Military Institute of Science and Technology

IPE 308

Product Design II Sessional

Versatile Machining Tools

30/10/2019

Submitted to

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Acknowledgement

We would like to thank the Department of Industrial and Production Engineering (IPE), Military Institute of Science and Technology (MIST) for granting the opportunity to work on such a significant mechanical product of “Versatile Machining Tools”, as part of the course work of product design sessional (IPE 308).

Lot of efforts and hardworking was needed in designing and developing of the product. However, it would not have been possible without the kind support and help of many individuals. We would like to extend our sincere thanks to all of them. The help we get from our respected course teachers was enormous, without their guidance and constant supervision as well as necessary information we could not complete our product properly.

Authors

Summary

As part of our course, we were commended to design and develop an engineering product. From our selection list we have choose “Versatile Machining Tools” which was approved by our honorable teachers. This product was chosen because of its uniqueness, easy functionality and for being innovative.

The ‘Versatile Machining Tools’ is like a compact package of three tools drilling, grinding & sawing can be performed simultaneously or individually. This product will be very useful for rural and for urban areas also where electricity is not that much available. It designed and developed in a very smart way where operator can use it and find it very comfortable to use.

Initially, market analysis was done to identify the potential customer, customer needs and target market which were then organized into a hierarchical list. A house of quality was developed as a part of quality function deployment to identify how the needs can be satisfied considering technical features and competing products. By functional decomposition the main functions and sub functions, performed by the Versatile Machining Tools were recognized. SolidWorks 2019 software was used for designing all the parts of our product. The material and manufacturing process selection was first done qualitatively. Then weighted average method was employed for the quantitative analysis of materials and manufacturing processes to determine the best among the alternatives. It was followed by a stress analysis and cost analysis to deduce the break-even point and the profit margin respectively.

Chapter 1

Introduction

In industries different types of conventional heavy machines are used for machining. In domestic level we also need to do some of those machining operations like drilling, grinding, sawing etc. Industries use heavy drilling machines to drill metals, some use medium level drilling machines to drill wood. Some heavy machines are also used for grinding. Especially they are used for grinding metal cutting tools, polishing, smoothing & fine finishing surface, and some kind of sharping metal edge also. For Domestic use there are some portable small size grinding, drilling and sawing machines. Which are powered by electric motors and very costly. But these operations are done in a large scale in home and outdoors. People usually do make furniture of wood which are easy to build. And to make wooden furniture drilling and sawing tools are must. For these operations individual tools are used and some skills are needed to perform them accurately.

In carpentry shops drilling, sawing and grinding is done by manual hand driven tools which is less efficient than leg driven or motor driven tools. Pedal powered devices / machines have the mechanism which makes machines energy efficient. A person can generate four times more power by pedaling than by hand cranking. Pedal power enables a person to drive devices at the same rate as that achieved by hand cranking, but with far less effort and fatigue. Pedal power also lets one drive devices at a faster rate than before, or operates devices that require too much power for hand cranking.

Abstract

The Versatile Machining Tools will be a compact package of those three tools drilling, grinding & sawing. In this machine pedal gear mechanism will be used to give motion in it. It will produce rotary. The principle involved in sawing is the Rotary motion of pedaling operation will be converted to the reciprocatory motion of the shaft attachment. It will consist of a crank and slider mechanism. In the mechanism pedal is directly connected to the hacksaw through crank and slider mechanism for the process of cutting. In drilling Bevel Gear will be used to

transmit the motion at 90 degrees to the drill bit. Because Bevel gears are gears where the axes of the two shafts intersect and the tooth-bearing faces of the gears themselves are conically shaped. Bevel gears are most often mounted on shafts that are 90 degrees apart. Grinding wheel needs rotary motion to rotate. This rotary motion will be provided from the rotation of pedal by using chain and sprocket system. A sprocket or sprocket-wheel is a profiled wheel with teeth, or cogs that mesh with a chain, track or other perforated or indented material. The name 'sprocket' applies generally to any wheel upon which radial projections engage a chain passing over it. It is distinguished from a gear in that sprockets are never meshed together directly, and differs from a pulley in that sprockets have teeth and pulleys are smooth, which is very efficient without slip.

Conclusion

The Versatile Machining Tools will be powered by pedaling by leg. Or it may be powered by electric motor. Therefore, Versatile Machining Tools will be energy efficient, less costly and user-friendly with higher accuracy machining and cutting operations.

Chapter 2

Literature Review

Introduction

A **literature review** is both a summary and explanation of the complete and current state of knowledge on a limited topic as found in academic books and journal articles. There are two kinds of literature reviews you might write at university: one that students are asked to write as a stand-alone assignment in a course, often as part of their training in the research processes in their field, and the other that is written as part of an introduction to, or preparation for, a longer work, usually a thesis or research report. The focus and perspective of your review and the kind of hypothesis or thesis argument you make will be determined by what kind of review you are writing. One way to understand the differences between these two types is to read published literature reviews or the first chapters of theses and dissertations in your own subject area. Analyze the structure of their arguments and note the way they address the issues.

A **literature review** or **narrative review** is a type of review article. A literature review is a scholarly paper, which includes the current knowledge including substantive findings, as well as theoretical and methodological contributions to a particular topic. Literature reviews are secondary sources, and do not report new or original experimental work. Most often associated with academic-oriented literature, such reviews are found in academic journals, and are not to be confused with book reviews that may also appear in the same publication. Literature reviews are a basis for research in nearly every academic field.

Producing a literature review may also be part of graduate and post-graduate student work, including in the preparation of a thesis, dissertation, or a journal article. Literature reviews are also common in a research proposal or prospectus (the document that is approved before a student formally begins a dissertation or thesis).

Literature Review of Journal Paper

[1].Dharwa Chaithanya Kirthikumar, "A Research on Multi-Purpose Machine", International Journal for Technological Research in Engineering (Vol.1, Issue.1, ISSN: 2347-4718) (2013).

Human Powered Multi-Purpose Machine is a manually pedal operated system which can be used for drilling, grinding, sawing etc. Pedal power is the transfer of energy from a human source through the use of a foot pedal and crank system. Industries are basically meant for Production of useful goods and services at low production cost and low inventory cost. Today in this world every task has been made quicker and fast due to technology advancement but this advancement also demands huge investments and expenditure, every industry desire to make high productivity rate maintaining the quality and standard of the product at low average cost. We have developed a conceptual model of a machine which would be capable of performing different operation simultaneously, and it should be economically efficient. As Bangladesh is a developing country, electricity is irregular and sometimes nonexistent in some places. This machine can be used in those places as there is no use of electricity. It is designed as a portable one which can be used for cutting in various places. Anyone can use this machine for drilling, grinding etc. because it is very is to operate.

Energy is the most vital aspect in the development of modern technological civilization. In the present work, a human powered multipurpose machine is developed which can perform three types of operations drilling, sawing and grinding. Power required for pedaling is well below the capacity of an average healthy human being. So even women and children can contribute in machining operations. The system is also useful for the work out purpose because pedaling will act as a health exercise and also doing a useful work. Since machine uses no electric power and fuel, this is very cheap. So general people can easily afford this machine and do their machining operations.

[2]. Stephen, Tambari, Dan Orawari Gloria, Oruene W. Diabi, Ayejah Victor, "Technical Study on the Design and Construction of a Pedal Powered Hacksaw Cutting Machine" e-

ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 12, Issue 4 Ver. I (Jul. - Aug. 2015), PP 48-52

This project work deals with the design and fabrication of a pedal powered multitasking machine. The machine uses bicycle technology, with speed increasing gearing and a flywheel, which drive the process unit through a spiral jaw clutch and torque increasing gearing. The operator uses the pedal power to operate the machine and transmit this power through crank chain to free wheel to the working unit. In this developing world, small business sector established in rural areas are facing different problems such as power and economical crises due to which the productivity of several items is decreased. Power operated machines exist, but they are impractical in rural regions because the electric are expensive or unavailable. Hand operated machine are available but they required more time and required more effort than pedal operated machine. In this regard attempts have been made to develop or to enhance human powered equipment for plastic and wooden factories. The aim of this work is to design and construct a pedal driven hacksaw machine that will use a less effort pedaling power to produce uniform cutting of PVC pipes, metals, wood and as the same time serve as an exercising machine for fitness.

Industries are basically meant for Production of useful goods and services at low production cost, machinery cost and low inventory cost. Today in this world every task have been made quicker and fast due to technology advancement but this advancement also demands huge investments and expenditure, every industry desires to make high productivity rate maintaining the quality and standard of the product at low average cost in an industry a considerable portion of investment is being made for machinery installation. So in this paper we have proposed a machine which can perform operations like industrial applications as Cutting & Striking for PVC materials, steels, wooden blocks etc. & domestic application as grinding & Indoor cycling for exercise. This project presents the concept of Human Powered Multi-Purpose Machine carried out for industrial and domestic purpose. The objectives of this machine are to reduce the human effort, human time and carry out the number of operations simultaneously. It is economically efficient. This machine can be used in remote places where electricity is irregular or insufficient. It is designed as a portable one. The machine is operated without any external energy like fuel or electric supply. Since machine uses no electric power and fuel, this is very cheap.

[3] Saikat Dey, Dr Sajal Chandra Banik and Swapnil Das, "DESIGN AND FABRICATION OF MULTIPURPOSE MECHANICAL MACHINE", (ICMERE2017-PI-163)

Industries are basically meant for production of useful goods and services at low production cost, machinery cost and low inventory cost. Today in this world every task has been made quicker and fast due to technology advancement but this advancement also demands huge investments and expenditure, every industry desire to make high productivity rate maintaining the quality and standard of the product at low average cost in an industry a considerable portion of investment is being made for machinery installation. This project offers different metal cutting operations like sawing, grinding and drilling without using the electricity. Using bicycle technology with some gear arrangement, enough power can be transmitted to for cutting. Electric motor is just replaced by a bicycle pedal. In this machine, Scotch Yoke mechanism is used for sawing operation. Bevel gear gives drive to drilling center and grinding center. V belt and v belt pulley is used to transmit power from electric motor to the main shaft.

In a developing country like ours, people from village and remote areas are still far from modern technologies. They have resources but they can't use it for production because of technologies. The proposed machine is basically well suited for this type of area where electricity isn't so much or expensive and modern industries having some modern machining tools are absent. A machine driven by physical force will save not only power it will be also more efficient than doing anything bare hand or old traditional way. Because of a mechanism of a bicycle it will be also familiar to the people. Drilling, grinding, sawing is a regular use in the carpentry shops. Even in the cities, the local carpentry shops are away from modern technologies. This is a kind of tool which can be an introduction to them to be familiar with modern technologies.

[4]S.G.Bahaley, Dr. A.U.Awate, S.V. Saharkar, "Performance Analysis of Pedal Powered Multipurpose Machine", International Journal of Engineering Research and Development (IJERD) (Vol.1, Issue.5, e-ISSN: 2278-0181) (2012)

In these days, industries are trying to minimize the product cost and maximize the profit. For manufacturing industries, to be specific wooden Furniture industries, machining process is

must. In addition, electricity plays a vital for running the machines and it becomes very costly for small industries like carpentry shops. It is very necessary to develop machines, which will not be so costly like traditional or modern electricity consuming machines. Engineers are working on it.

There are some researches on manual machines, which are powered by pedal and are able to machine PVC, wood, steels. These machines are very useful in those type of industries, which mentioned above.

Pedal powered multipurpose machine is a human powered machine which is developed for lifting the water to a height 10 meter and generates 14 Volt, 4 amperes of electricity in most effective way. Power required for pedaling is well below the capacity of an average healthy human being. The system is also useful for the work out purpose because pedaling will act as a health exercise and also doing a useful work.

This multipurpose machine which does not require electricity for several operations like cutting, grinding etc. This is a human powered machine runs on chain drives mainly with human efforts. But it can be operated by electric power. It has some special attachment so use both human power as well as electric power. The design is and can be built using metal base, chain, pulley, rubber belt, grinding wheel, saw, bearing, foot pedal electric motor, chain socket. A Pedal Driven Wood Turning Lathe Machine can do turning and cutting operation on wood. The pedal driven setup has a simple mechanism operated with pedal and wheel arrangement. It operates on the principle of rotating work piece and a feeding cutting tool. It is different from normal lathe machine as the power given to run the machine is manual.

[5] Ashish Kumar Senapati,Sahu Samirkumar Satishkumar, Sanjeev Kumar Pal, Sibabrata Mhanty "Fabrication of Two-Way Pedal Powered Hacksaw Machine",International Journal of Innovative Science, Engineering and Technology (ISSN:2348-7968) (Volume 3, Issue 3, March 2016).

By successfully completion of the project to eliminate the shortcomings of the one-way acting hacksaw machine. The two-way acting pedal powered hacksaw machine will cut two work pieces at the same time reducing the amount of time taken by the earlier one. The design and

fabrication of a portable work, platform or machine by a bicycle was carried out meeting the required design standards. The versatile machining tool is operated by pedal of a bicycle by human power. Because of the ever-increasing energy crisis (based on a lots of study), have to switch to other option of energy generation, one of which is human power because of reasons such as unavailability of power, less skilled operator, unemployment, bicycle exercising related health issues. This type of project is working easily by human effort. The main objective is to provide a product with versatile way of machining when there is no electricity. It has to be understood that in rural areas, it is a very stressful and laborious task. So, the product which is a pedal driven machine, it satisfies the need of rural people by giving them versatile way of machining which is quick, cost effective and eco-friendly. The product designed has zero operating cost, cost-effective, and it can be used with minimal effort.

In the present scenario most of machines are electrically driven to increase the productivity and reduce the manpower but in the rural area electricity is irregular or insufficient. Therefore, human powered machine which can use in rural area and also in urban area to reduce the cost and to increase manpower utilization. Today in the industries production have been made very quicker and fast because of a new technology but this technology also demands a high investment. This human powered machine is cheap that's why it reduces a cost of production. Electrically driven machines are mostly heavy weighted because of this it cannot be used for a mobile use. This automation is also become a cause of a worker's weaker health. Pedal operated machine also increases human health by a pedaling process its work as an exercise. Mostly electrically driven machines are single purpose machines. That's why it increases a machine equipment cost. This multipurpose machine can be used for a more than one operation simultaneously on a same platform. But this machine is not fit for mass production. This machine is more time consuming as compared to electrical driven machine. This machine will be used in rural area, because of irregular electricity supply. This machine reduces worker health issue. It can also use for domestic purpose and different situation like, to drill hole in u\tube, wood and to grind mild steel, stainless steel etc.

Conclusion

After completion of literature review which summaries the important aspects of the existing body of literature. It also evaluates the current state of the literature reviewed and also identify significant flaws or gaps in existing knowledge. A narrow-scope literature review may be included as part of a peer-reviewed journal article presenting new research, serving to situate the current study within the body of the relevant literature and to provide context for the reader. In such a case, the review usually precedes the methodology and results sections of the work.

Chapter 3

Market Analysis

Introduction

This project work deals with the design and fabrication of a pedal powered multitasking machine. The machine uses bicycle technology, with speed increasing gearing and a flywheel, which drive the process unit through a spiral jaw clutch and torque increasing gearing. The operator uses the pedal power to operate the machine and transmit this power through crank chain to free wheel to the working unit. In this developing world, small business sector established in rural areas are facing different problems such as power and economic crises due to which the productivity of several items is decreased. Power operated machines exist, but they are impractical in rural regions because the electric is expensive or unavailable. Hand operated machine are available but they required more time and required more effort than pedal operated machine. In this regard attempts have been made to develop or to enhance human powered equipment for plastic and wooden factories. The aim of this work is to design and construct a pedal driven hacksaw machine that will use a less effort pedaling power to produce uniform cutting of PVC pipes, metals, wood and as the same time serve as an exercising machine for fitness.

Potential Consumers

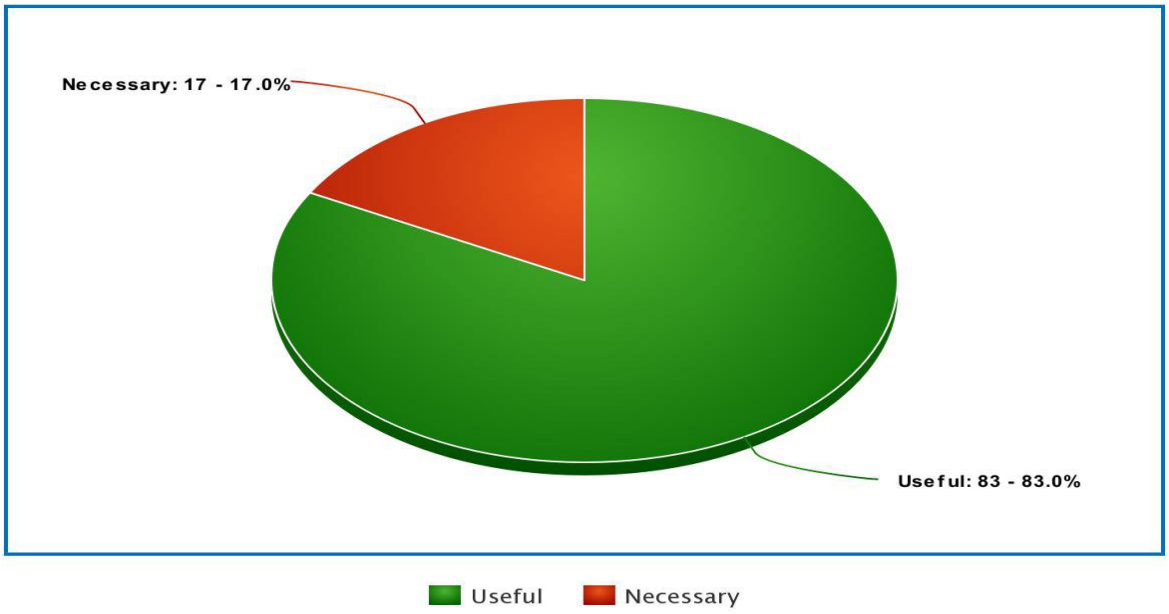
- Individual (domestic use)
- Workers of carpentry shop
- Businessmen

Locations of survey

- Carpentry shops (Outside Dhaka)
- Rural places
- Motor workshops

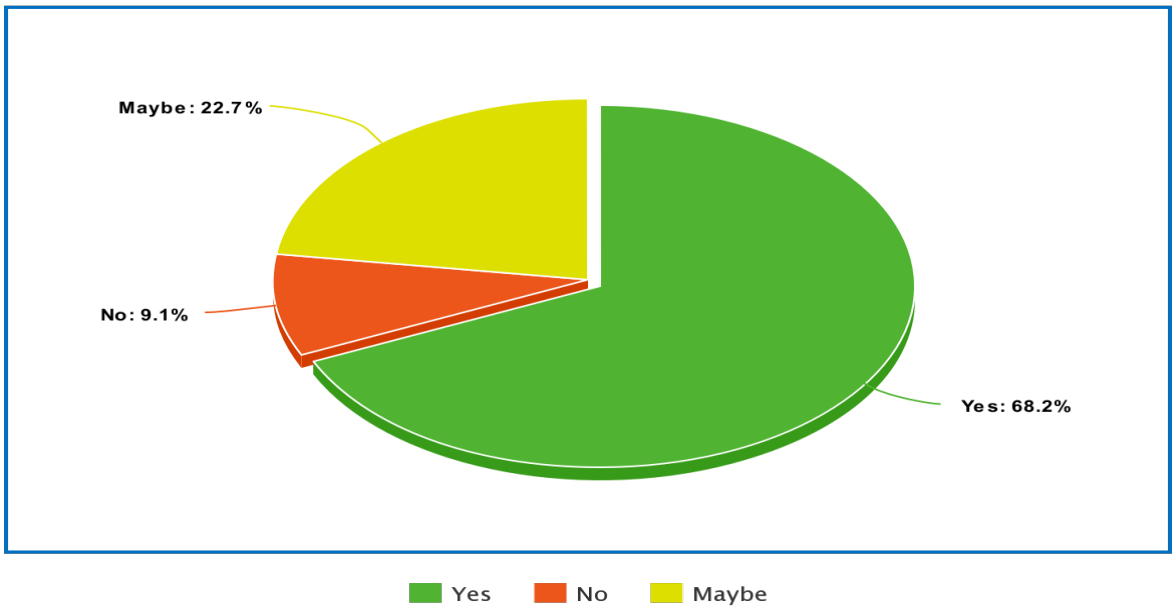
1. According to the description what do you think about our product?

- Useful
- Not useful
- Necessary
- Unnecessary



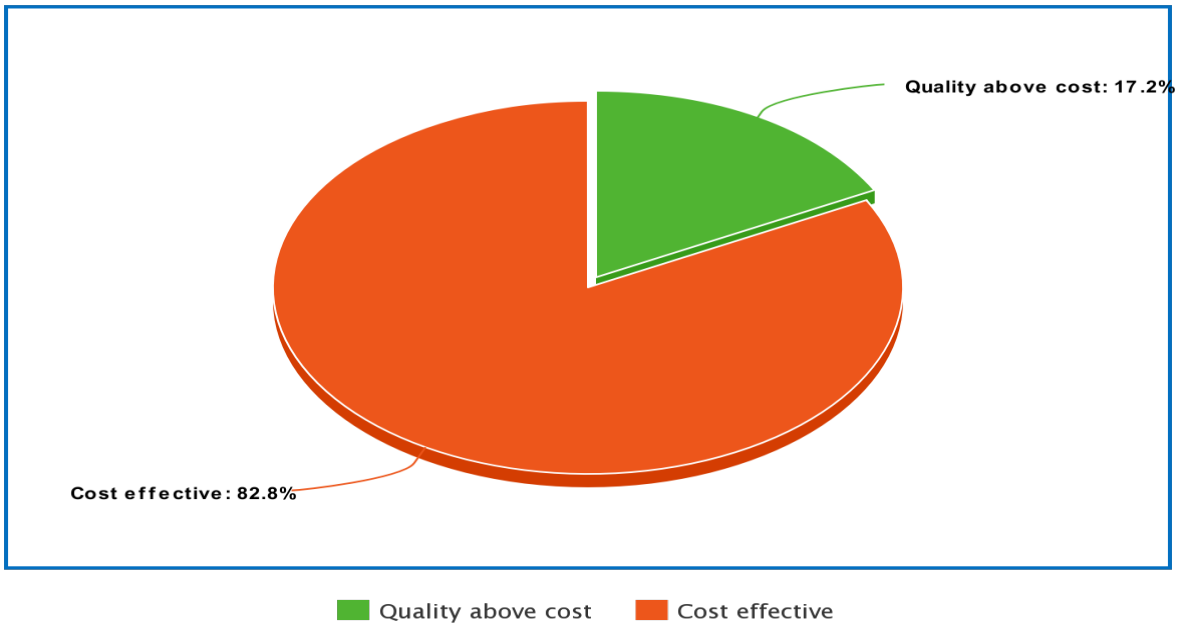
2. Do you think this product is useful both for both home and industrial purpose?

- Yes
- No
- Maybe



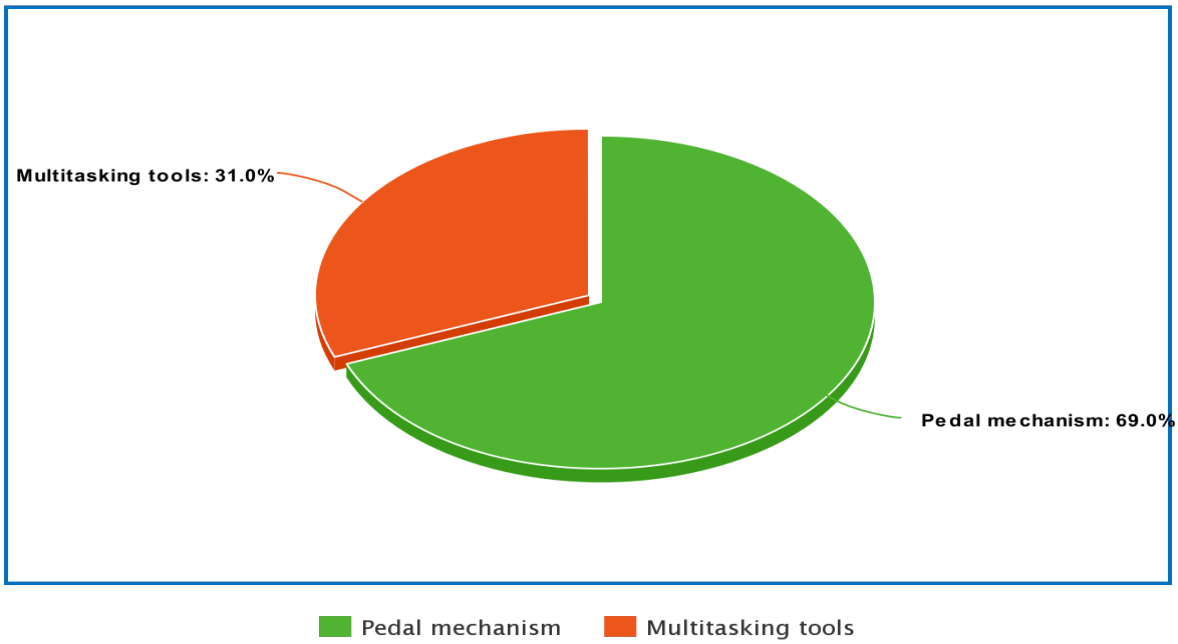
3. What do you prefer most in this product?

