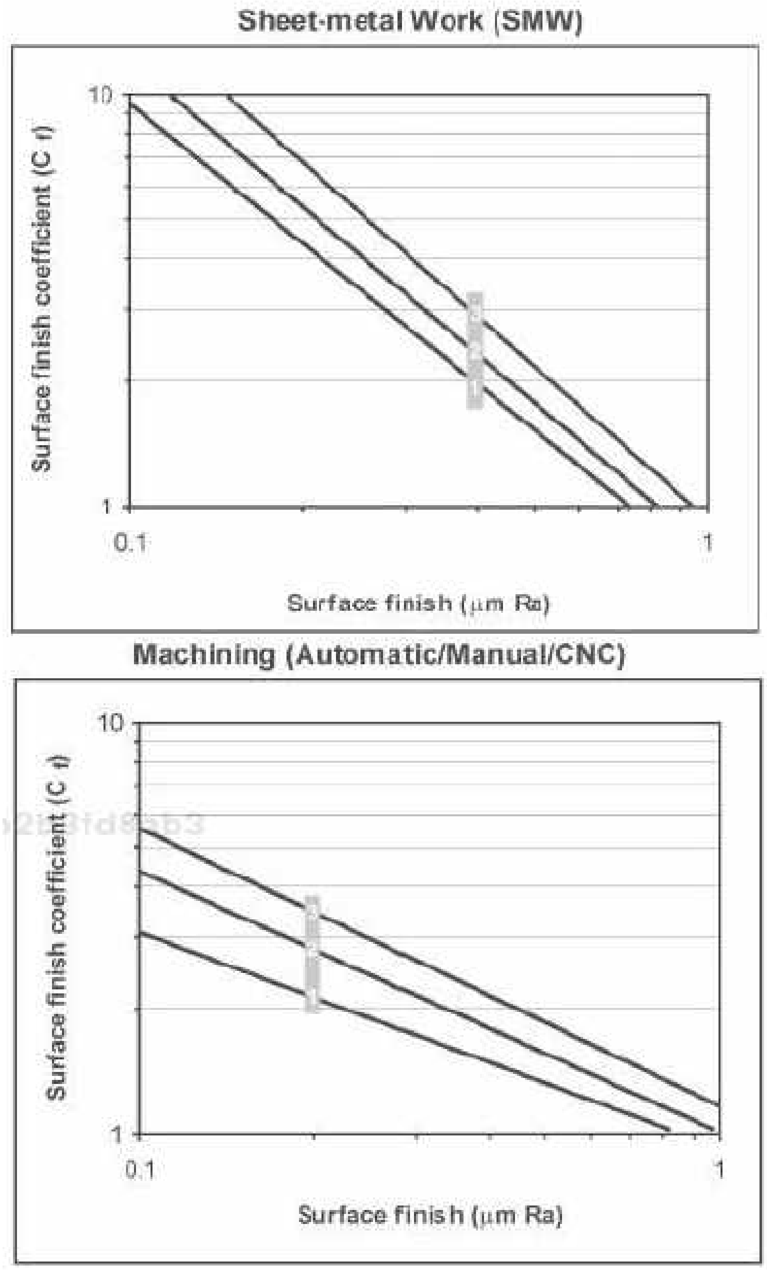


Figure 35 Determination of the surface finish coefficient C_f for sheet metal work and manual machining (Swift & Booker 2003, 270-271.)

For the cost of material per unit C_{mt} can be found from following table 8:

Table 8 Sample material cost value per unit volume for commonly used material classes (Swift & Booker 2003, 272.)

Material	Material Cost (C_{mt}) (pence/mm^3)*
Cast Iron	0.00048
Low Carbon Steel	0.00041
Alloy Steel	0.00157
Stainless Steel	0.00206
Copper Alloy	0.00259
Aluminium Alloy	0.00083
Zinc Alloy	0.00124
Thermoplastic - nylon, PMMA	0.00065
- other (PVC, PE, PS)	0.00018
Thermoset	0.00035
Elastomer	0.00018

*Average cost per unit volume sourced in the UK, 2002.

Stainless steel is the material used for both ideas. The total price unit was turned into Euros for comparison.

The waste coefficient value W_c can be found in the following table 9:

Table 9 Waste coefficient for the sample processes relative to shape classification category (Swift & Booker 2003, 273.)