- Quality above cost
- Cost effective



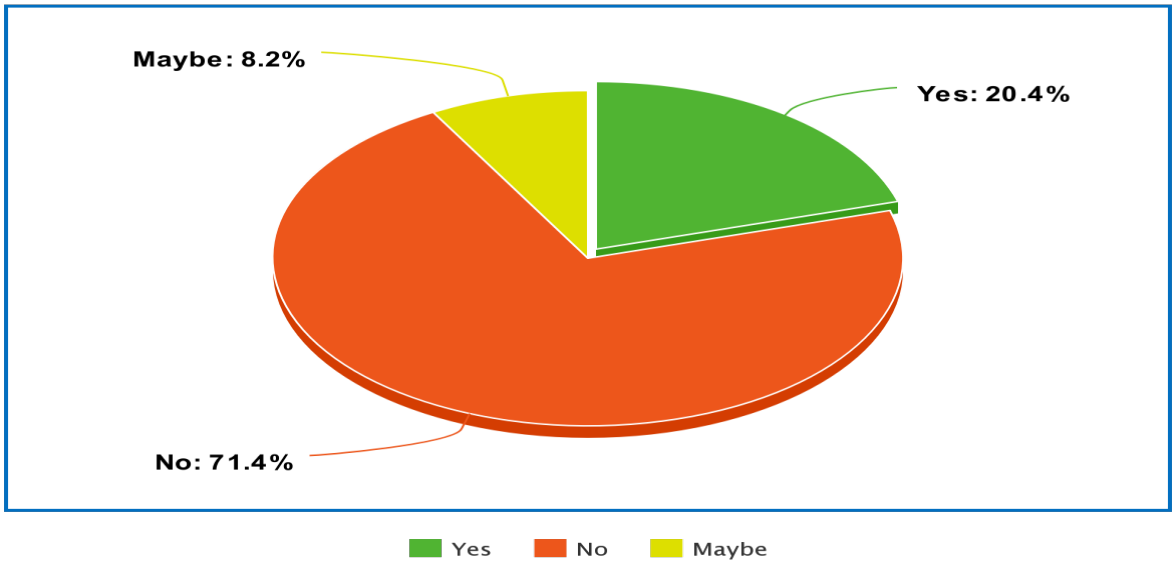
4. Which feature of our product attracts you the most?

- Pedal mechanism
- Multitasking tools



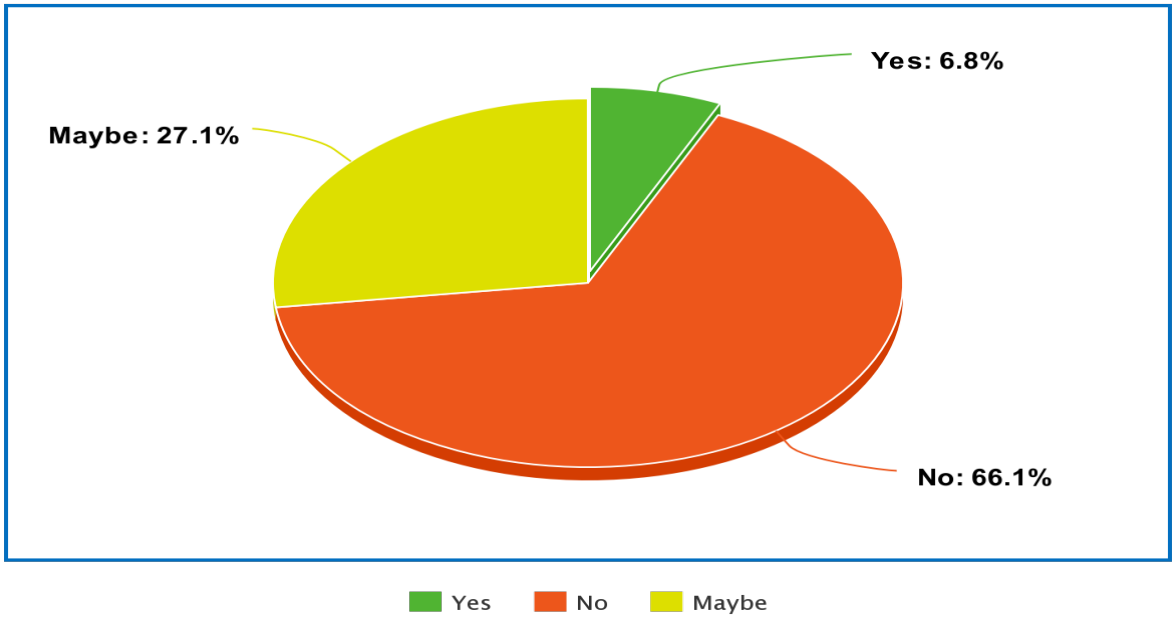
5. Do you feel any kind of pain or difficulties while operating?

- Yes
- No
- Maybe



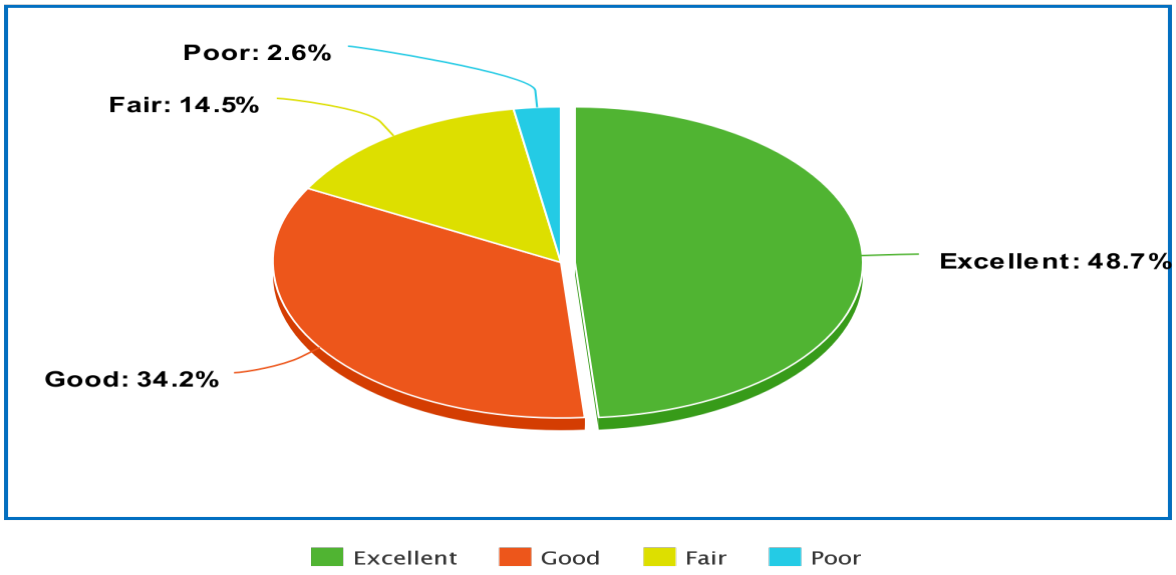
6. Do you feel uncomfortable while using fixed height sitting position or pedaling?

- Yes
- No
- Maybe



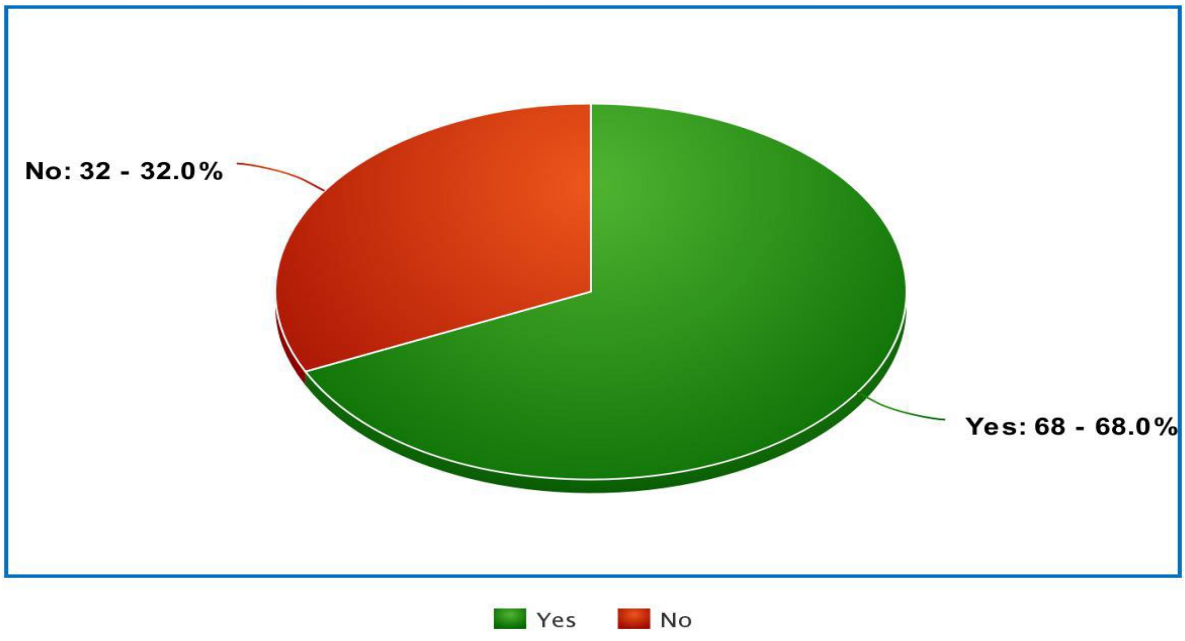
7. What do you think about the features (manual and pedaling) of the product?

- Excellent
- Good
- Fair
- Poor



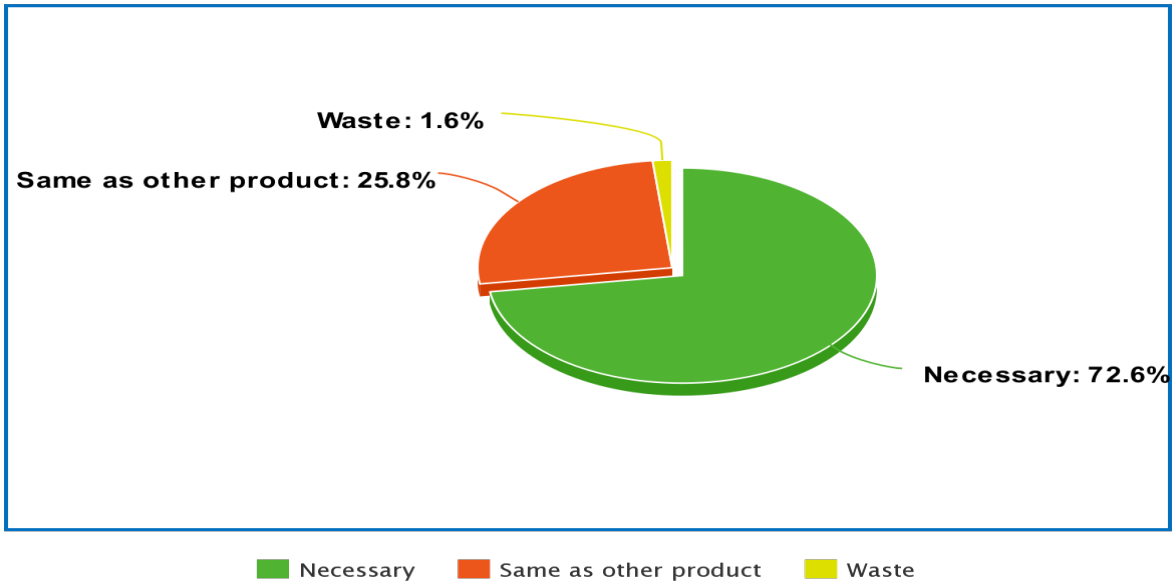
8. Do you believe this product will save your time and money (electricity bill) or energy savings?

- Yes
- No
- Maybe



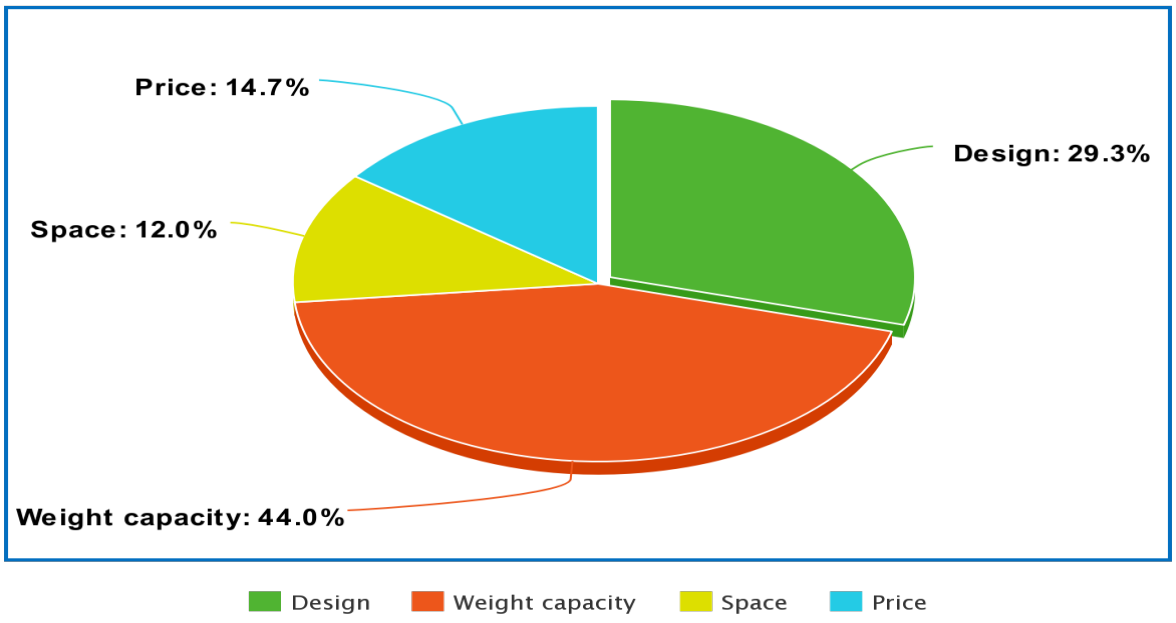
9. What do you think about the necessity of our product against the existing product in the market?

- Necessary
- Same as other product
- Waste



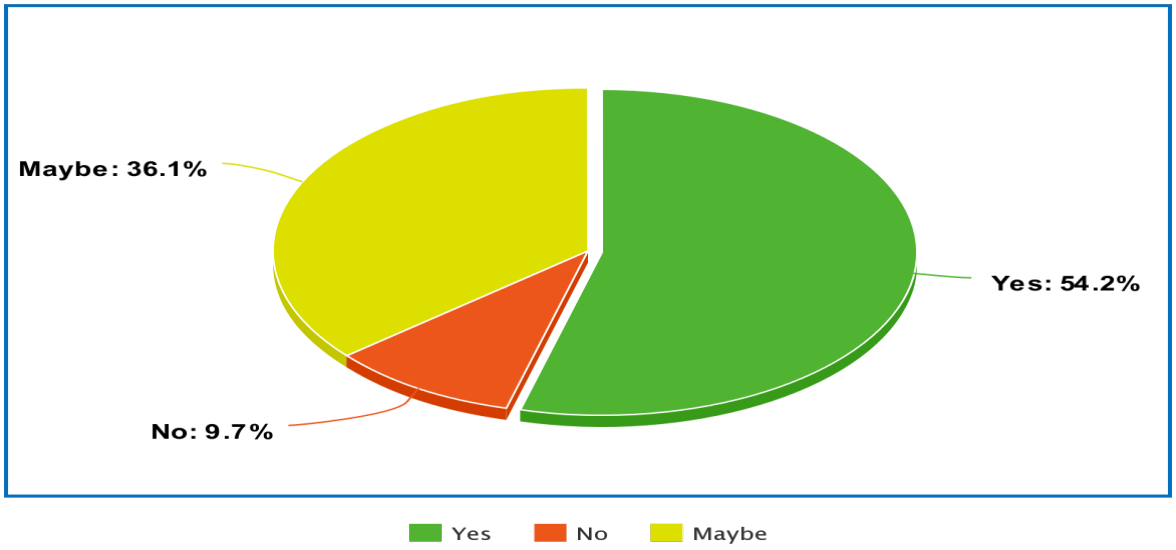
10. Which of the following attributes of our idea you want to change mostly?

- Design
- Weight capacity
- Space
- Price



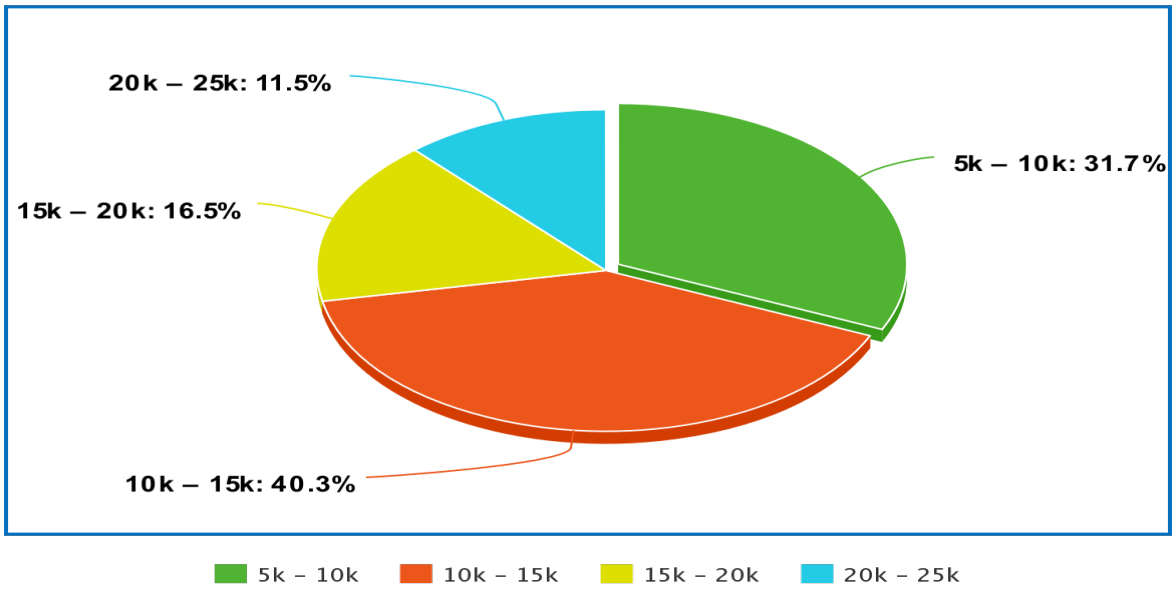
11. Do you think it will be helpful to your work and in rural places?

- Yes
- No
- Maybe



12. What do you expect about the price range?

- 5k – 10k
- 10k – 15k
- 15k – 20k
- 20k – 25k



13. What's your favorite aspect of the idea?

Comment…

14. If any feature needed to add in our product, what it should be? Feel free to explain.

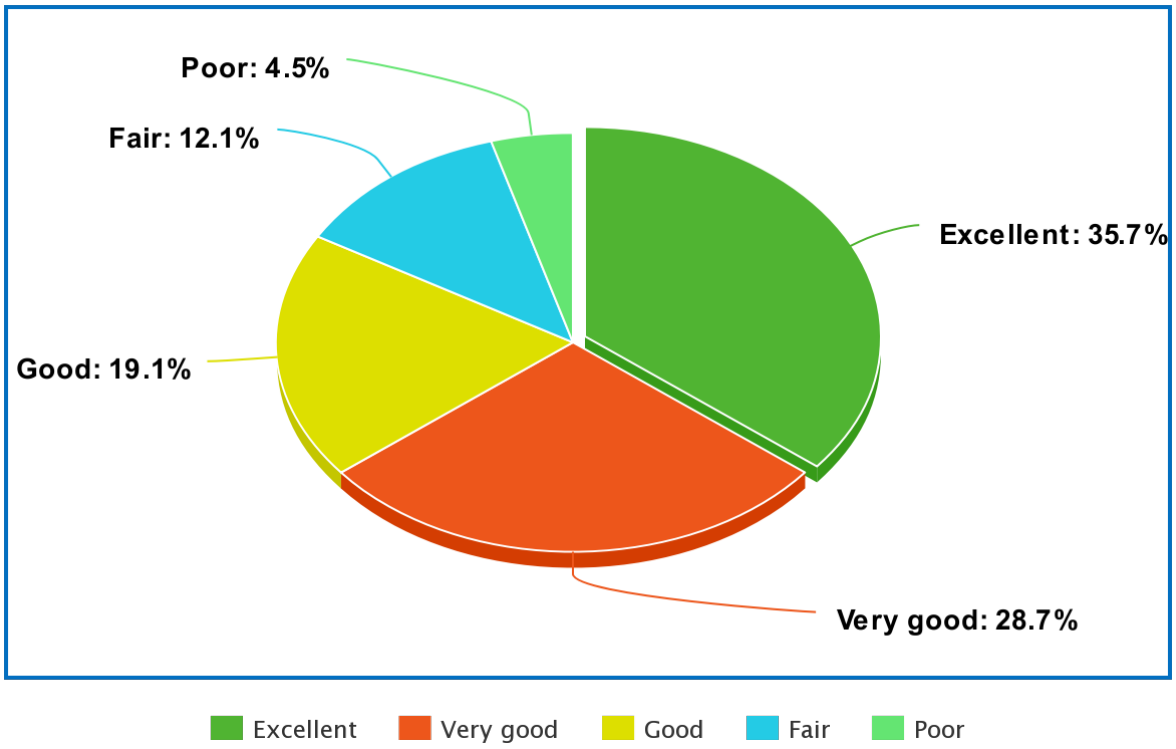
Comment…

15. If you don't like the idea of this product, please feel free to explain, why?

Comment…

16. How would you rate the idea overall?

- Excellent
- Very good
- Good
- Fair
- Poor



Customer's requirements

- Cost effective
- Multitasking tools
- Fasten the process
- Durability
- Pedal powered mechanism
- Drilling
- Grinding
- Sawing
- Removable tools

Conclusion

We can see that all the production-based industries wanted low production cost and high work rate, which is possible through the utilization of multi-function-operating machine. It requires less power as well as less time, since this machine provides working at different center it really reduced the time consumption up to appreciable limit. And from the survey result, our team is working to meet the customer's requirements.

Chapter 4

Quality Function Deployment (QFD)

Introduction

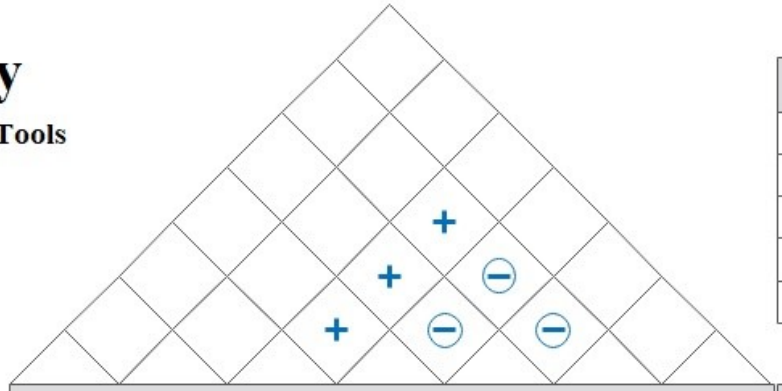
Quality must be designed into the product, not inspected into it. Quality can be defined as meeting customer needs and providing superior value. This focus on satisfying the customer's needs places an emphasis on techniques such as Quality Function Deployment to help understand those needs and plan a product to provide superior value.

Quality Function Deployment (QFD) is a structured approach to defining customer needs or requirements and translating them into specific plans to produce products to meet those needs. The "voice of the customer" is the term to describe these stated and unstated customer needs or requirements. The voice of the customer is captured in a variety of ways: direct discussion or interviews, surveys, focus groups, customer specifications, observation, warranty data, field reports, etc. This understanding of the customer needs is then summarized in a product planning matrix or "house of quality". These matrices are used to translate higher level "what's" or needs into lower level "how's" – product requirements or technical characteristics to satisfy these needs.

While the Quality Function Deployment matrices are a good communication tool at each step in the process, the matrices are the means and not the end. The real value is in the process of communicating and decision-making with QFD. QFD is oriented toward involving a team of people representing the various functional departments that have involvement in product development: Marketing, Design Engineering, Quality Assurance, Manufacturing/ Manufacturing Engineering, Test Engineering, Finance, Product Support, etc.

House of Quality

Product: Versatile Machining Tools



Relationship Matrix	
Sign	Relation
⊕	Strong Positive
+	Positive
−	Negetive
⊖	Strong Negetive

Relationship	
Sign	Relation
↑	Excellent(5)
□	Moderate(3)
↓	Poor(1)

			Technical Requirements							Comparative Assessment				
		Preference Rating(1-5)	Mild Steel Body	Pedal Powered	Gear Mechanism	Drilling	Grinding	Sawing	Removable Tools	Our Company	Company A	Company B	Future Target	Improvement Ratio
Customer Preferences	Moveable	2	□						↑	2	5	4	5	2.5
	Strength	3		□	↑					3	4	3	4	1.3
	Durability	3	□							4	4	3	5	1.2
	Multitasking	5				↑	↑	↑	□	4	3	3	4	1.0
	Power Consumability	5		↑	↑					5	3	4	5	1.0
	Efficiency	4		□	↑				↑	3	4	5	5	1.6
	Appearence	1		↓	□					2	5	3	5	2.5
	Reasonable Cost	4	↑	↑	□	□	□	□	↓	3	1	2	3	1.0
	Importance		35	68	75	37	37	37	49					
	% Importance		10.3%	20.1%	22.1%	10.9%	10.9%	10.9%	14.4%					

The active involvement of these departments can lead to balanced consideration of the requirements or "what's" at each stage of this translation process and provide a mechanism to communicate hidden knowledge – knowledge that is known by one individual or department but may not otherwise be communicated through the organization. The structure of this methodology helps development personnel understand essential requirements, internal capabilities, and constraints and design the product so that everything is in place to achieve the desired outcome – a satisfied customer. Quality Function Deployment helps development personnel maintain a correct focus on true requirements and minimizes misinterpreting customer needs. As a result, QFD is an effective communications and quality planning tool.

Relation Analysis

The house of quality, a part of QFD, is the basic design tool of quality function deployment. It identifies and classifies customer desires (What's), identifies the importance of those desires, identifies engineering characteristics which may be relevant to those desires (How's), correlates the two, allows for verification of those correlations, and then assigns objectives and priorities for the system requirements.

Here, the left most column indicates the customer preferences (What's) and the topmost row indicates engineering characteristics. In the top left corner, are some signs and what the signs indicates are given. These signs will create a correlation between the customer desires and engineering characteristics.

Above the table, here is a triangle which is known as the house. It creates relation between the technical descriptors. If the engineering characteristics are somehow related to each other and how strong that relation is the house indicates that.

The bottom most columns shows the importance of the features of the product. First, customer desires are rated with number from 1 to 5 according to their importance. Then, using the signs correlations are made. Then the importance number are multiplied by the number that the signs indicate and the total scores are used to calculate the importance.

The right side of the table shows the comparative analysis between our company and two other companies. Every customer desire is rated by the average value of the indicated sign numbers. And then every numbers are compared to other company ratings. If other company rating is higher, that becomes the future target of our company. And the improvement ratio is calculated from the data.

Here's how we can make a decision as the most important customer need and the most important feature of the product are known. Also, the feature which needs to be improved is known by analyzing the house of quality diagram.

Interrelation between the Technical Requirements

- The gear mechanism has strong relation to the drilling, grinding and sawing tools. Higher number of gears increase speed of the rotation of the conventional tool. So, the operation will be faster.
- The cutting tools are opposed to each other as only a tool can be active at a time. So, they have negative relation to each other.

Relation between the Customer Desires and Technical Requirements

Here, we analyze the customer needs and the feature that will help to fulfil those needs.

Movable

- Aluminum body of the machine give us a lighter structure than stainless steel. It is 2.5 time lighter than stainless steel. So, it's easier to move.
- Removable tools feature makes the machine easier to move. Because, if all the tools are attached at the same time it will be a problem for movement of this product.

Strength

- Pedal mechanism helps to create force more easily than people can do with bare hand, which increases the strength of the machine moderately.

- Gear mechanisms such as Bevel gear (drilling) and Scotch Yoke (sawing) mechanism increases the cutting force greatly.

Durability

- Aluminum's strength and durability is trusted in the most extreme transportation environments, where strength, safety and durability are critical. Aluminum is naturally corrosion resistant, which helps maintain a product's structure and increase lifespan.

Multitasking

- As the machine can do three different types of cutting operations (drilling, sawing, grinding), multitasking is the main feature of this product.
- Removable tools give us the advantage to work with any of these tools simultaneously. Otherwise, there will be a power loss.

Power Consume

- This is also the sector our product is rated higher than most other products in the market. Using the bicycle pedal mechanism powered by physical force we are greatly reducing the cost of electricity as well as getting the efficiency mush higher than working with bare hand.
- By adding a significant amount of gear, we can also reduce the physical power we need for the operations.

Efficiency

- Using bicycle pedal increasing the efficiency of the cutting operations than what is done with bare hand. But still, it's far more less than what we do in conventional lathe machine. So, pedal increasing the efficiency moderately.
- Using more gear will increase the spinning of the cutting tools. So, adding more gear will greatly increasing the efficiency.

- Removable tool feature is also saving the energy by removing the unused tool that would have been waste some energy generated. So, it's helping to increase the efficiency of the machine.

Appearance

- Adding pedal to a conventional cutting machine somehow looks a little unusual, which won't be so appealing.
- Different types of gear which will be visible, all working together will give it an appealing mechanical look.

Reasonable Cost

- Aluminum is more expensive than steel. So, using aluminum will increase the price moderately.
- As pedal and gear mechanism reducing the cost of electricity and this is also cheaper than electric motor, the price will be lower.
- The price of the drilling bit, conventional sawing tool, and grinding tool aren't much expensive. We can get the required cutting tools by the range of 1500-2000 taka.
- The removable tool feature may have some extra cost. So, the price will be higher for this feature.

Comparative Assessments

From the house of quality, we can see that the most important customer need is less power consumption and multitasking as they are rated higher and we can fulfil them by using the pedal and gear mechanism, which is also the main feature of our product.

By comparing the rating of the customer desires which our company can provide, we can know that which feature needs improvement. We can see we should reduce the price more and care should be given on the appearance of the product. So, this becomes our future target for improvement.

Conclusion

Quality Function Deployment is an extremely useful methodology to facilitate communication, planning, and decision-making within a product development team. It is not a paperwork exercise or additional documentation that must be completed in order to proceed to the next development milestone. It not only brings the new product closer to the intended target, but reduces development cycle time and cost in the process.

QFD is a method to translate customer needs and requirements into the quality characteristics in order to improve quality for an existing product to develop a new product that satisfy the customers. The house of quality interprets the voice of the customer into design requirements that meet specific target values and matches that against how an organization will meet those requirements.

After performing relation analysis in house of quality we can see that the customer doesnt concern about the appearance or the aesthetic. Because customer desire of appearance is rated 2 out of 5 which is lower in customer preference. That means the appearance or the aesthetic is less significant. But customers are more concern about power consumability. Because customer desire of power consumability is rated 5 out of 5 which is highest in customer preference. Thats why power consumability is most significant .

References

1. https://en.wikipedia.org/wiki/Quality_function_deployment
2. https://study.com/academy/lesson/quality-function-deployment-qfd-example-template.html
3. http://www.wikiwand.com/en/Quality_function_deployment
4. https://sixsigmastudyguide.com/house-of-quality-hoq/

Chapter 5

Specification and Design Analysis

Design Analysis

Product design analysis refers to planning out the detailed specifications of the parts of a product so that the whole product can function efficiently and effectively in a desired manner.

Design analysis can also be beneficial in optimization or failure analysis contexts and is useful to understanding where a design may be improperly functioning. It can allow for direct optimization of design feature based on surface response model analysis. It can provide structural and dynamic analysis of mechanical components and assemblies.

Product analysis techniques

- **Product breakdown:** Divide the product into components and subcomponents.
- **Systems engineering:** Ensure that the product satisfies customer needs, cost requirements, and quality demands.
- **Value engineering:** Consider alternative designs and construction techniques to reduce cost or increase profit.
- **Value analysis:** Assets the cost or quality ratio to ensure that the product is cost effective.
- **Function analysis:** Ensure that the product has features appropriate to customer requirements.

Design analysis of different parts of 'Versatile Machining Tools'

This product has some basic parts. Body frame, machining tools like drill bit, grinding wheel and saw cutter, gear and chain mechanism, connecting rods, pedaling components, handle, brake and also some fitting elements.

Body frame: It is the frame of the total assembly that holds the other components.

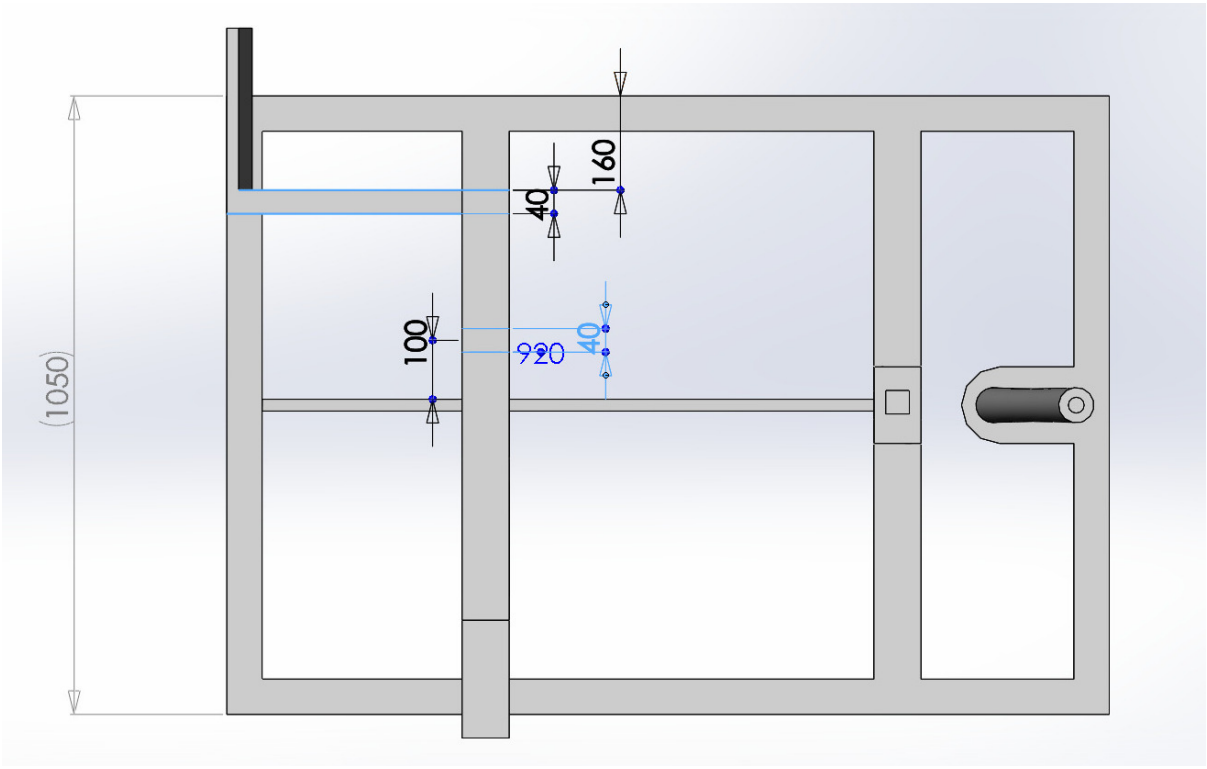


Fig 5.1: Body frame top view

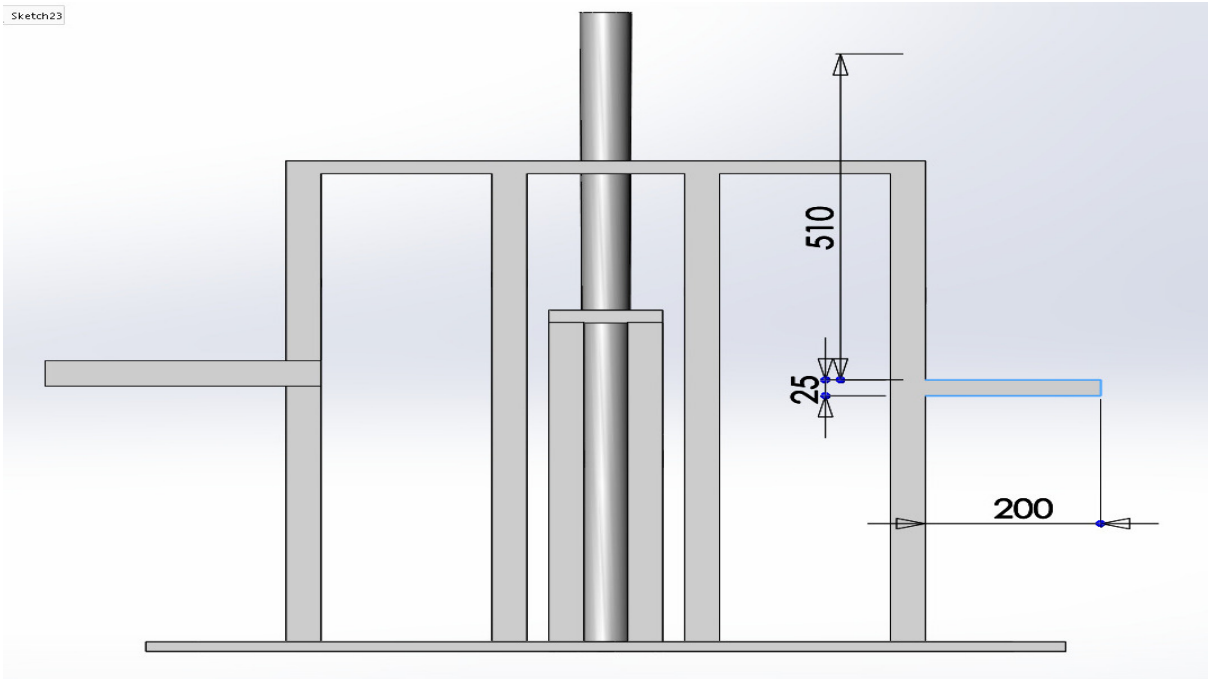


Fig 5.2: Body frame right hand side view

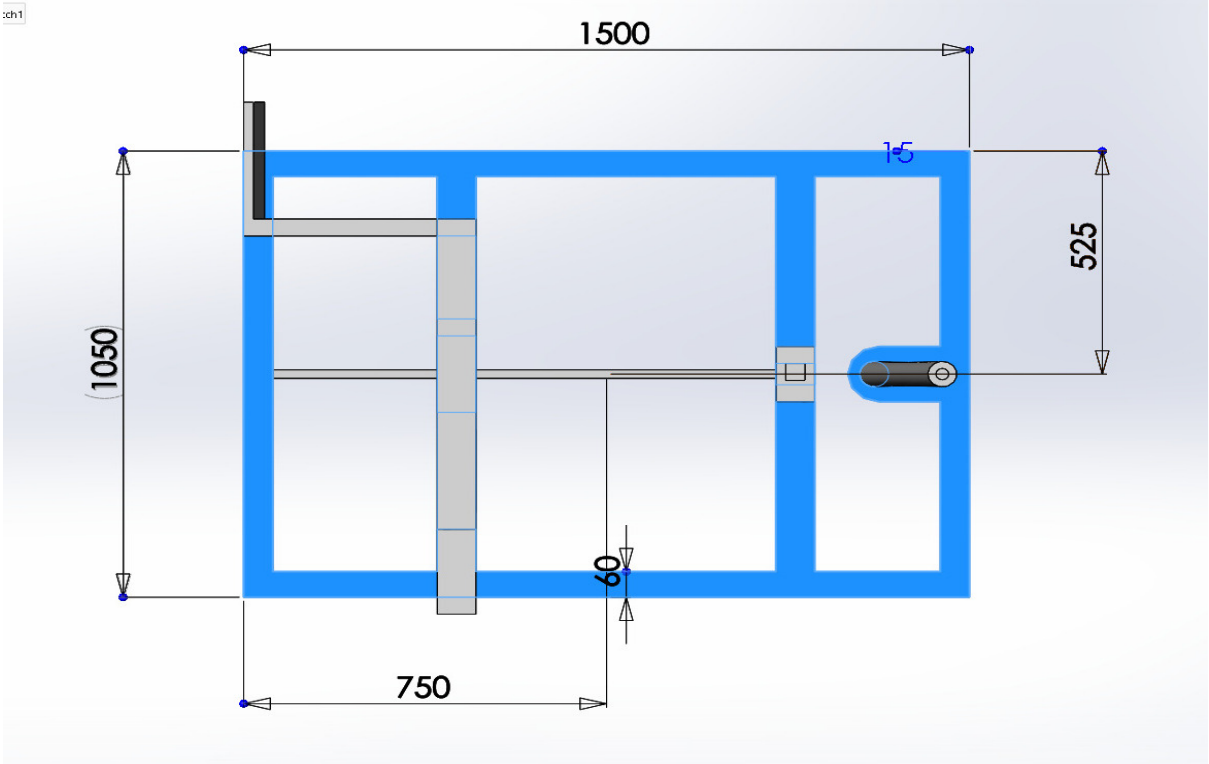


Fig 5.3: Body frame top view

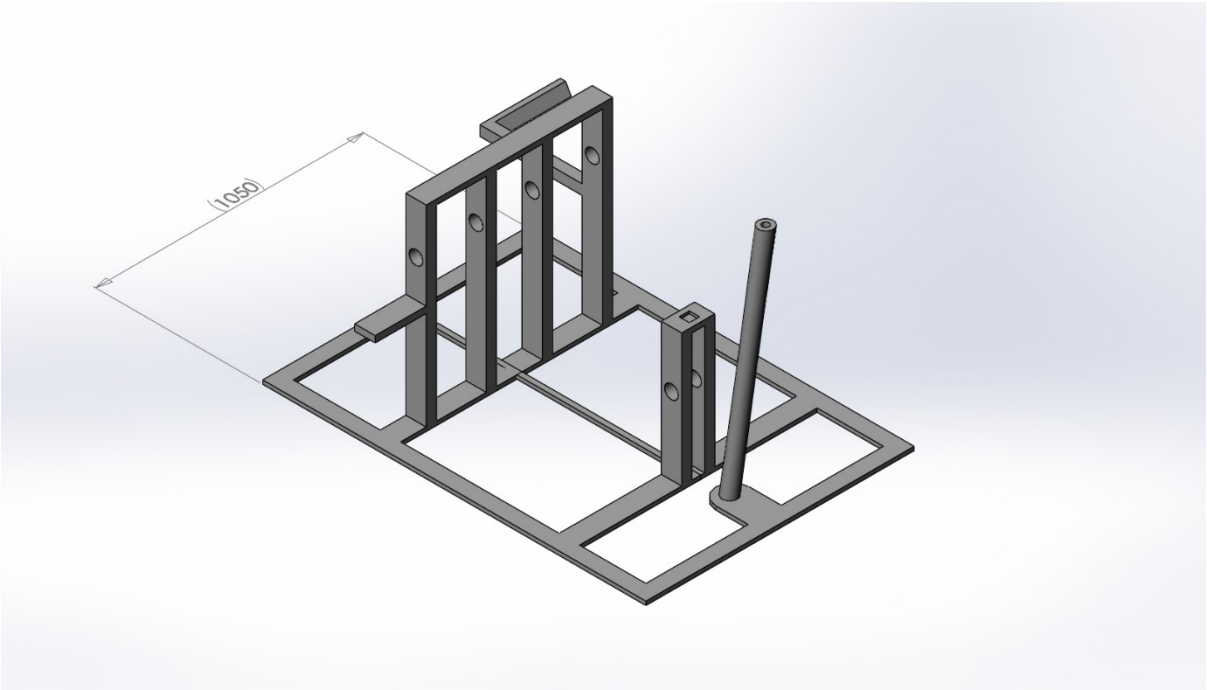


Fig 5.4: Body frame structure

Machining Tools: These are attached to the main frame through the chain and gear mechanism to operate drilling, cutting and sawing operation.

Drill bit:

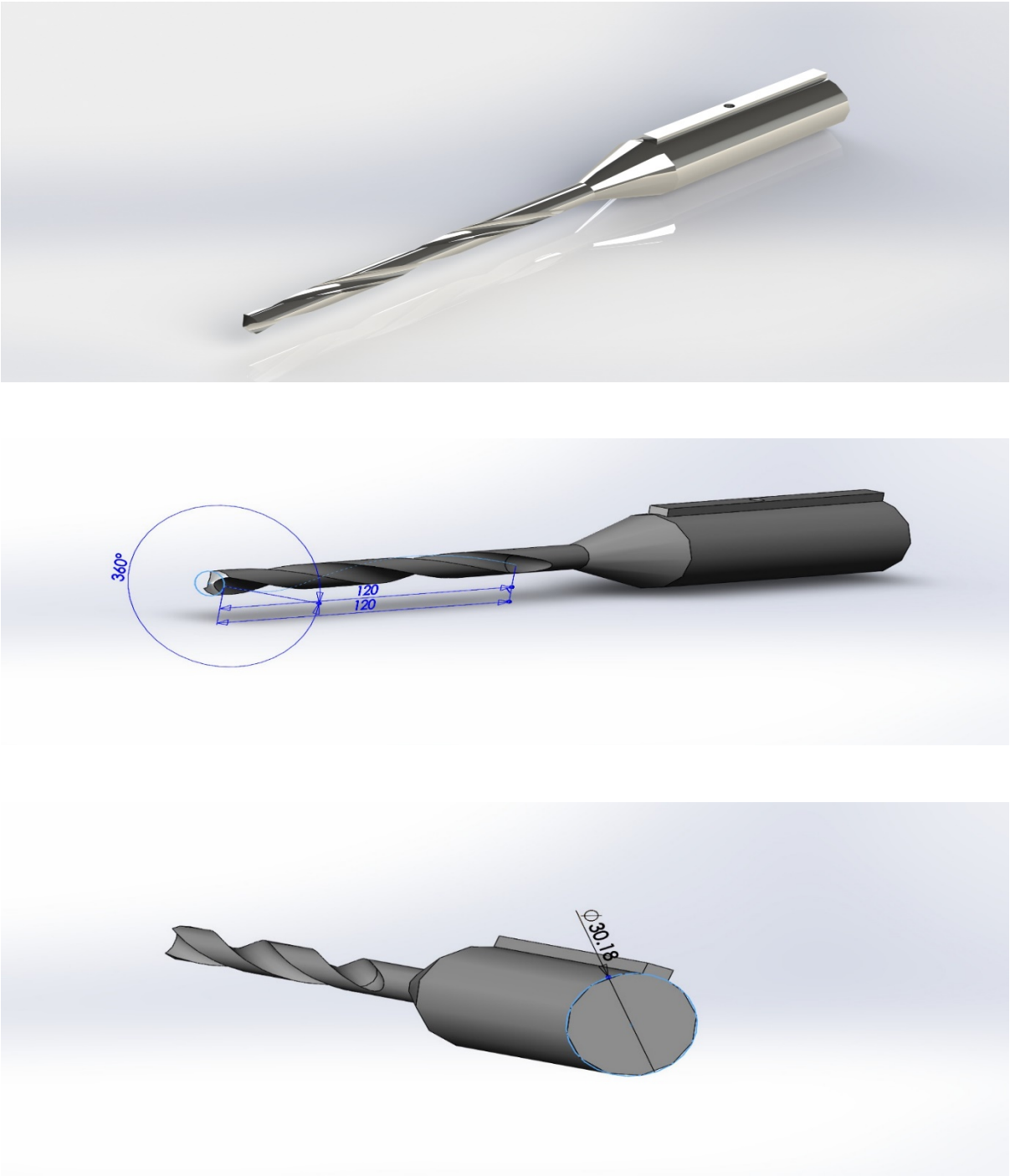


Fig 5.6: Drill bit

Saw:

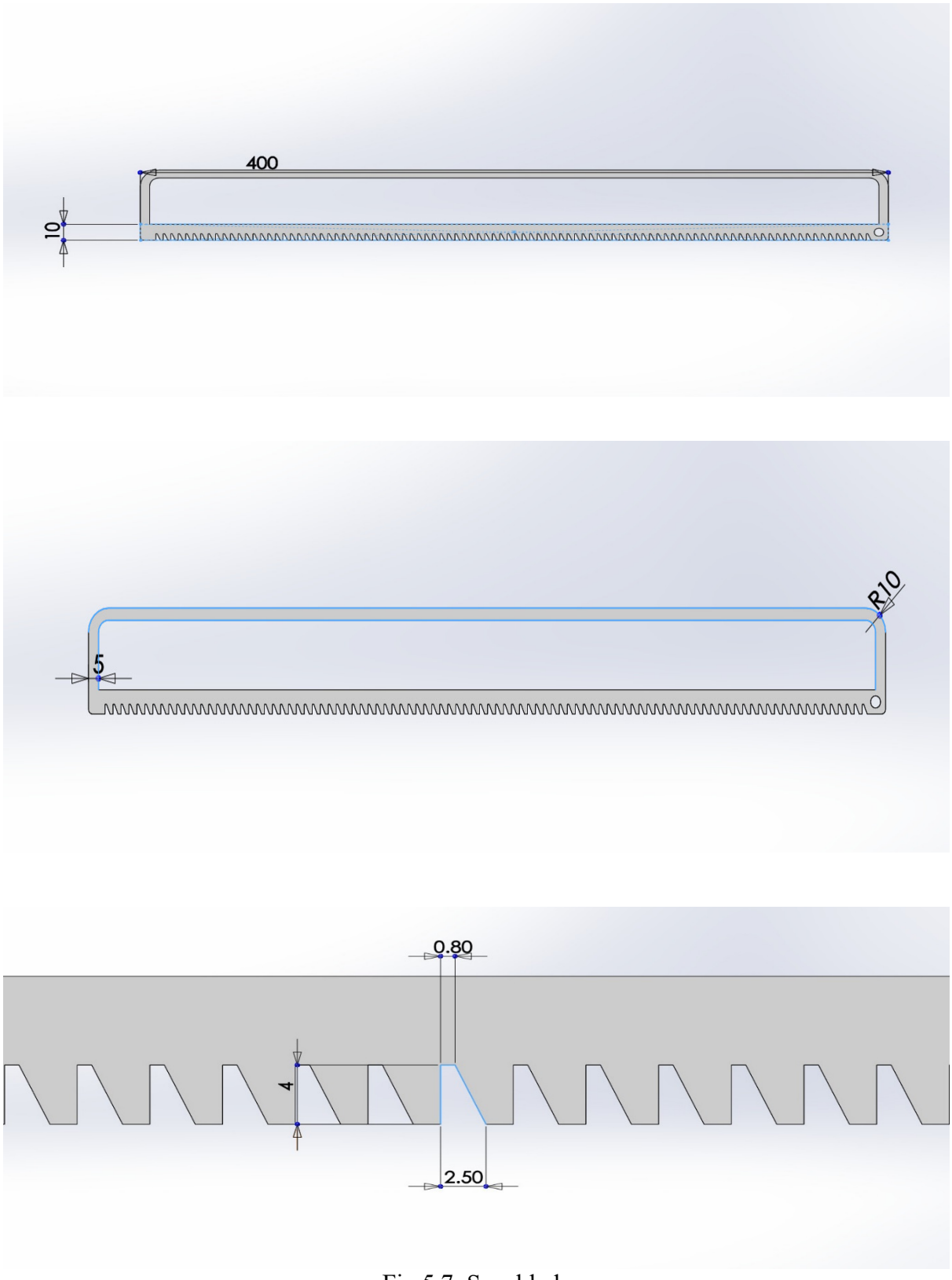


Fig 5.7: Saw blade

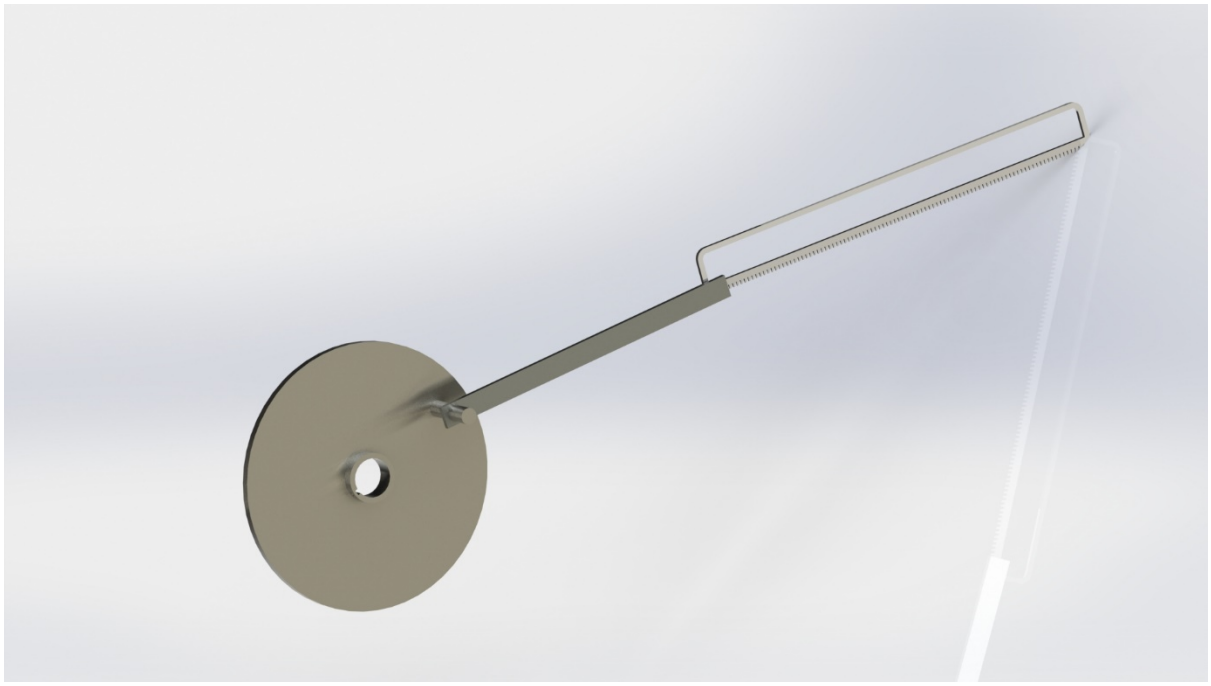


Fig 5.8: Saw and Pulley Assembly

Sprocket & Chain:

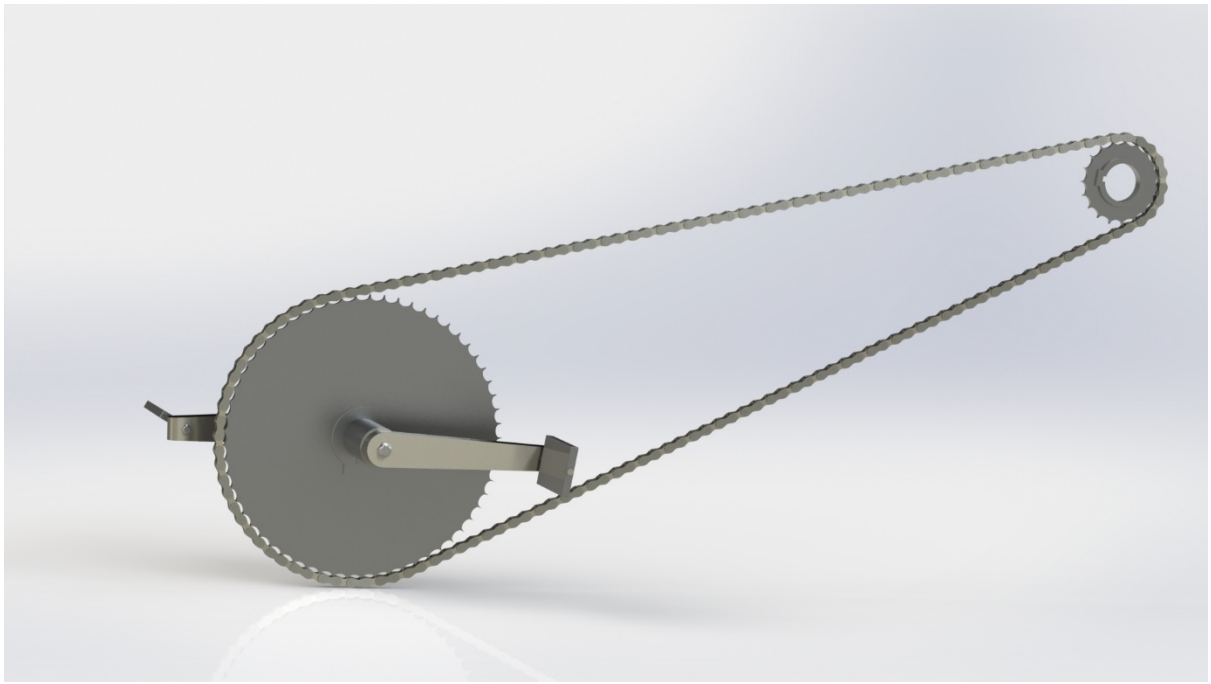


Fig 5.9: Sprocket & Chain Assembly

Grinding Wheel:

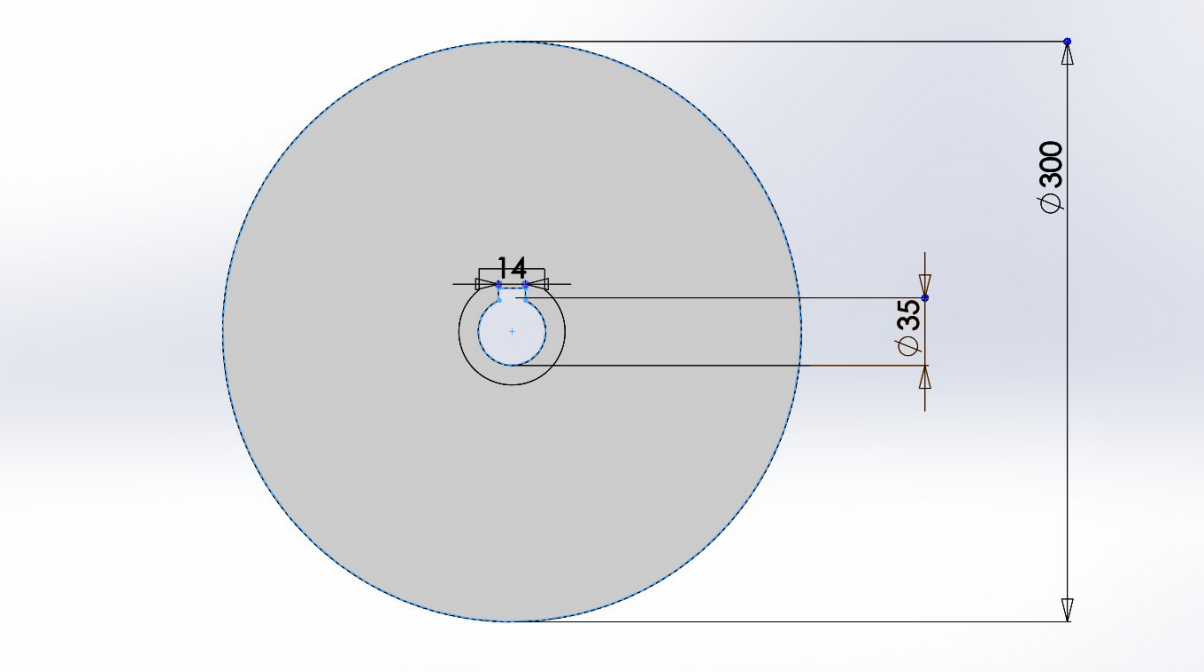


Fig5.10: Grinding wheel

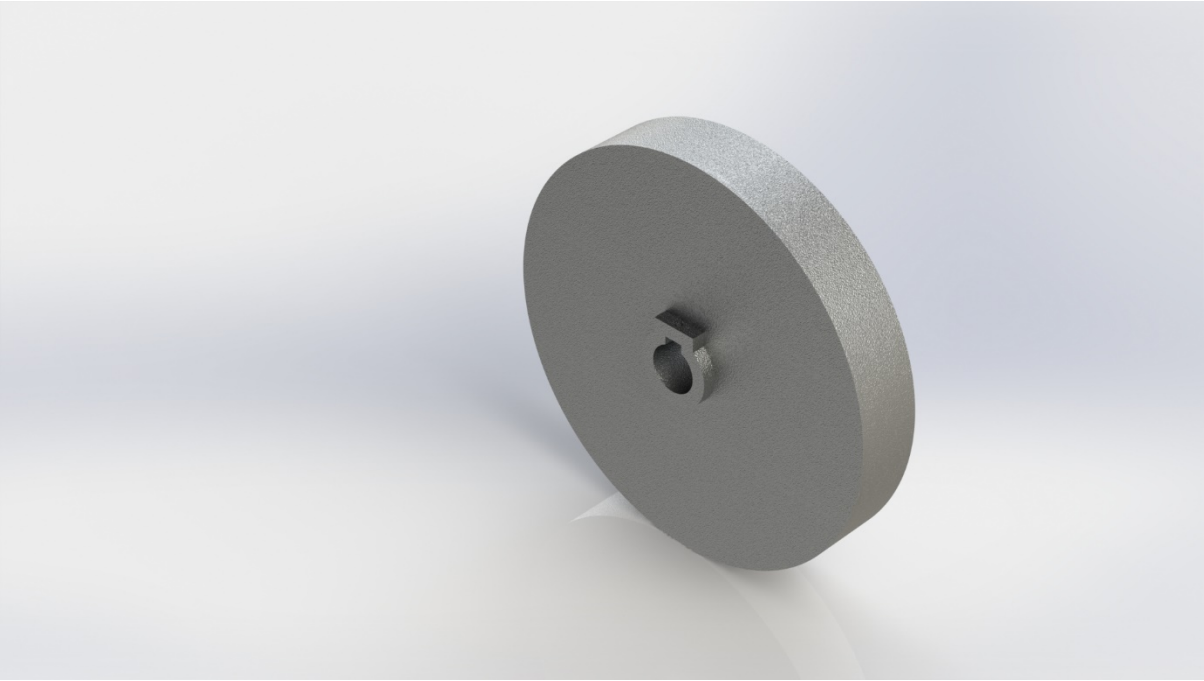


Fig 5.11: Grinding wheel 3D

Fittings and Connectors:

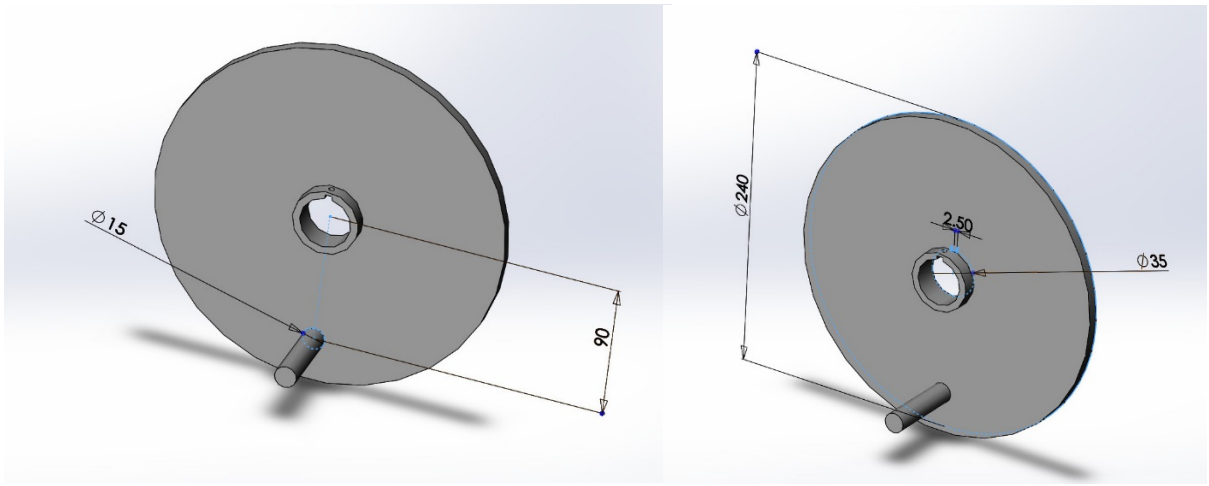


Fig 5.12: Cutting Saw pulley

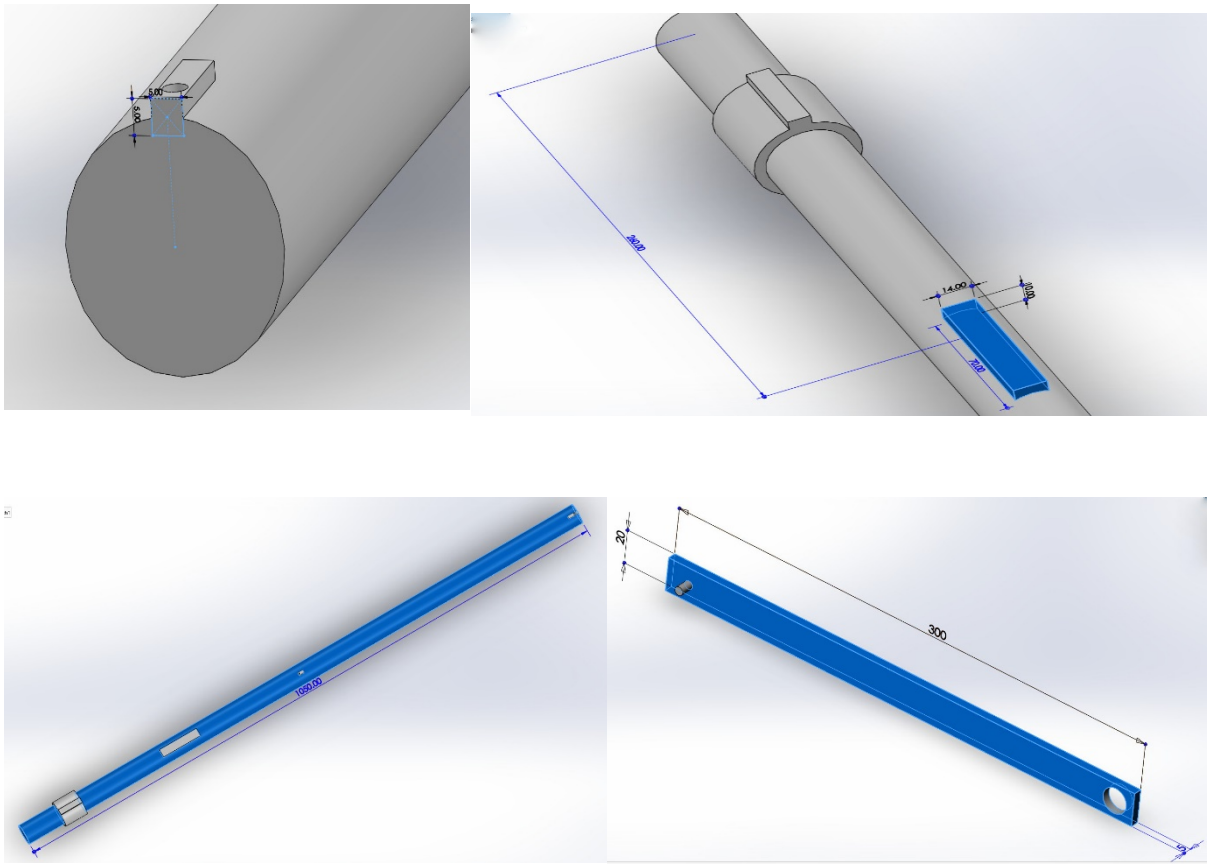


Fig 5.13: Connecting rods

Pedaling Components:

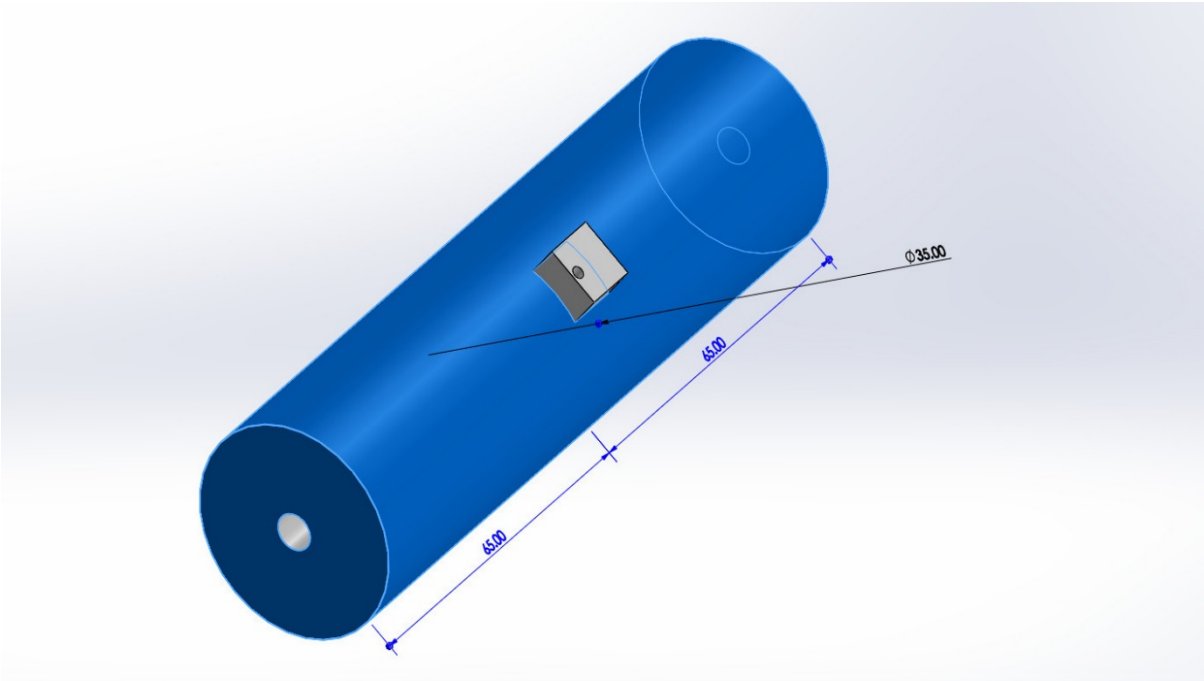


Fig 5.14: Pedal connector

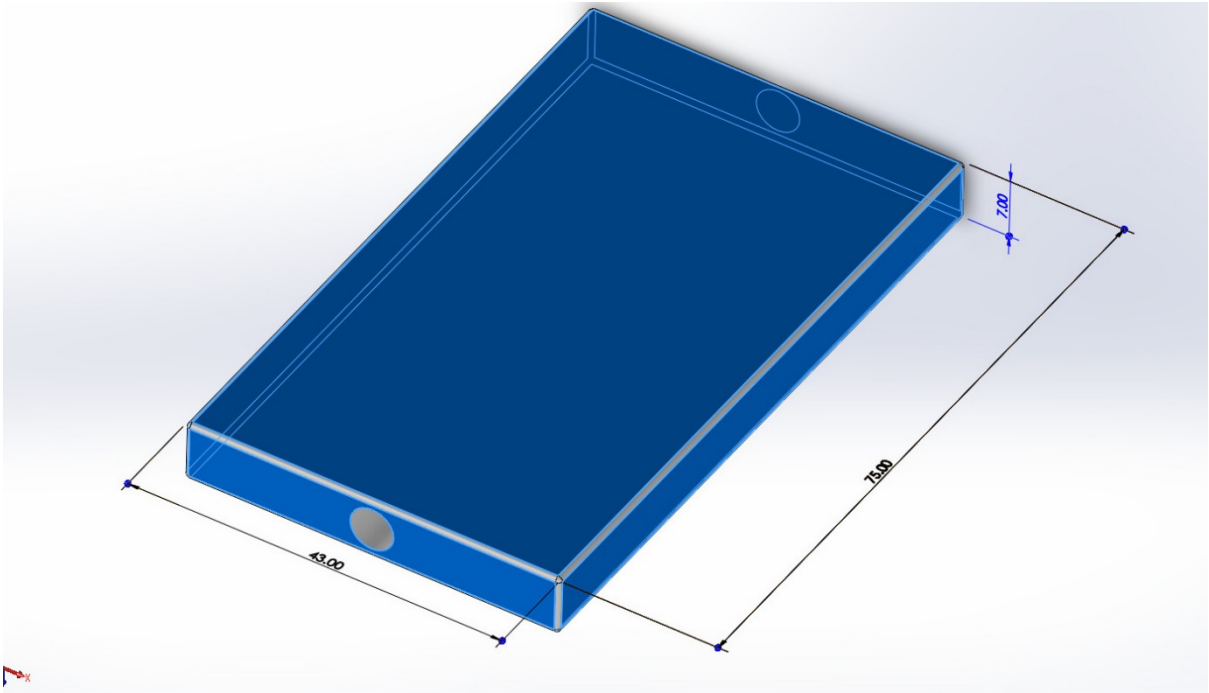


Fig 5.15: Pedal feet part

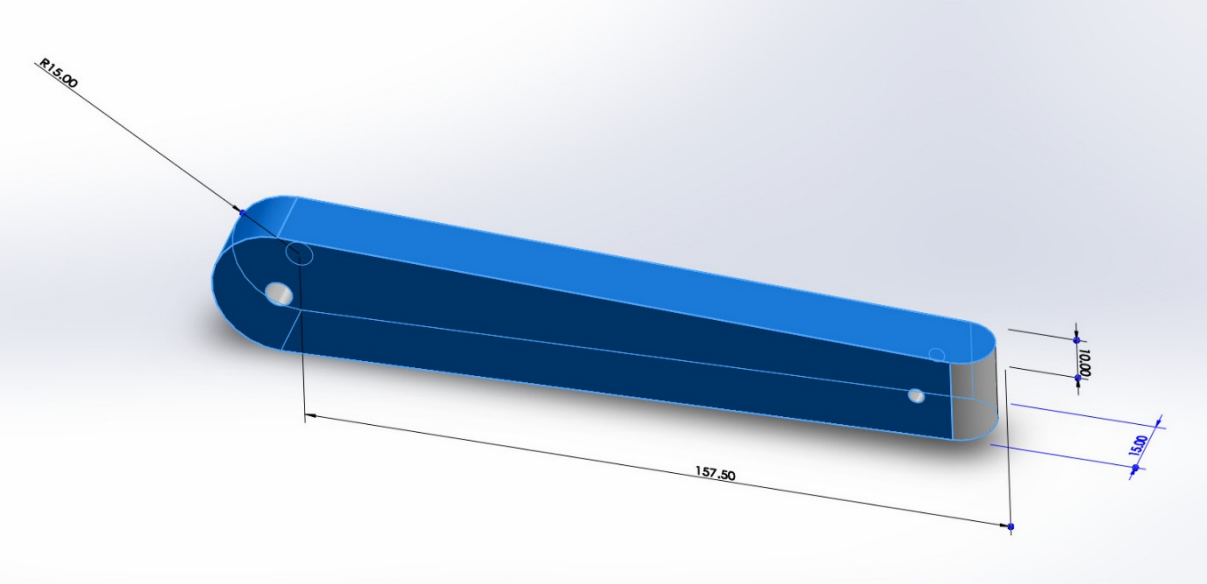


Fig 5.16: Pedal connecting rod

Sprockets:

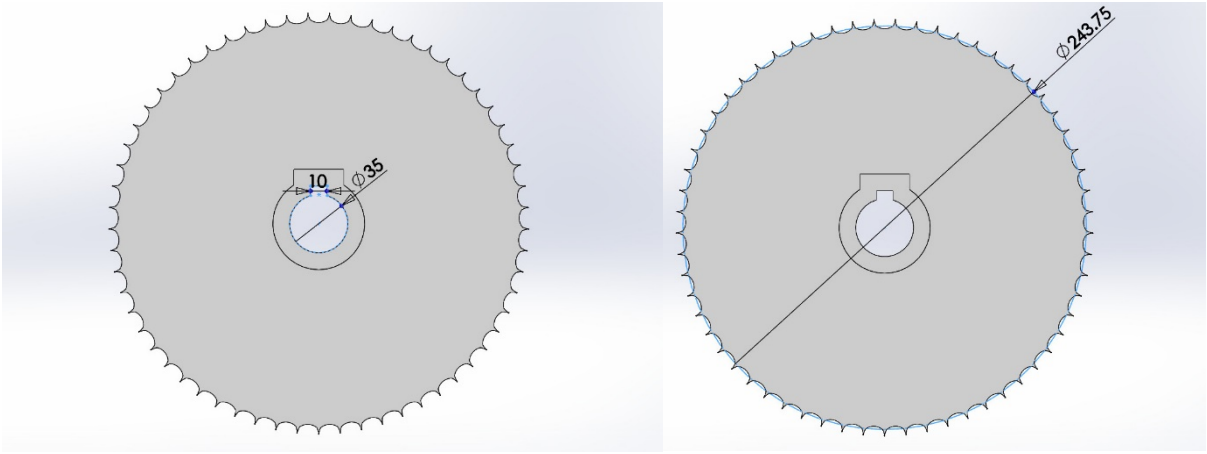


Fig 5.17: Big sprockets (teeth = 61)