Shape Classification \ Process	AM	CCEM	CDF	CEP	CF	CH	CMC	CNC	CPM	GDC	HCEM	IC	IM	MM	PDC	PM	SM	SC	SMW	VF
A1	1.6	1	1.1	1	1	1	1.1	1.6	1	1	1	1	1.1	1.6	1	1	1	1.1		1
A2	2	1	1.1	1.1	1	1	1.1	2	1.1	1.1	1	1	1.1	2	1.1	1	1.1	1.1		1.1
A3	2.5	1.5	1.2		1	1	1.2	2.5	1.1	1.1	1.5	1.1	1.1	2.5	1.1	1	1.1	1.2		1.1
A4	3	2	1.2				1.3	3	1.2	1.2	2	1.1	1.1	3	1.2	1	1.2	1.3		1.2
A5	4	3	1.3				1.4	4	1.3	1.3	3	1.2	1.2	4	1.3	1.2	1.3	1.4		1.3
B1	1.7	1	1.1	1	1	1	1.1	1.7	1	1	1	1	1.1	1.7	1	1	1	1.1		1
B2	2.2	1	1.1	1.1	1	1	1.1	2.2	1.1	1.1	1	1	1.1	2.2	1.1	1	1.1	1.1		1.1
B3	2.8	1.5	1.2		1	1	1.2	2.8	1.1	1.1	1.5	1.1	1.1	2.8	1.1	1	1.1	1.2		1.1
B4	4	2	1.2				1.3	4	1.1	1.2	2	1.1	1.1	4	1.2	1	1.2	1.3		1.1
B5	6	3	1.3				1.4	6	1.2	1.3	3	1.2	1.2	6	1.3	1.2	1.3	1.4		1.2
C1	1.8	1	1.1	1	1	1	1.1	1.8	1	1	1	1	1.1	1.8	1.1	1	1.1	1.1	1.2	1
C2	2.4	1	1.1	1.1	1	1	1.2	2.4	1.1	1.1	1	1	1.1	2.4	1.1	1	1.1	1.2	1.2	1.1
C3	4	2	1.1		1	1	1.3	4	1.1	1.1	2	1.1	1.1	4	1.1	1	1.1	1.3	1.4	1.1
C4	6	3	1.2				1.4	6	1.1	1.2	3	1.1	1.2	6	1.2	1	1.2	1.4	1.5	1.1
C5	8	4	1.3				1.6	8	1.2	1.3	4	1.2	1.3	8	1.3	1.2	1.3	1.6	1.6	1.2

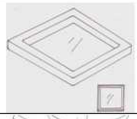
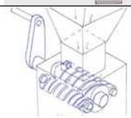
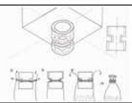
According to table 9 and figure 30, the waste coefficient could be found for sheet metal work and manual machining manufacturing process.

The value of finished volume of component V_t can be estimated from the customer's need of food waste volume.

After getting all the necessary unknown numbers from figures above and put them into equations, the component cost of some part can be calculated. The calculated cost and purchased price were added together to get the final price.

The prototype component cost result of idea 1 was presented in the following table 10:

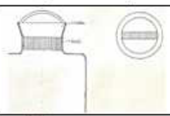
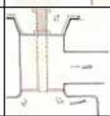
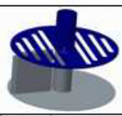
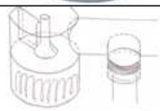
Table 10 Idea 1 component cost estimation

Ideas	function part	Figure of each part	Sourcing	Manufacturing	Commercial Price	Component cost	Total cost
Idea 1	Feeder		Commercial	Plastic casting	1 Euro	None	112 Euros+188860
	Milling tool		Commercial	3D printing	50 Euros	None	
	Container		Self-made	sheet metal work	None	7416pence+164160	
	packing & sealing		Self-made	manual mechining	None	12360pence+24700	

The commercial price was estimated according to research work experiences.

The prototype component cost result of idea 2 is presented in the following table 11:

Figure 44 Idea 2 component cost estimation

Ideas	function part	Figure of each part	Sourcing	Manufacturing	Commercial cost	Component cost	Total cost
Idea 2	Feeder		Commercial	Plastic casting	8 Euros	None	75 Euros+369360
	Flow control		commercial	sheet metal work and assembly work	10 Euros	None	
	Milling tool		Commercial	metal mechining	10 Euros	None	
	Fillter		selfmade	soft plastic assembly with sheet metal	None	1153.6pence+205200	
	Container		Selfmade	sheet metal work	None	8650pence+164160	
	packing & sealing		Commercial	metal mechining	2 Euros	None	

According to table 10 and table 11, the second idea seems to be more economical to produce; however, the second idea has a lot of details to be redesigned before put in mass production.

To sum up, ideas 2 is the recommended one, for the bagging solution is already an economical way of recycle, and the whole concept is to put the structure under the sink whole is more user friendly.

7 CONCLUSIONS

A product development process and mechanical design of a smart biowaste machine were the main topics in this thesis work.

The product development process included three main parts: an idea matrix, a house of quality form and idea screening method. The mechanical design process included a lot of research work, brainstorm and idea sketching.

The idea matrix can also be called an idea map during some project processes. After researching, there is no standard form of idea matrix. It is a flexible tool to organize existing ideas as well as creating new ideas. According to chapter 4.1, the idea matrix is made by breaking down the components from the imaginary product. Based on different components, more detailed sub ideas were created.

A house of quality form is one essential part in this product development process. From my point of view, it should be the first step before idea generation starts. It analyzes the most important customer's need and product features. It gives the limitation during idea screening and increase sub idea qualities.

The screening of idea process is the last stage in this thesis work. Two different methods were used in this project. It is essential to use different idea selecting method when there are two many sub ideas.

Research work, brainstorm and idea sketching were the main processes during the mechanical design in this thesis work. According to customer needs, it is preferential to find commercial product as sub ideas for they want to create a prototype quickly. Brainstorming help create more different ideas. Idea sketching in 3D, 2D or rough model can help customers understand the idea more easily.

The limitation of this thesis work is that this process may not suitable for a complicated product development process. The selected two ideas need more detailed design before they were put in prototype making.

This thesis work made some contributions to the product development process for future product development project. The mechanical design ideas will be used in FUSA summer school student group in the future, so the student group can keep developing new possible ideas and come out a working prototype.

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Idea screening methods and sub ideas catalogue.

Appendix 1: Idea screening table 1
Appendix 2: Idea screening table 2
Appendix 3: Sub ideas catalogue

(Idea screening tables and sub idea catalogue available as attachment in the hard copy version at HAMK Riihimäki library).