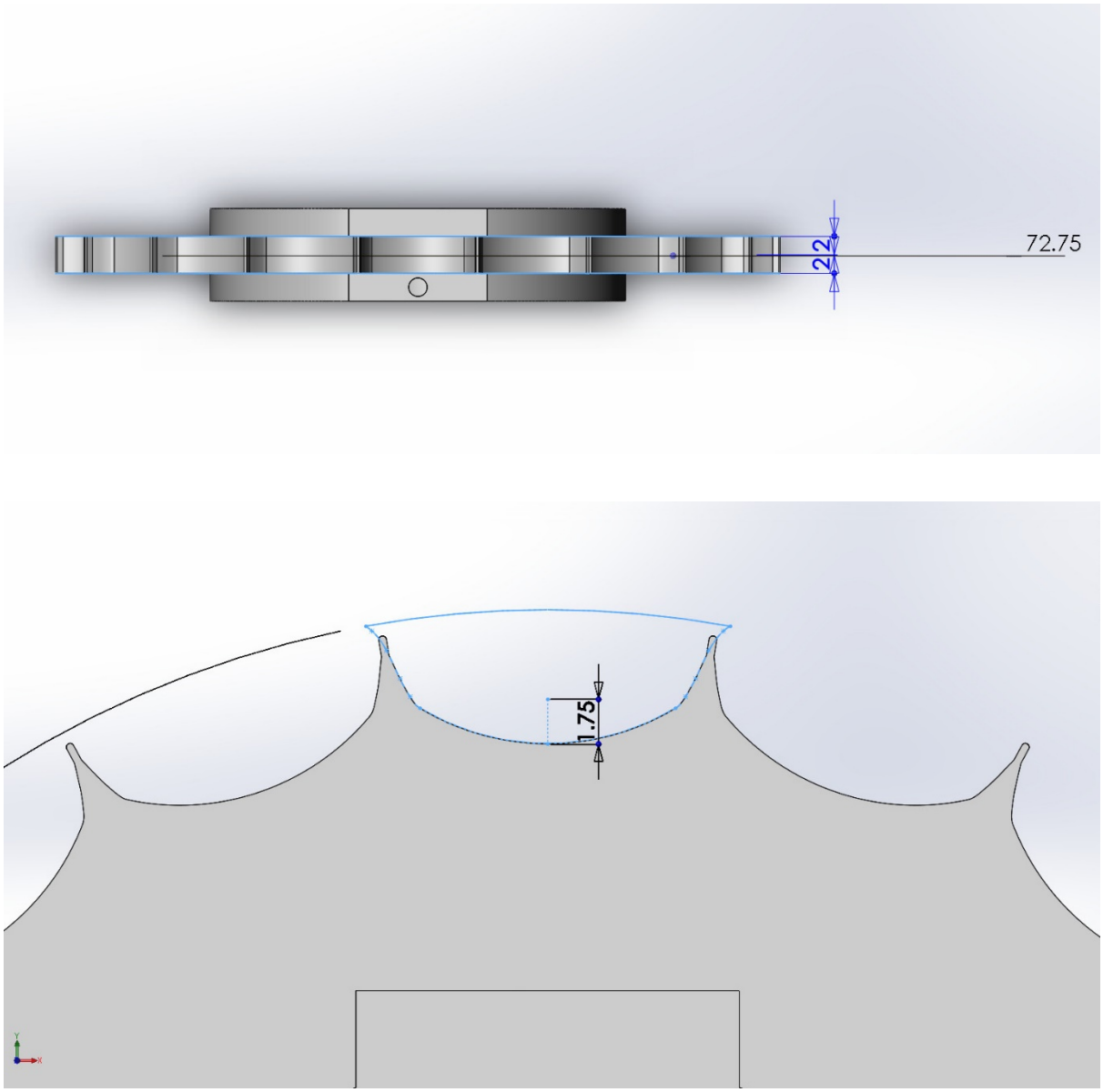
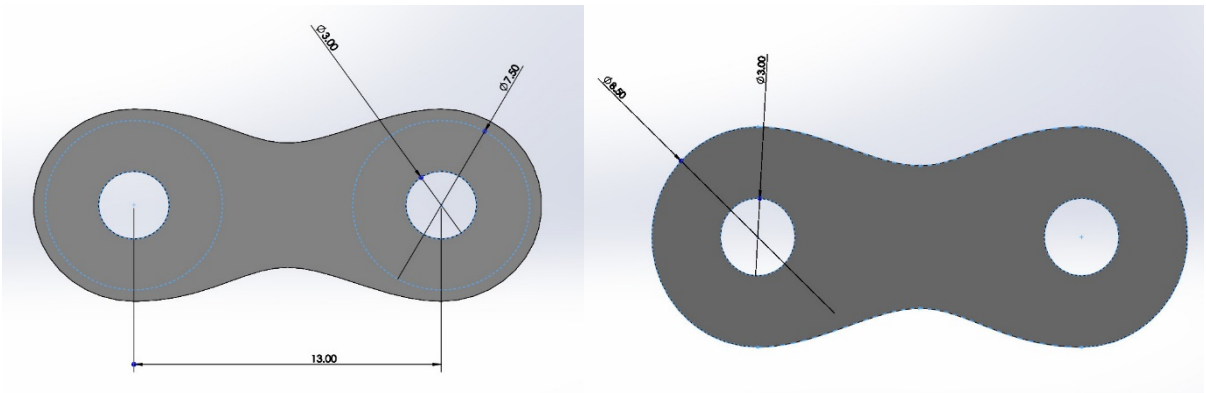
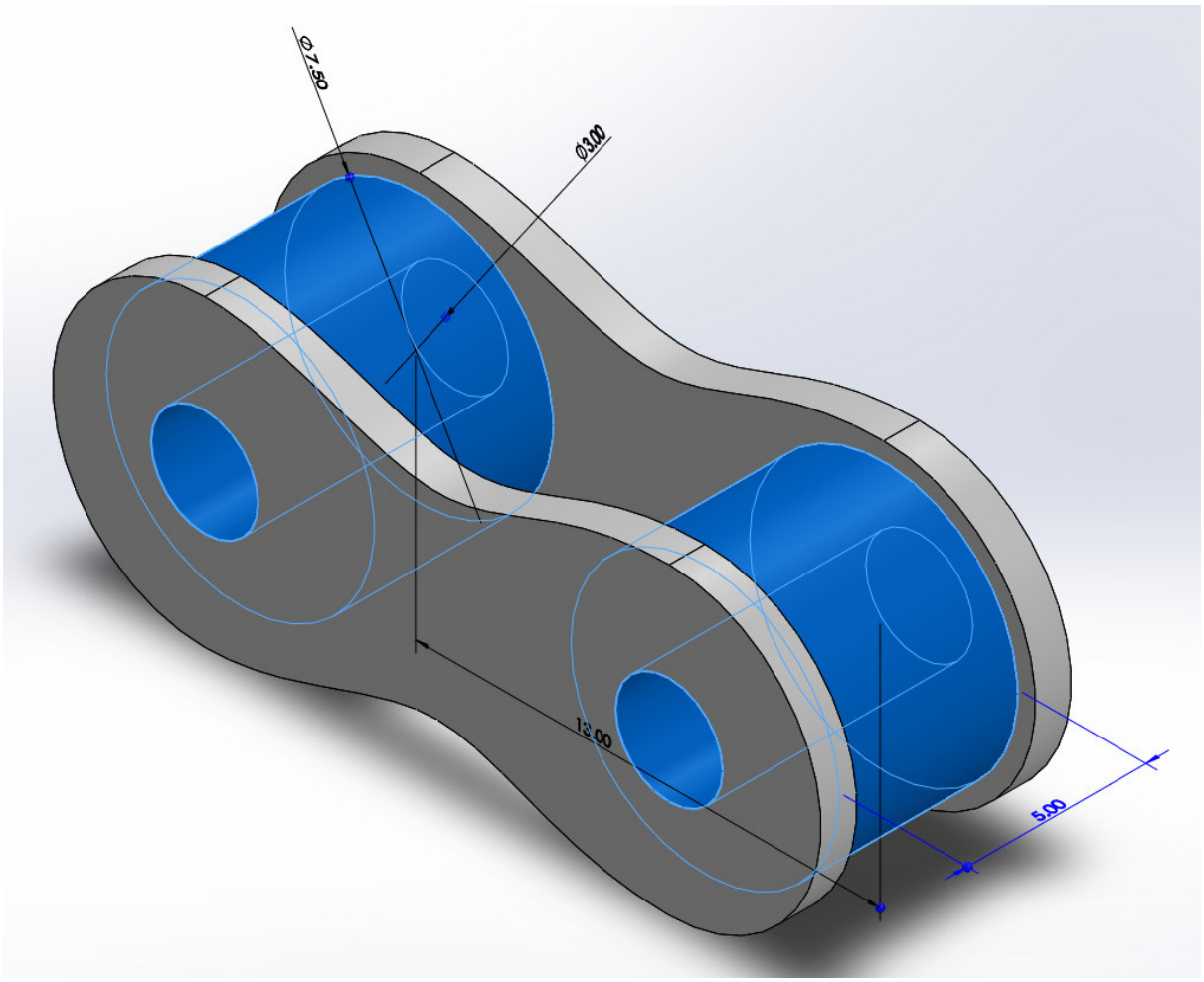


Fig 5.18: Small sprockets (teeth = 19)

Chain: Total chain link = 78





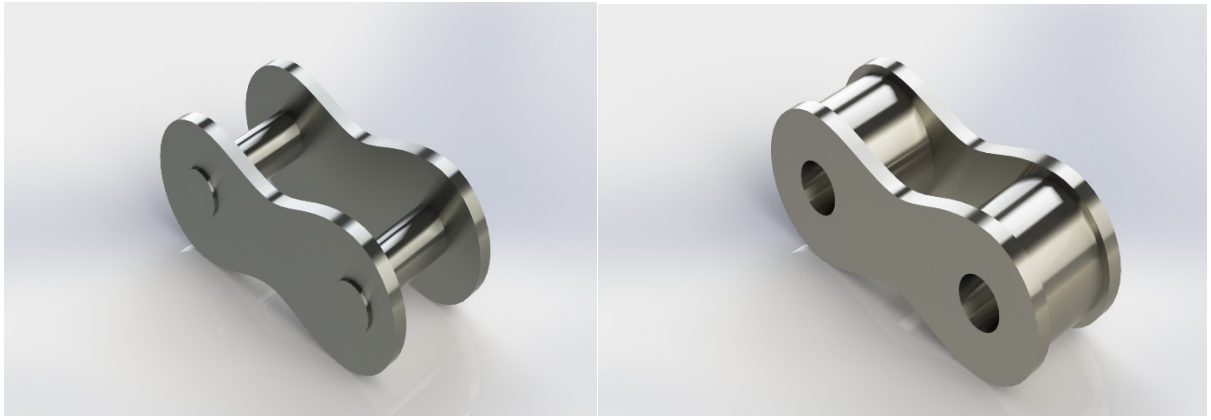


Fig 5.19: Outer and Inner chain

Gears: Bevel pinion teeth = 19; Straight bevel teeth = 49

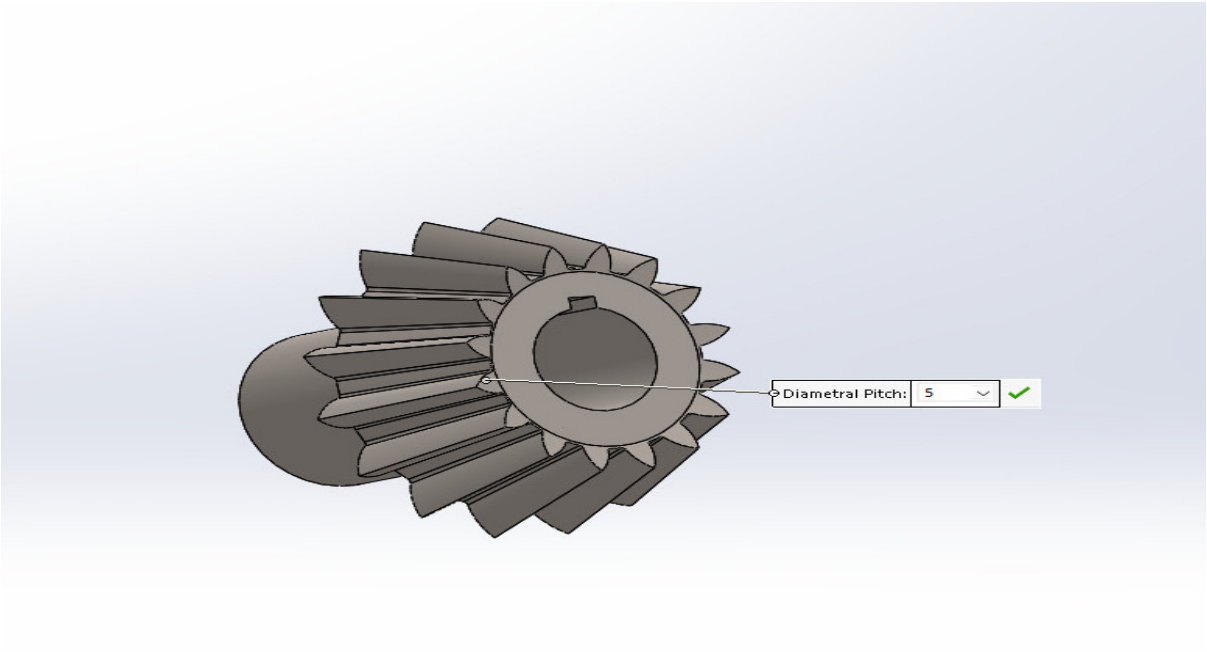


Fig 5.20: Bevel pinion

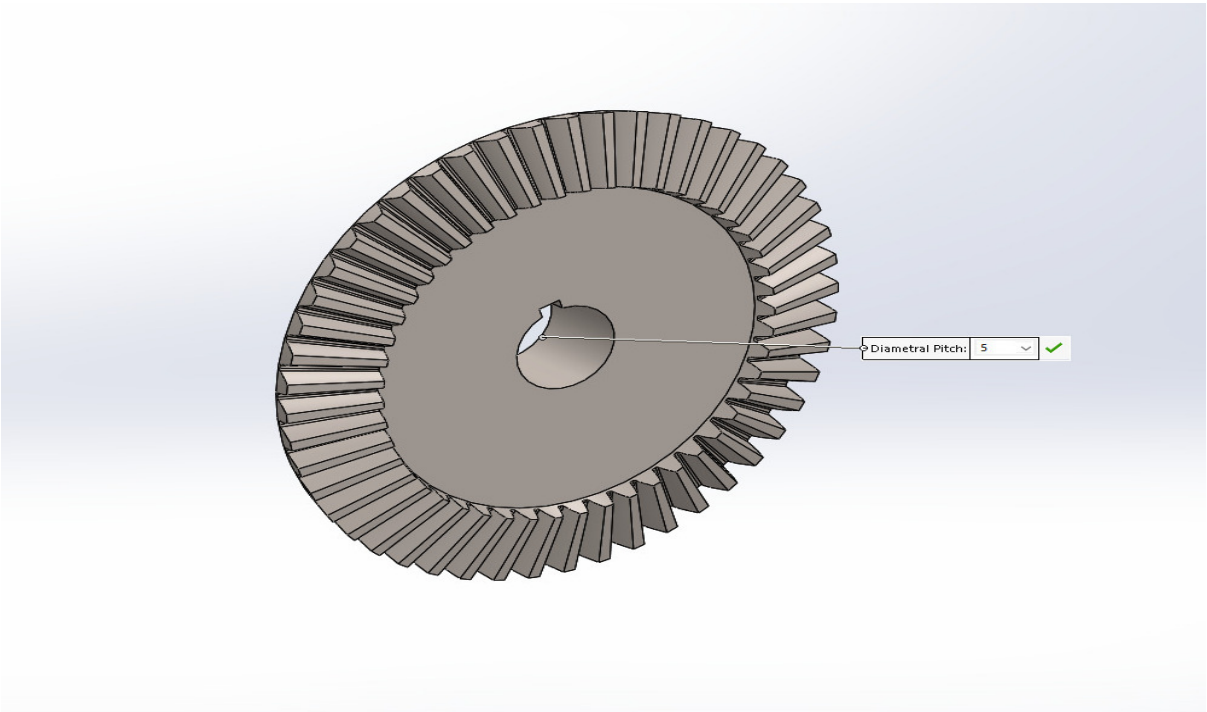


Fig 5.21: Straight bevel

Bevel Gear Mechanism:

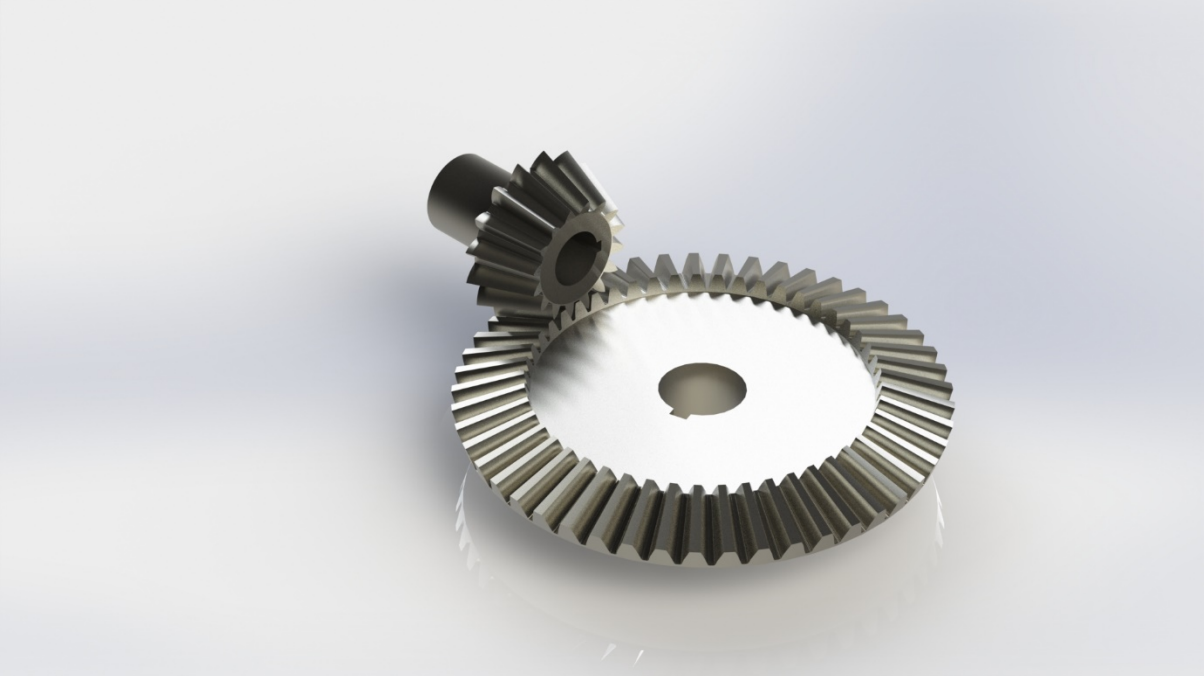


Fig 5.22: Bevel Gear Assembly

Hand Support:

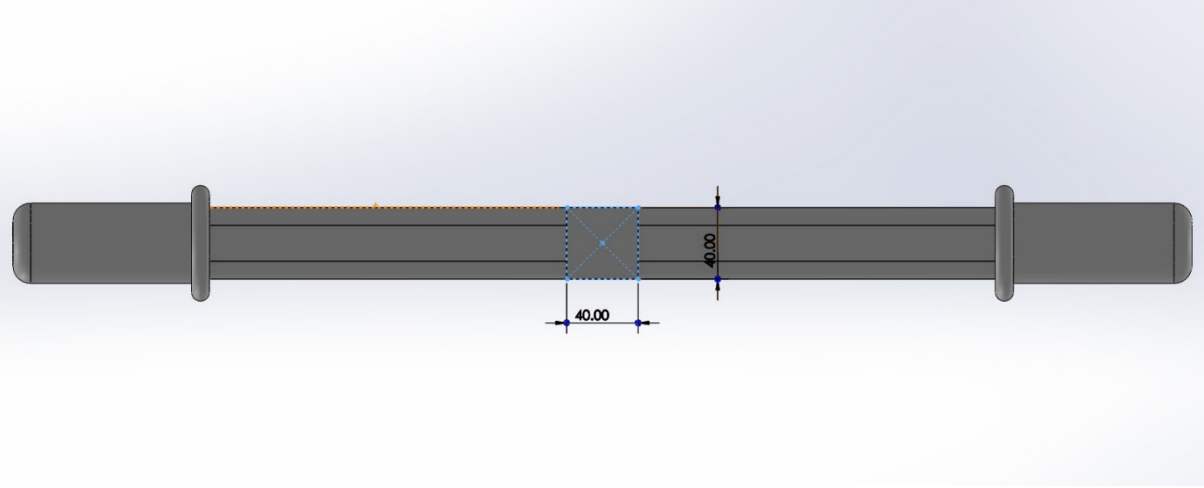


Fig 5.23: Handle bar top view

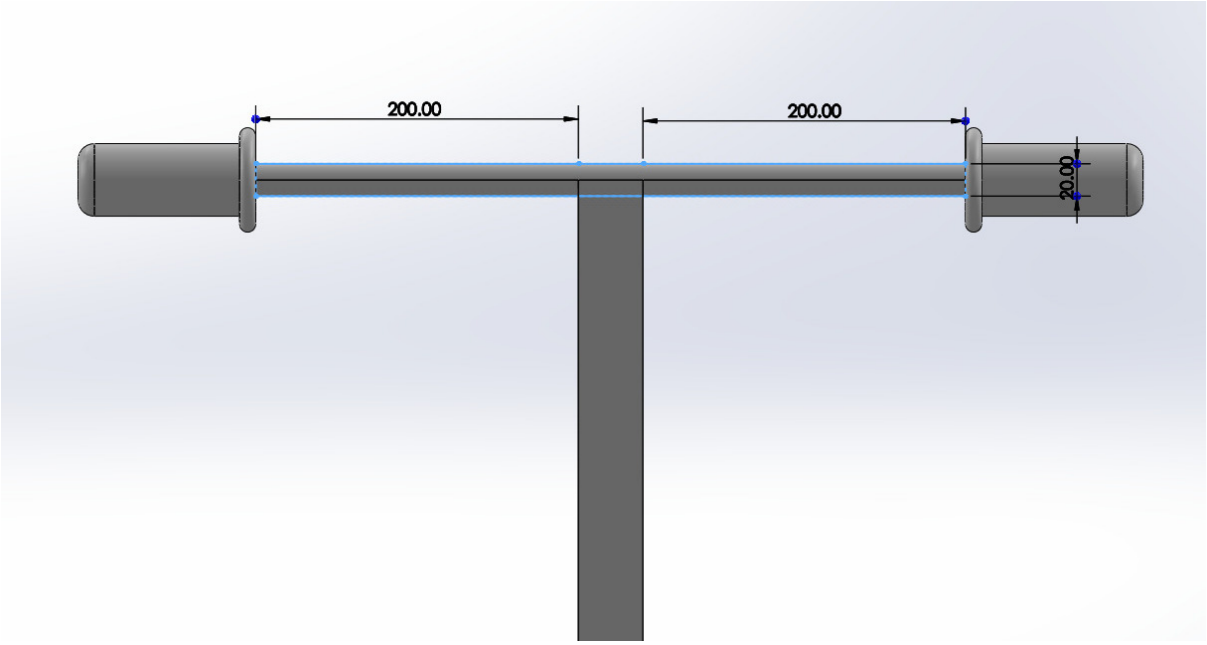


Fig 5.24: Handle bar front view

Seat:

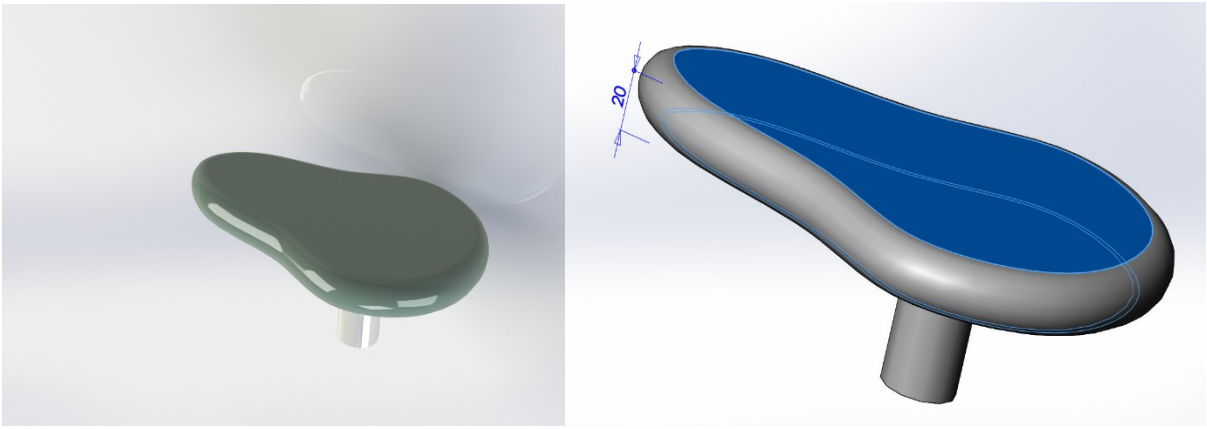


Fig 5.25: Seat

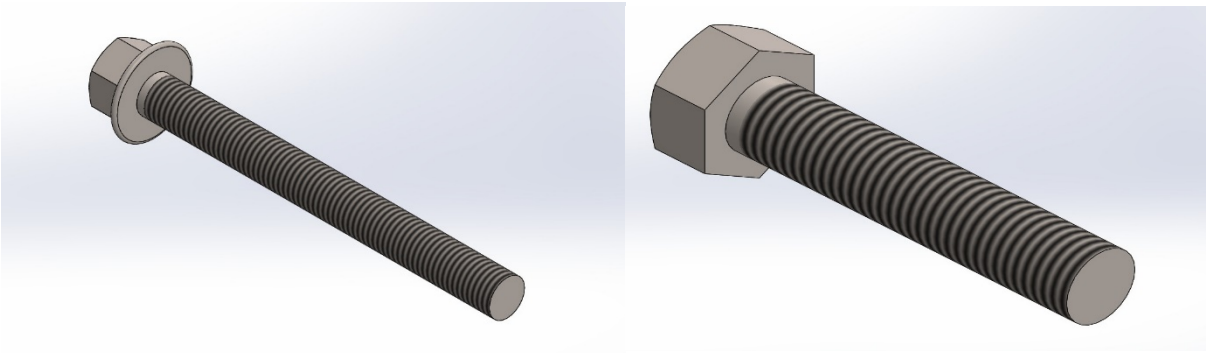


Fig 5.26: Hex flange machine screw

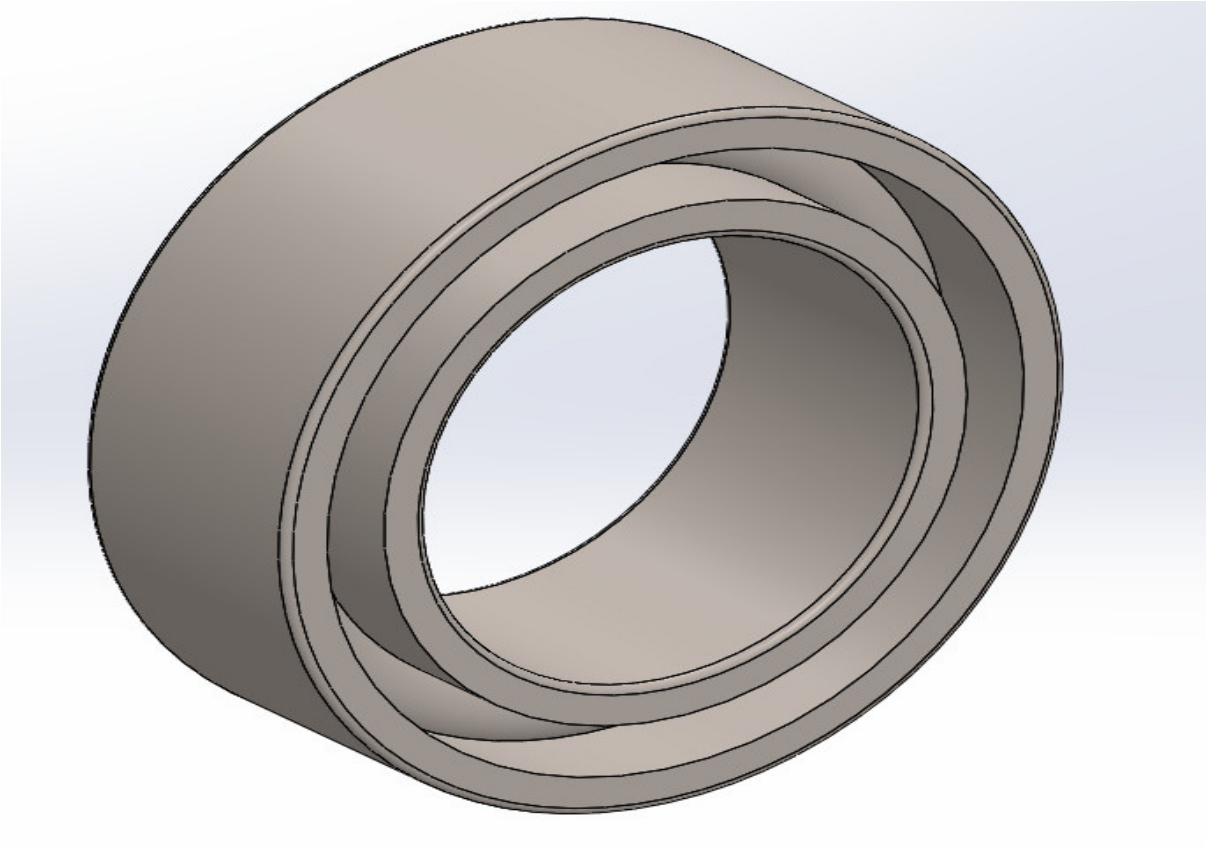


Fig 5.27: Radial ball bearing

Complete structure:

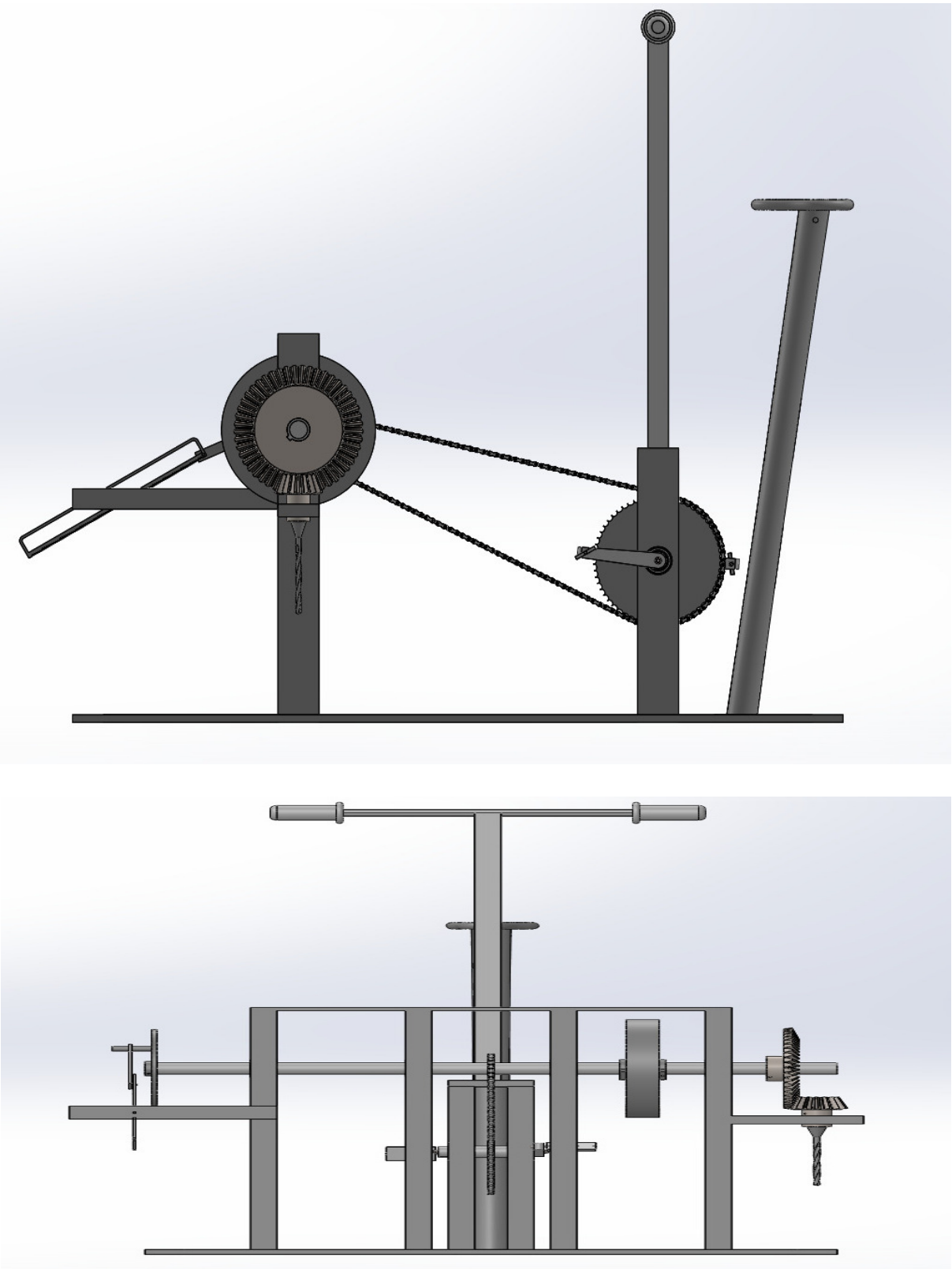


Fig 5.28: Complete Product front view and LHS view

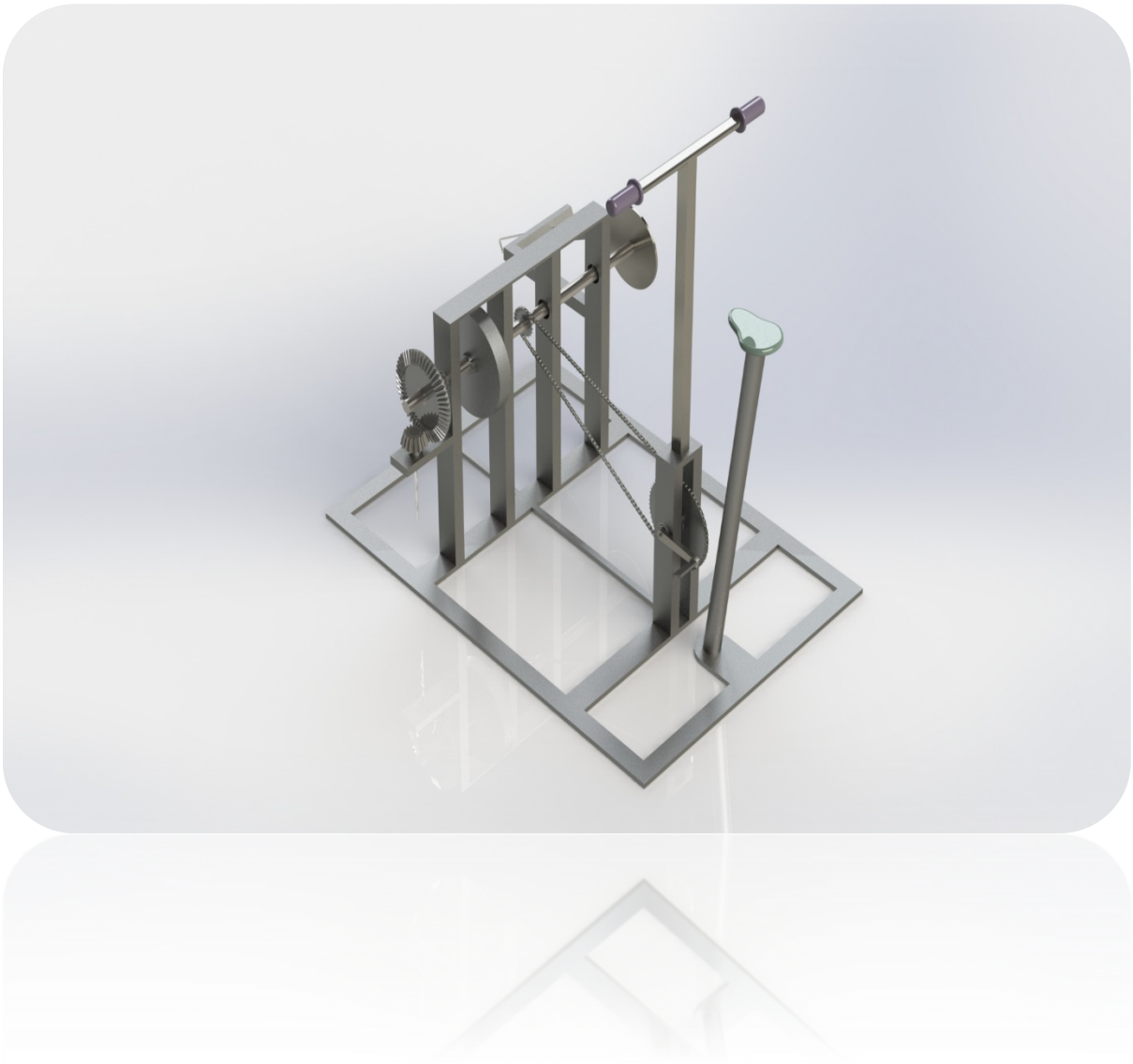


Fig 5.29: Versatile Machining Tools complete 3D view

Chapter 6

Stress Analysis

Introduction

Stress is a physical quantity that expresses the internal forces that neighboring particles of a continuous material exert on each other. Stress analysis is also used in the maintenance of such structures, and to investigate the causes of structural failures. In engineering, stress analysis is often a tool rather than a goal in itself.

The Versatile Machining Tools will be a compact package of those three tools drilling, grinding & sawing. In this machine pedal gear mechanism will be used to give motion in it. So, stress, strain and displacement analysis are done here.

Driver Sprocket

Stress profile

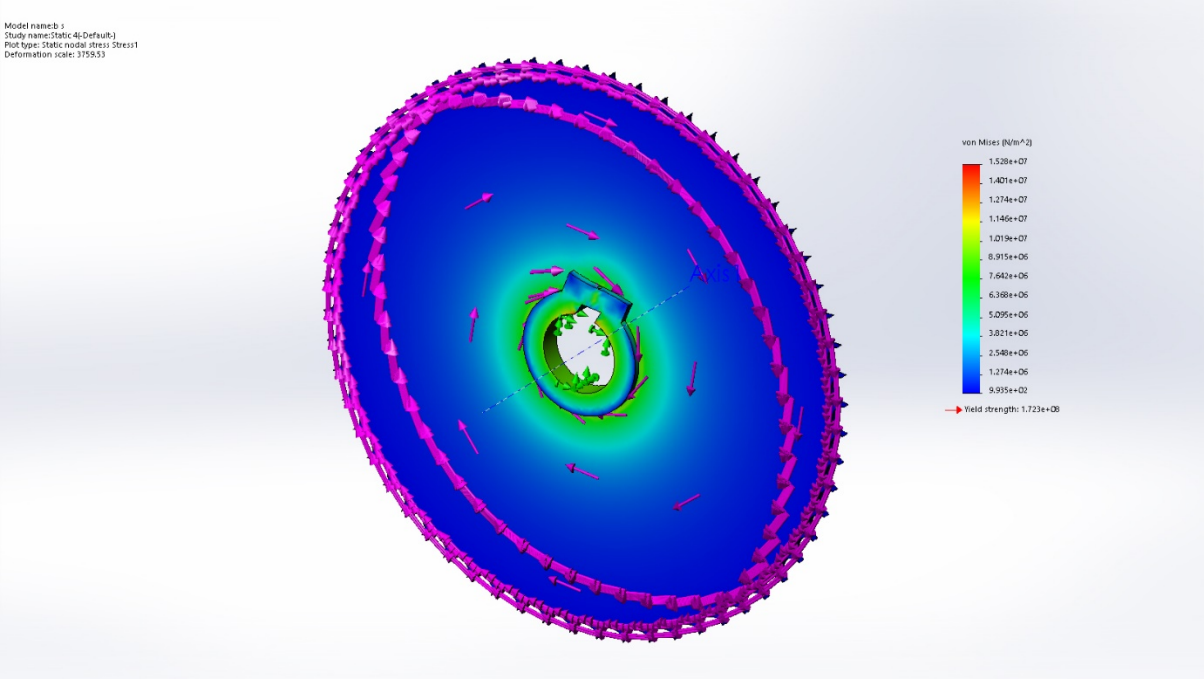


Fig 9.1: Stress profile of Driver Sprocket

Applied Torque = 100N.m

Yield Strength = 1.723e + 08 (N/m^2)

(N/m^2) Yield Strength > von Mises Strength

von Mises Strength=1.528e + 07

Factor of Safety = 11

So, the design can be considered as safe.

Displacement profile

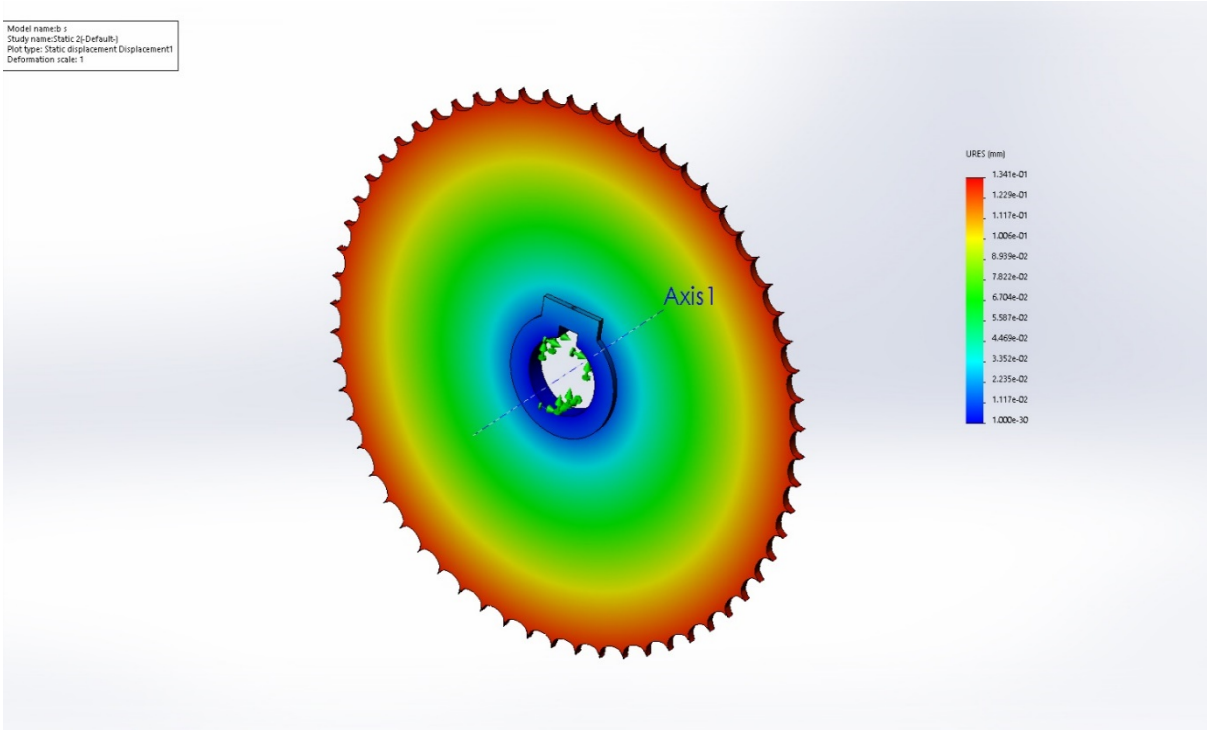


Fig 9.2: Displacement profile of Driver Sprocket

Strain profile

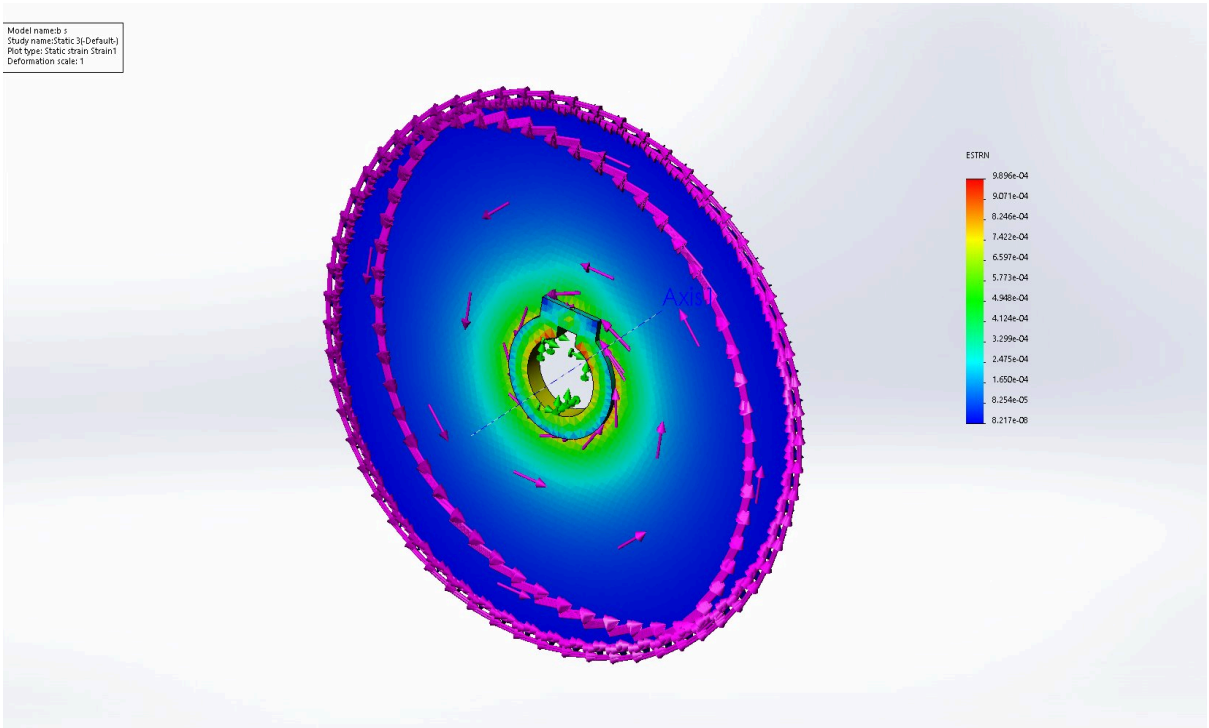


Fig 9.3: Strain profile of Driver Sprocket

Bevel Gear

Stress profile

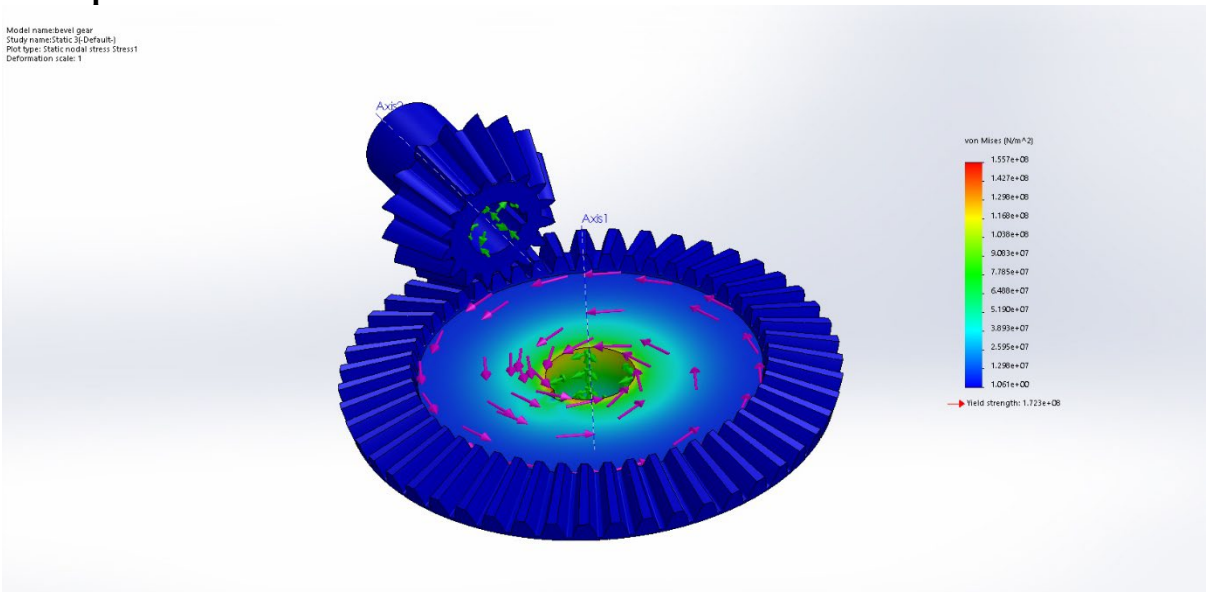


Fig 9.4: Stress profile of Bevel Gear

Applied Torque =5 000N.m

Yield Strength = 1.723e + 08 (N/m^2)

Yield Strength > von Mises Strength

von Mises Strength=1.557e + 08 (N/m^2)

Factor of Safety=1.1

So, the design can be considered as safe.

Displacement profile

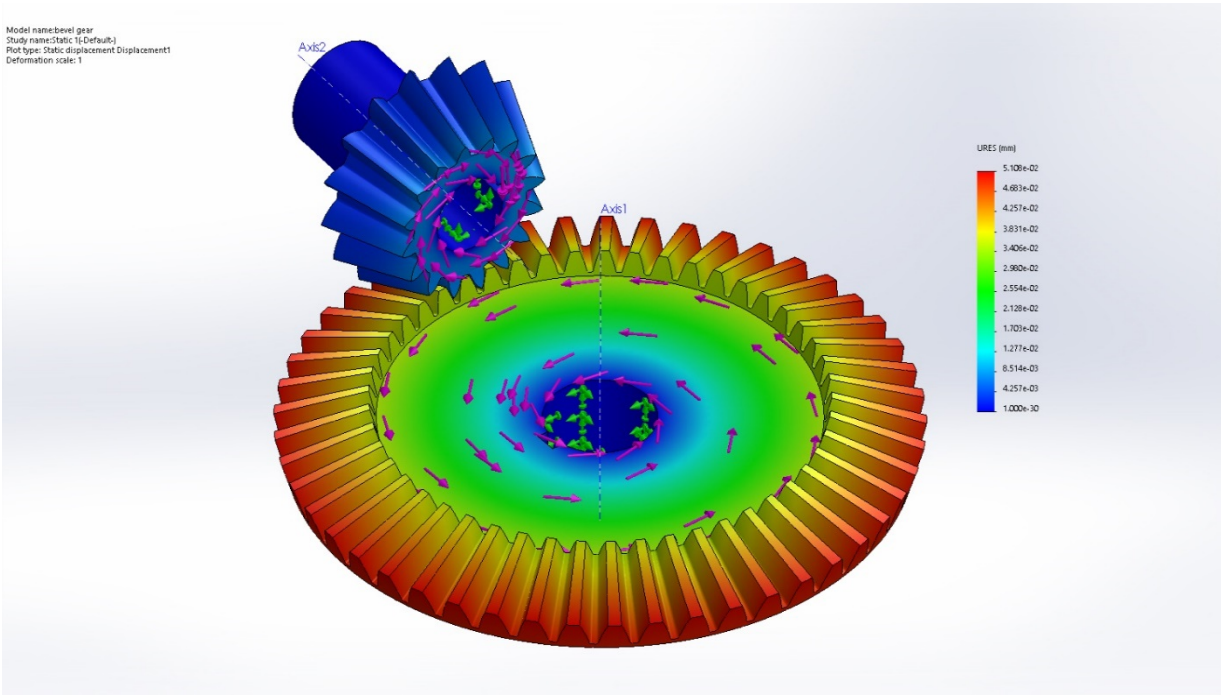


Fig 9.5: Displacement profile of Bevel Gear

Strain profile

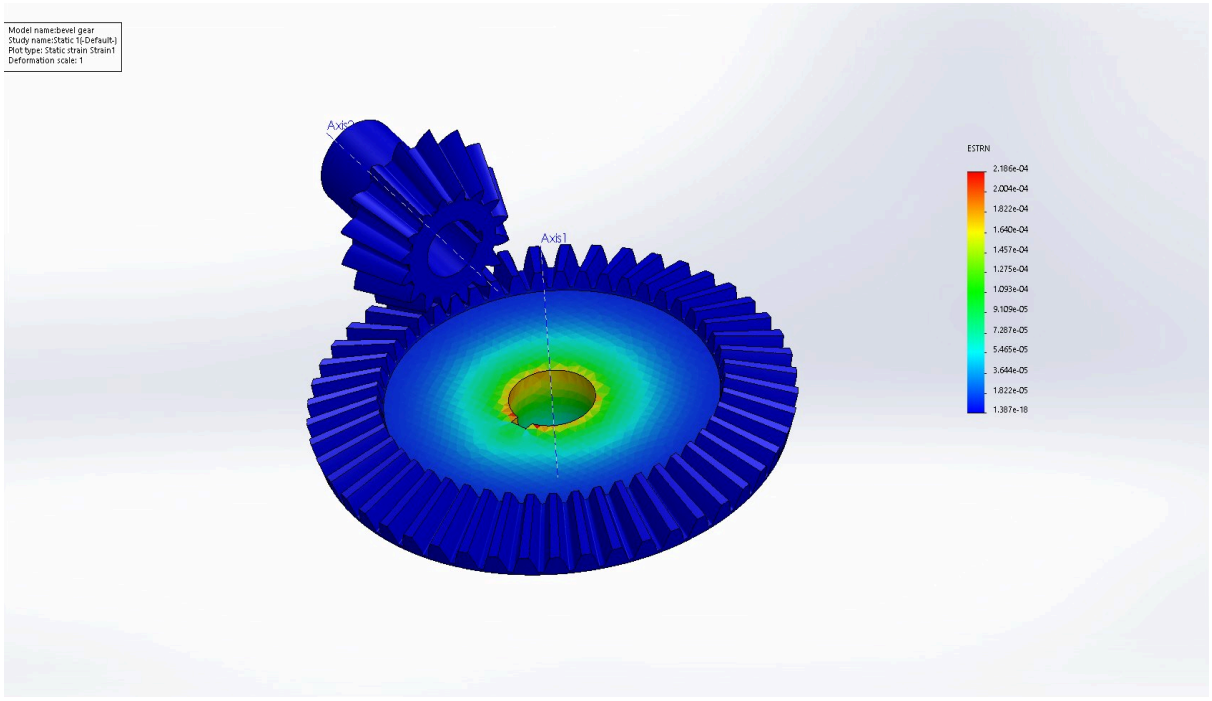


Fig 9.6: Strain profile of Bevel Gear

Pedal Connector

Stress profile

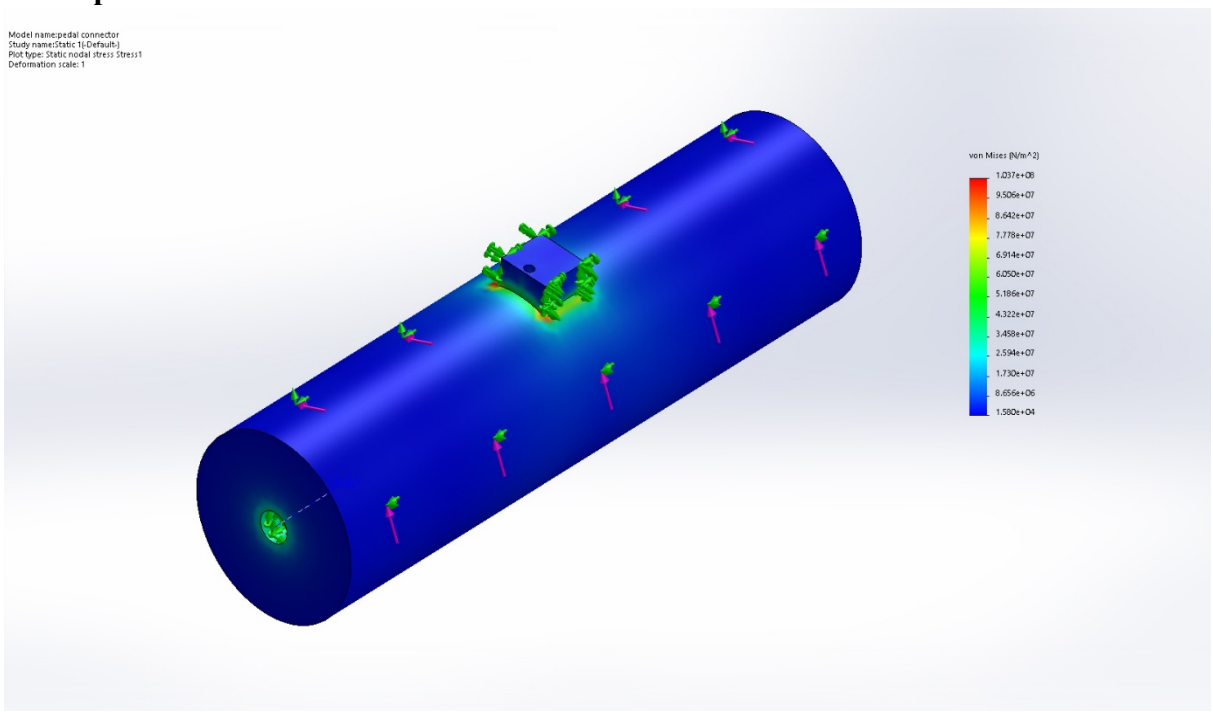


Fig 9.7: Stress profile of Pedal Connector

Applied Torque = 100N.m

Yield Strength =1 .451e + 08 (N/m^2) von Mises Strength = 1.037e + 08 (N/m^2)

Yield Strength > von Mises Strength Factor of Safety=1.4

So, the design can be considered as safe.

Displacement profile

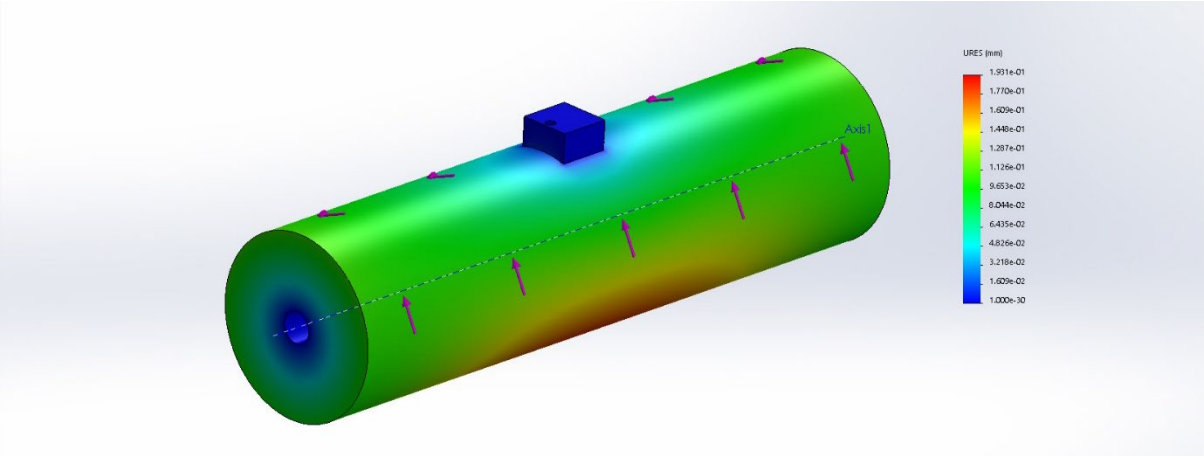


Fig 9.8: Displacement profile of Pedal Connector

Strain profile

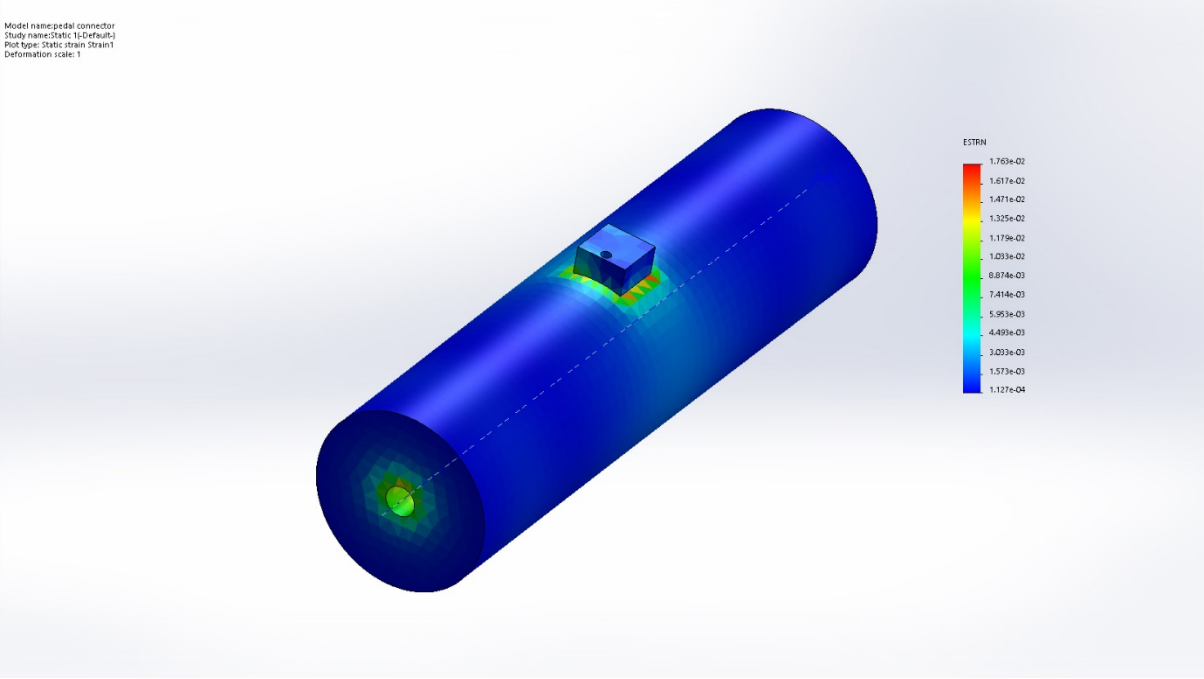


Fig 9.9: Strain profile of Pedal Connector

Pedal

Stress profile

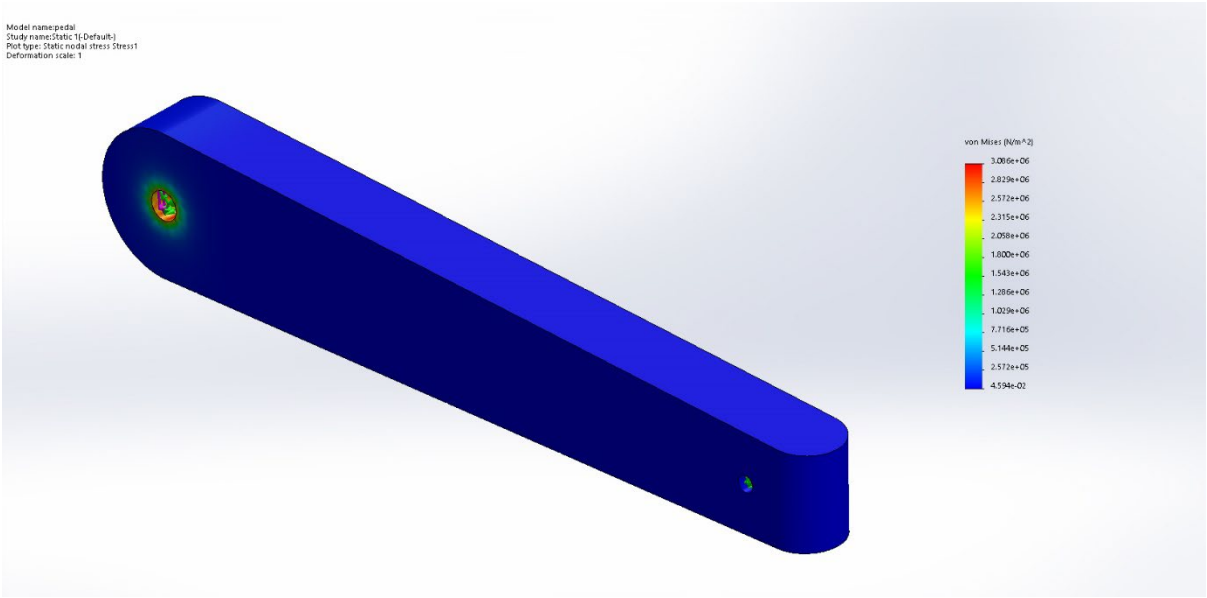


Fig 9.10: Stress profile of Pedal

Applied Load = 500N

Yield Strength=2.067e + 08 (N/m^2)

von Mises Strength = 3.086e + 06 (N/m^2)

Yield Strength > von Mises Strength

Factor of Safety=67

So, the design can be considered as safe.

Displacement profile

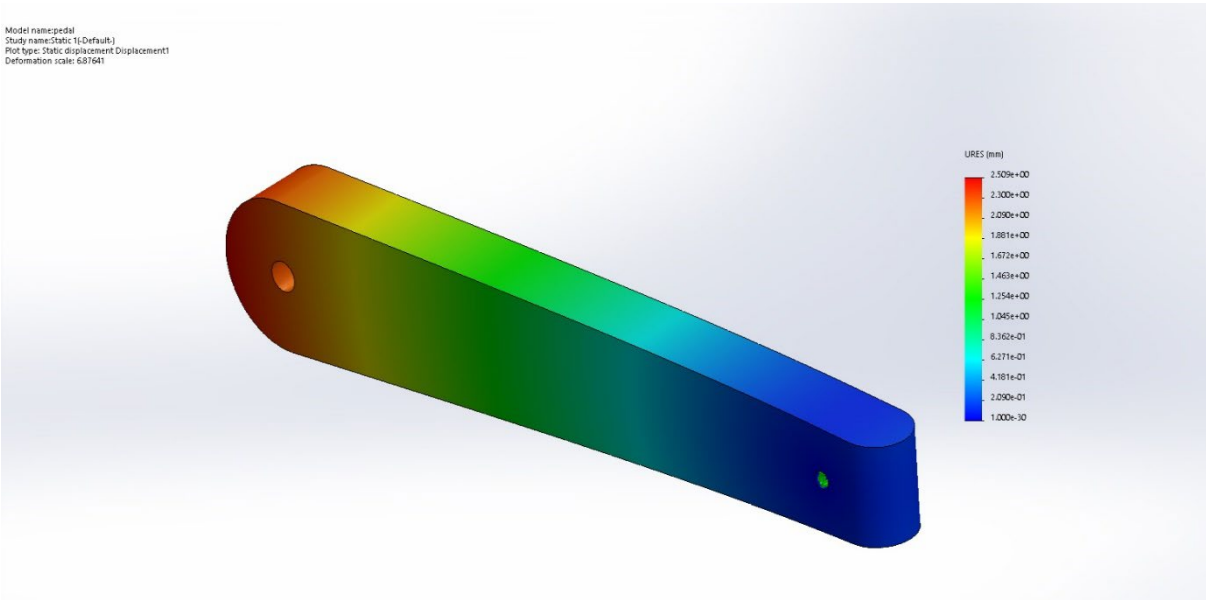


Fig 9.11: Displacement profile of Pedal

Strain profile

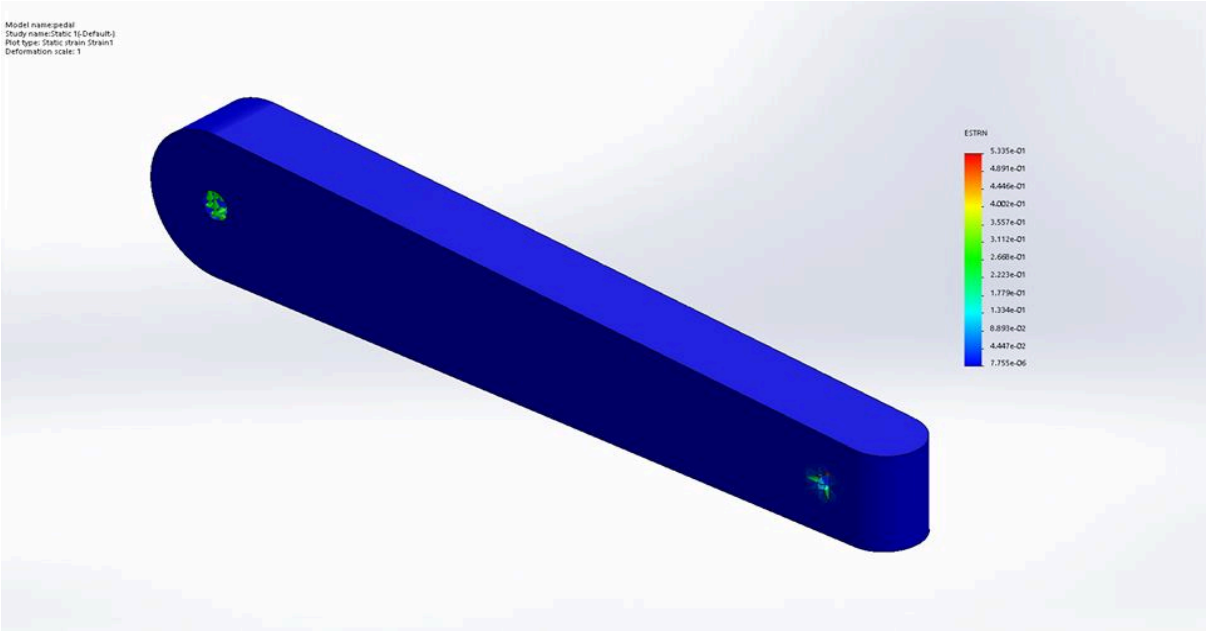


Fig 9.12: Strain profile of Pedal

Pulley

Stress profile

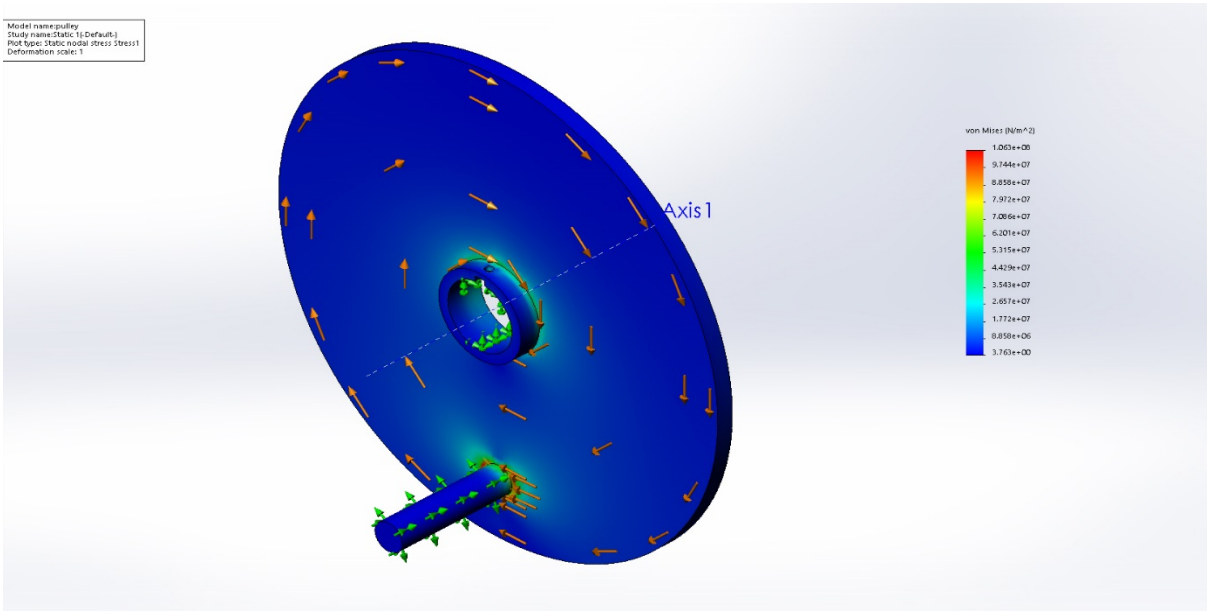


Fig 9.13: Stress profile of Pulley

Applied Torque = 1000N.m

Yield Strength = 1.594e + 08 (N/m^2) von Mises Strength = 1.063e + 08 (N/m^2)

Yield Strength > von Mises Strength Factor of Safety=1.5

So, the design can be considered as safe.

Displacement profile

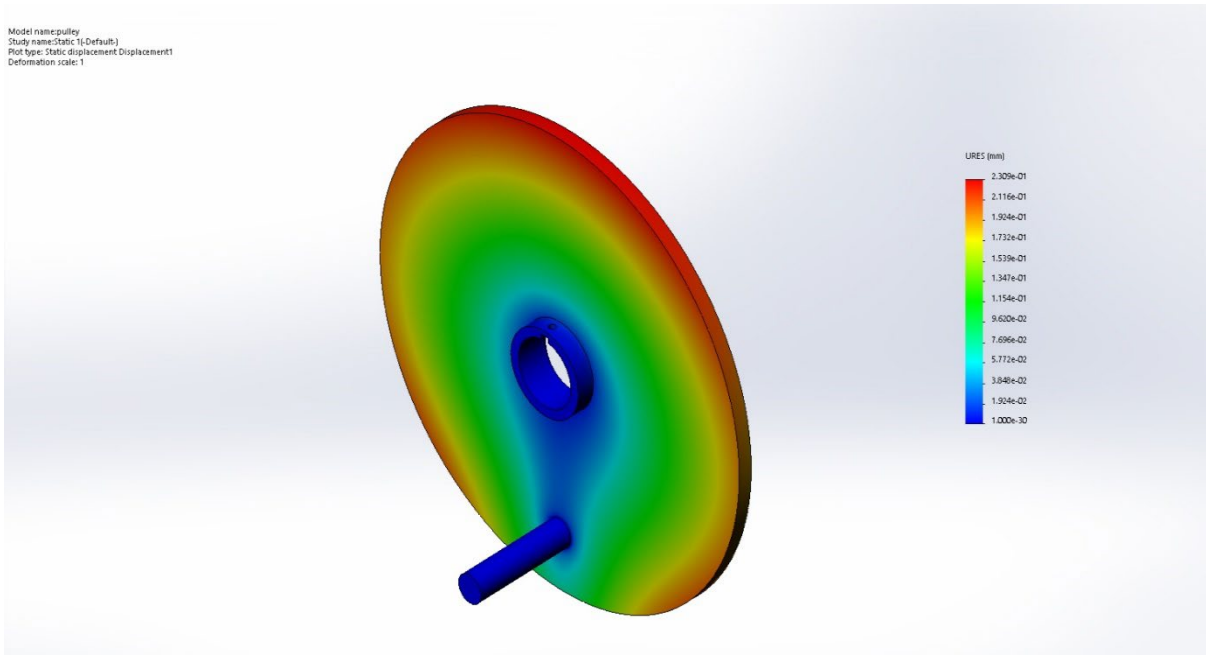


Fig 9.14: Displacement profile of Pulley

Strain profile

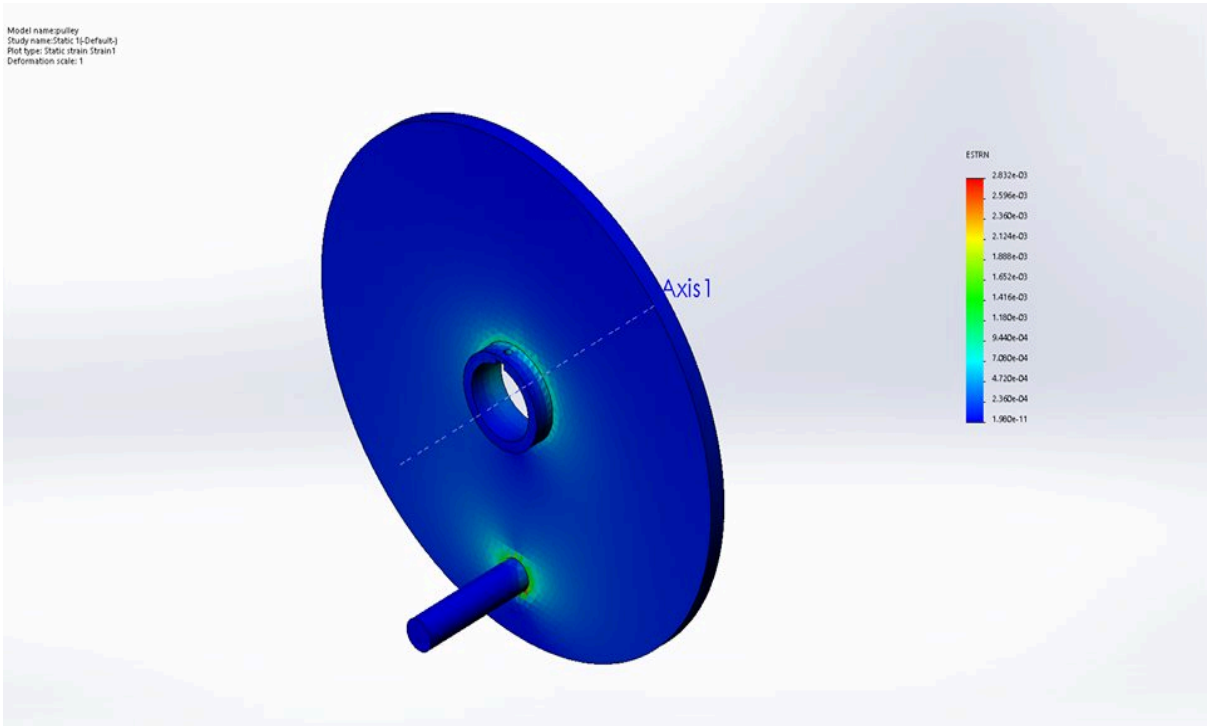


Fig 9.15: Strain profile of Pulley

Rotary Rod

Stress profile

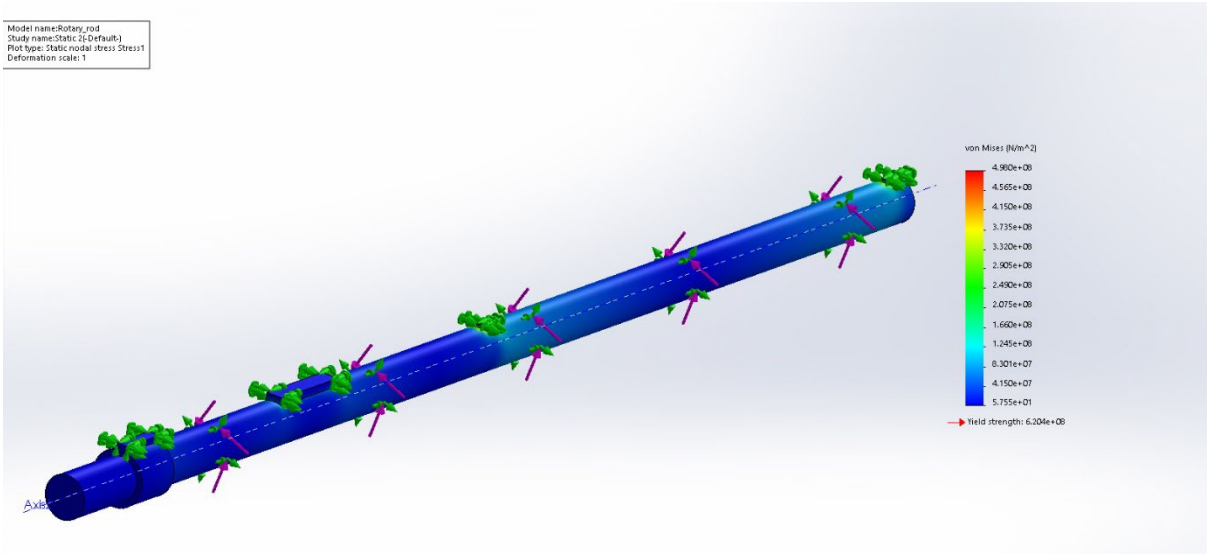


Fig 9.16: Stress profile of Rotary Rod

Applied Torque = 1500N.m

Yield Strength = 6.204e + 08 (N/m^2)

von Mises Strength = 4.980e + 08 (N/m^2)

Yield Strength > von Mises Strength

Factor of Safety = 1.2

So, the design can be considered as safe.

Displacement profile

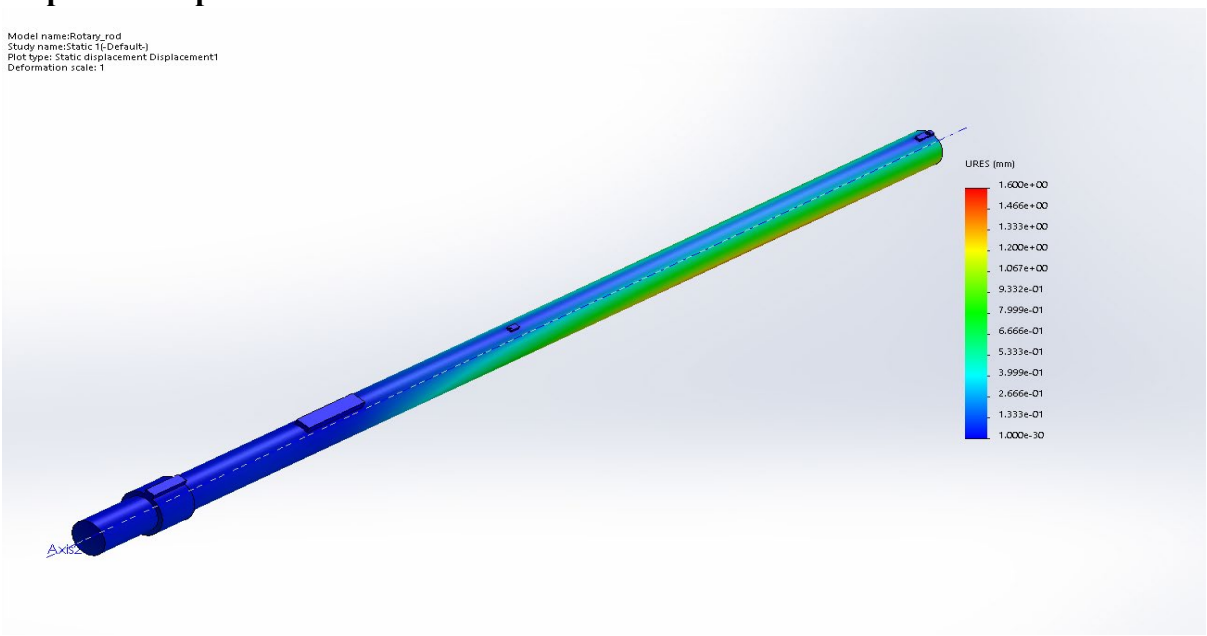


Fig 9.17: Displacement profile of Rotary Rod

Strain profile

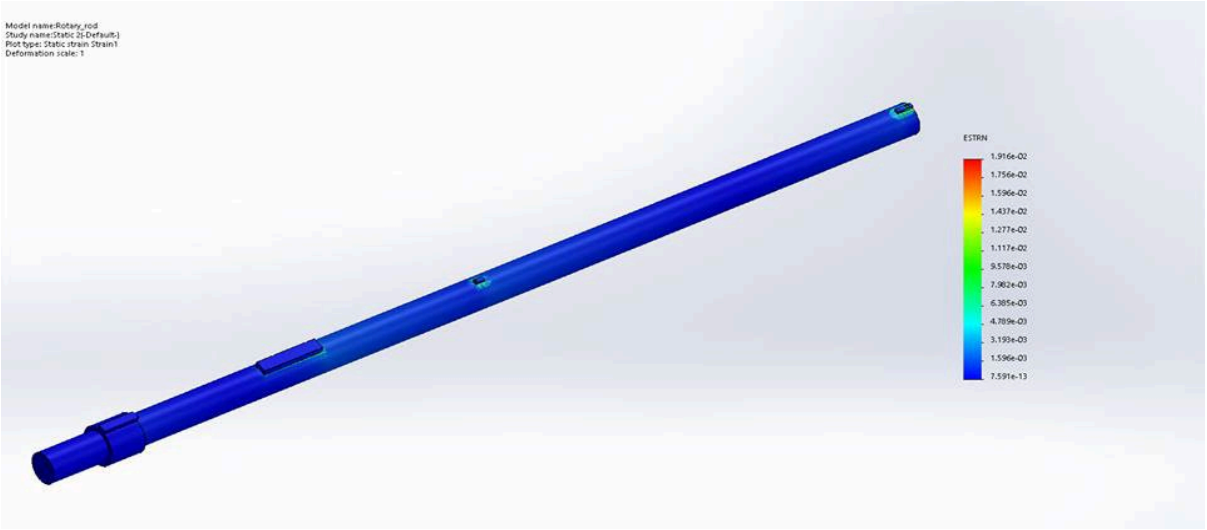


Fig 9.18: Strain profile of Rotary Rod

Driven Sprocket

Stress profile

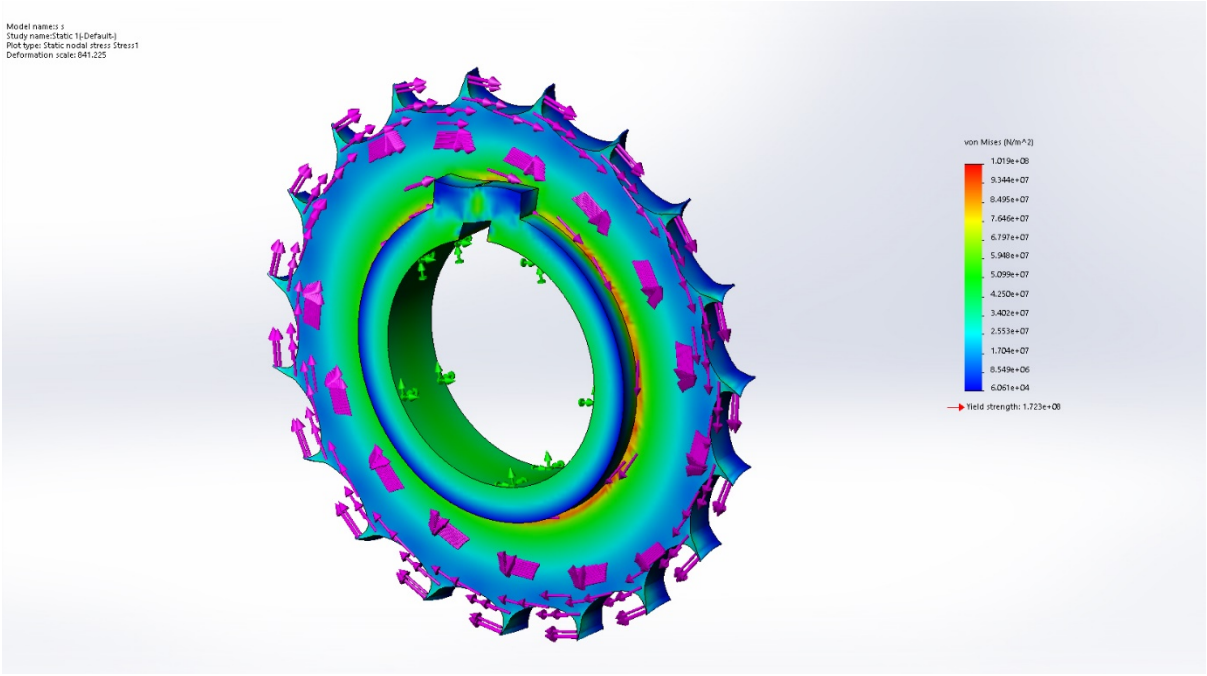


Fig 9.19: Stress profile of Driven Sprocket

Applied Torque = 500N.m

Yield Strength = 1.723e + 08 (N/m^2)

von Mises Strength = 1.019e + 08 (N/m^2)

Yield Strength > von Mises Strength

Factor of Safety = 1.7

So, the design can be considered as safe.

Displacement profile

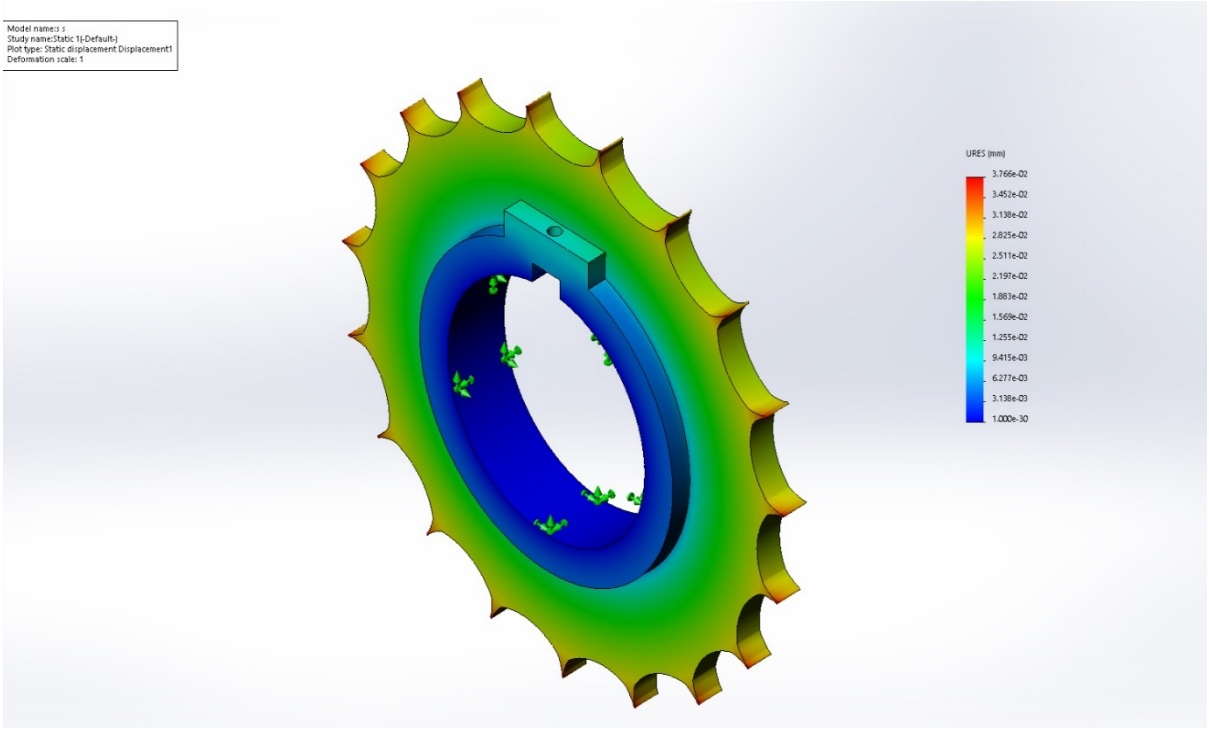


Fig 9.20: Displacement profile of Driven Sprocket

Strain profile

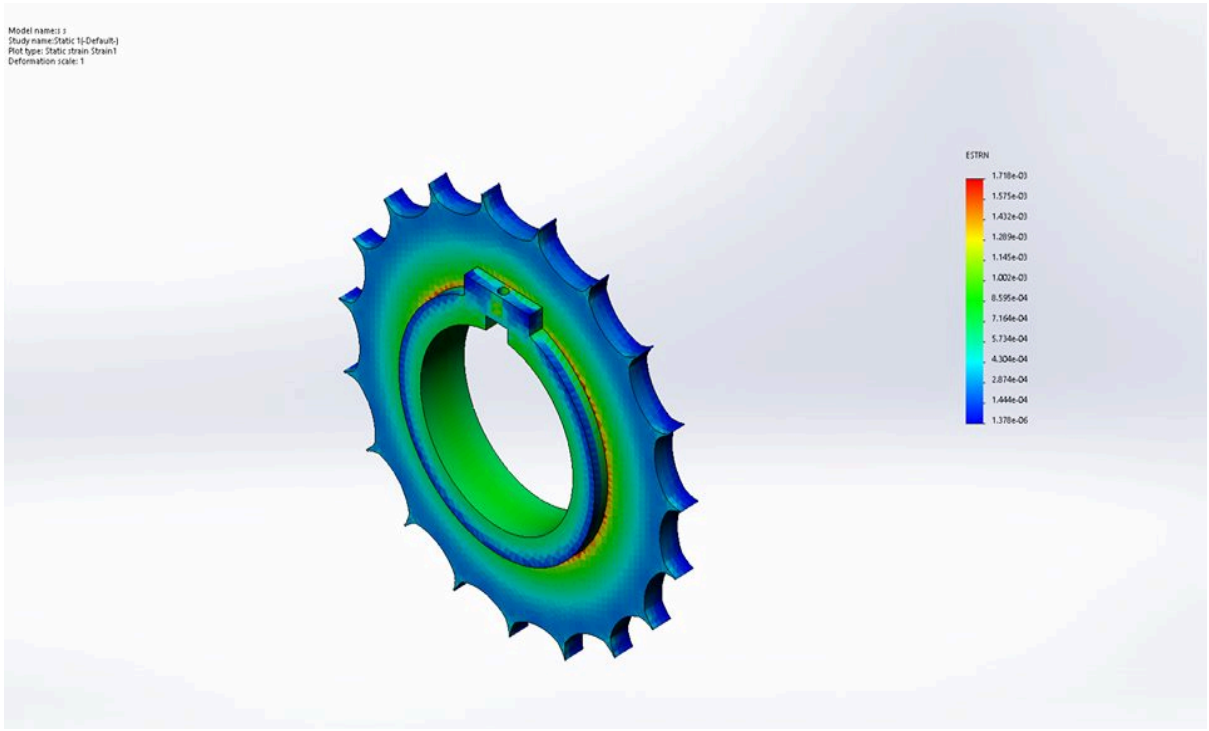


Fig 9.21: Strain profile of Driven Sprocket

Saw Connecting Rod

Stress profile

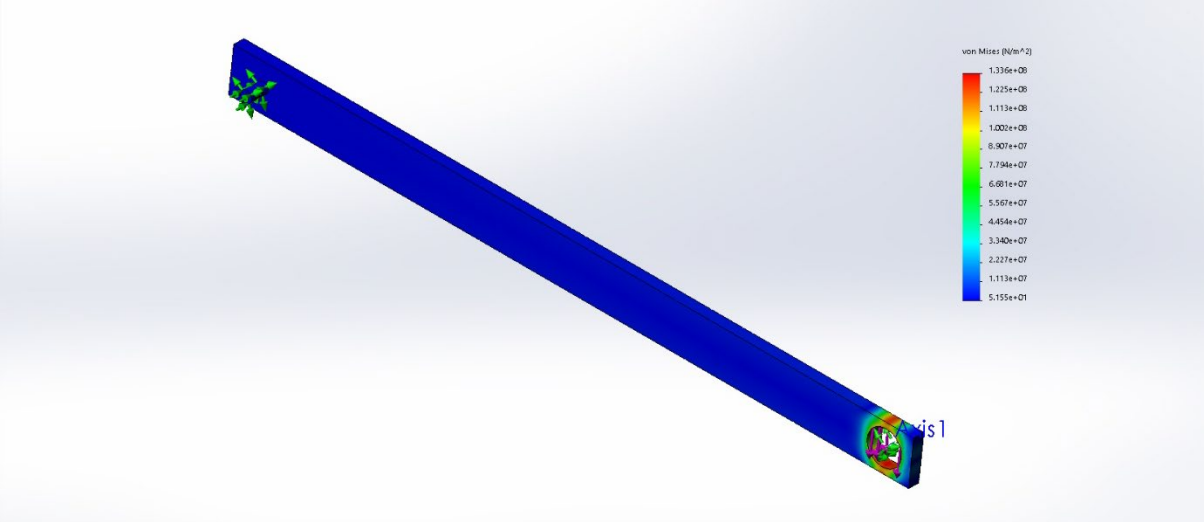


Fig 9.22: Stress profile of Saw Connecting Rod

Applied Torque = 2000N.m

Yield Strength = 1.603e + 08 (N/m^2)

von Mises Strength = 1.336e + 08 (N/m^2)

Yield Strength > von Mises Strength

Factor of Safety = 1.2

So, the design can be considered as safe.

Displacement profile

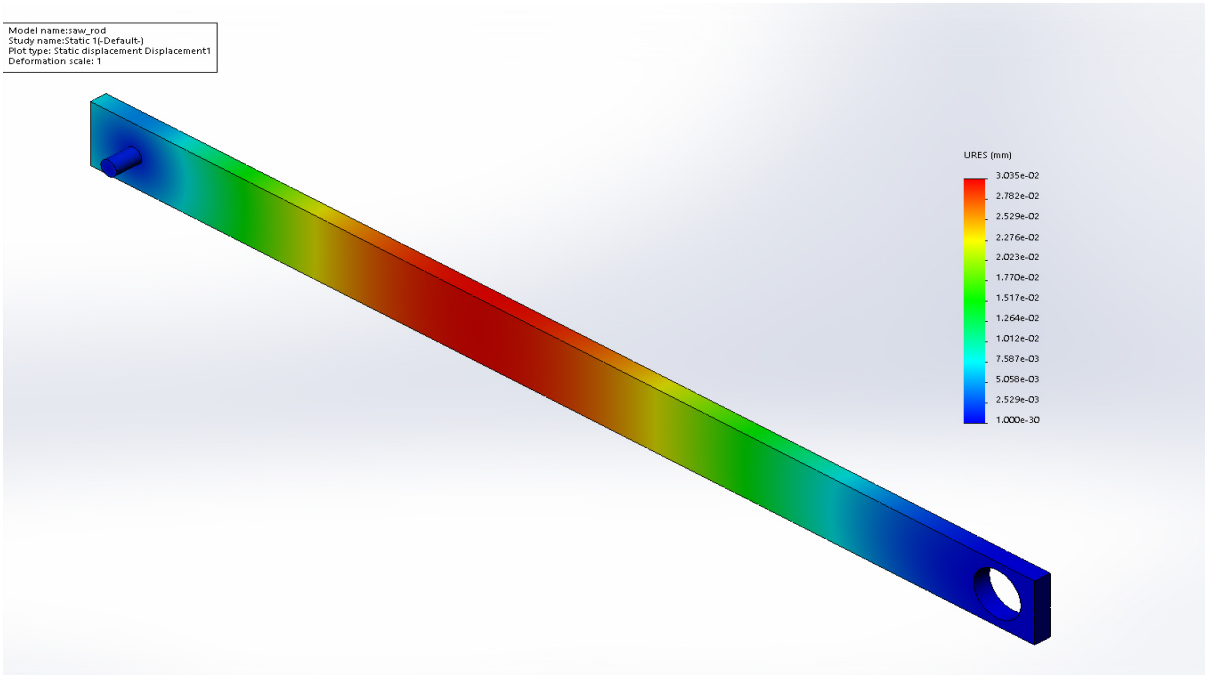


Fig 9.23: Displacement profile of Saw Connecting Rod

Strain profile

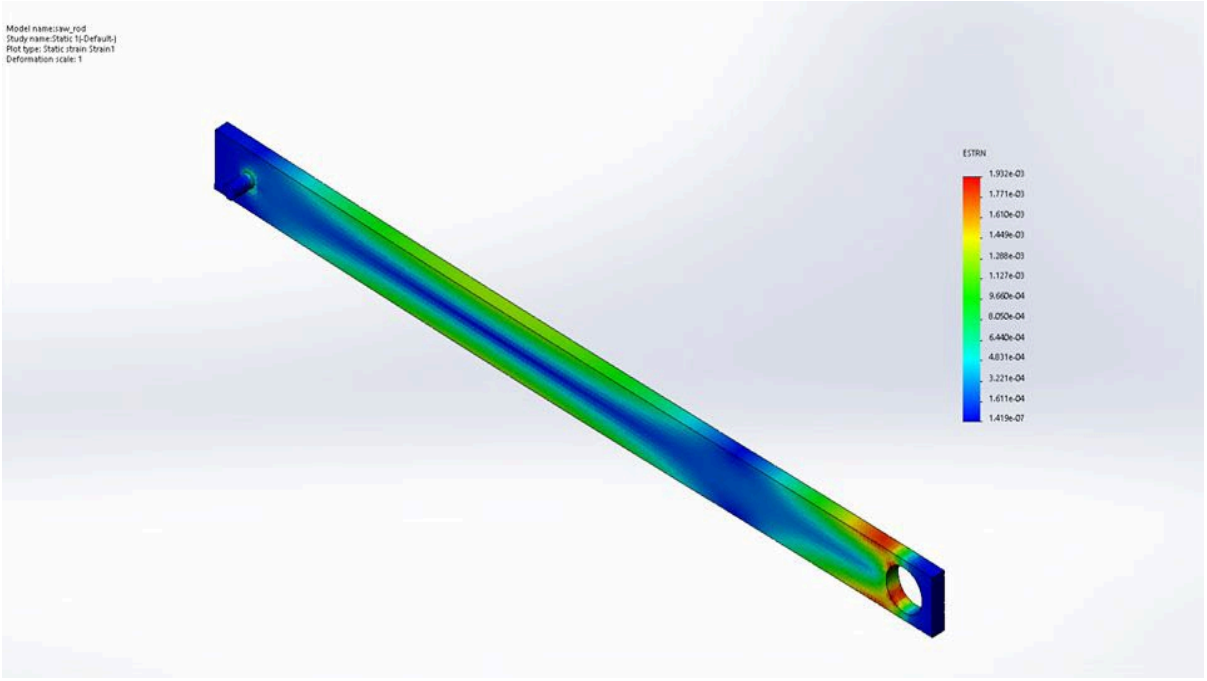


Fig 9.24: Strain profile of Saw Connecting Rod

Conclusion

Stress analysis is can evaluate a specific structural design will be able to withstand external and internal stresses and forces expected for the design. We have determined load analysis for static parts and stress, strain and displacement analysis for moving parts of our Versatile Machining Tool.

Chapter 7

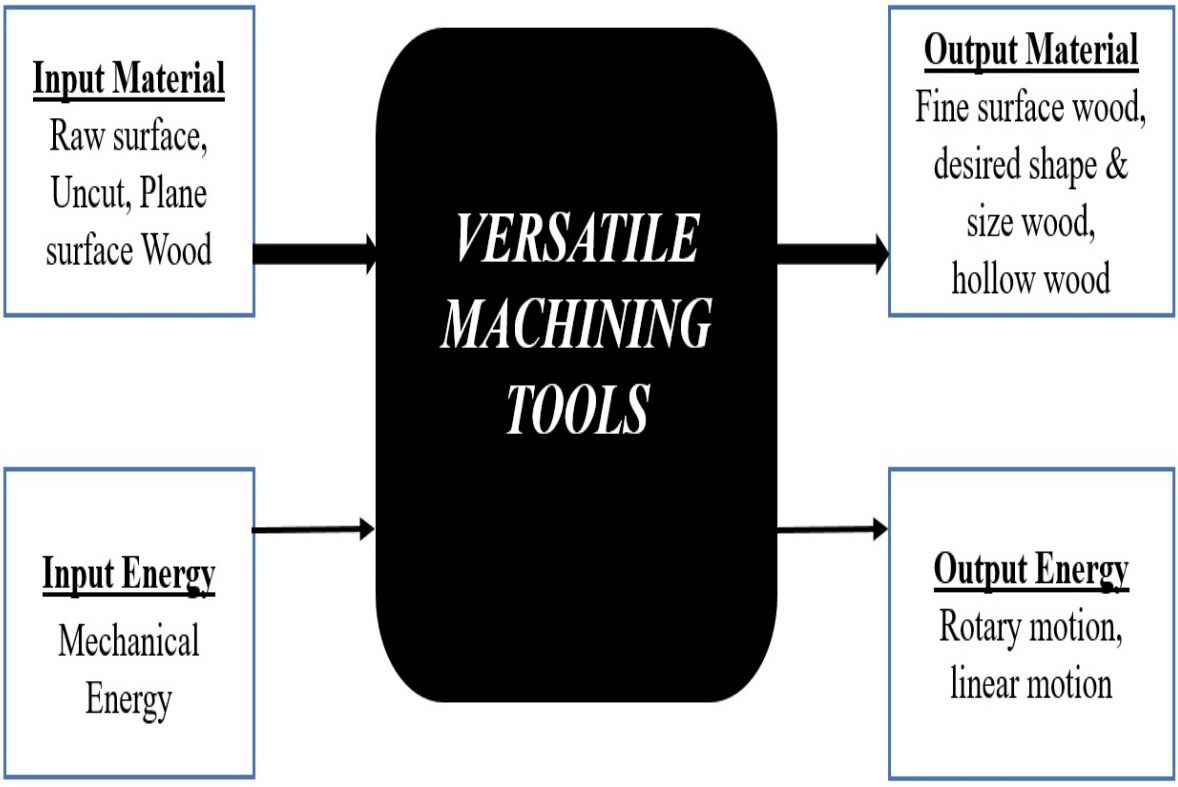
Functional Decomposition

Introduction

Functional Decomposition is the process of taking the complex process and breaking it down into its smaller, simpler parts. It breaks down the needed function of a product as simple as possible. Therefore, developing and testing those components becomes much easier. It also describes the functional requirements of the product.

Black Box Model of Functional Decomposition

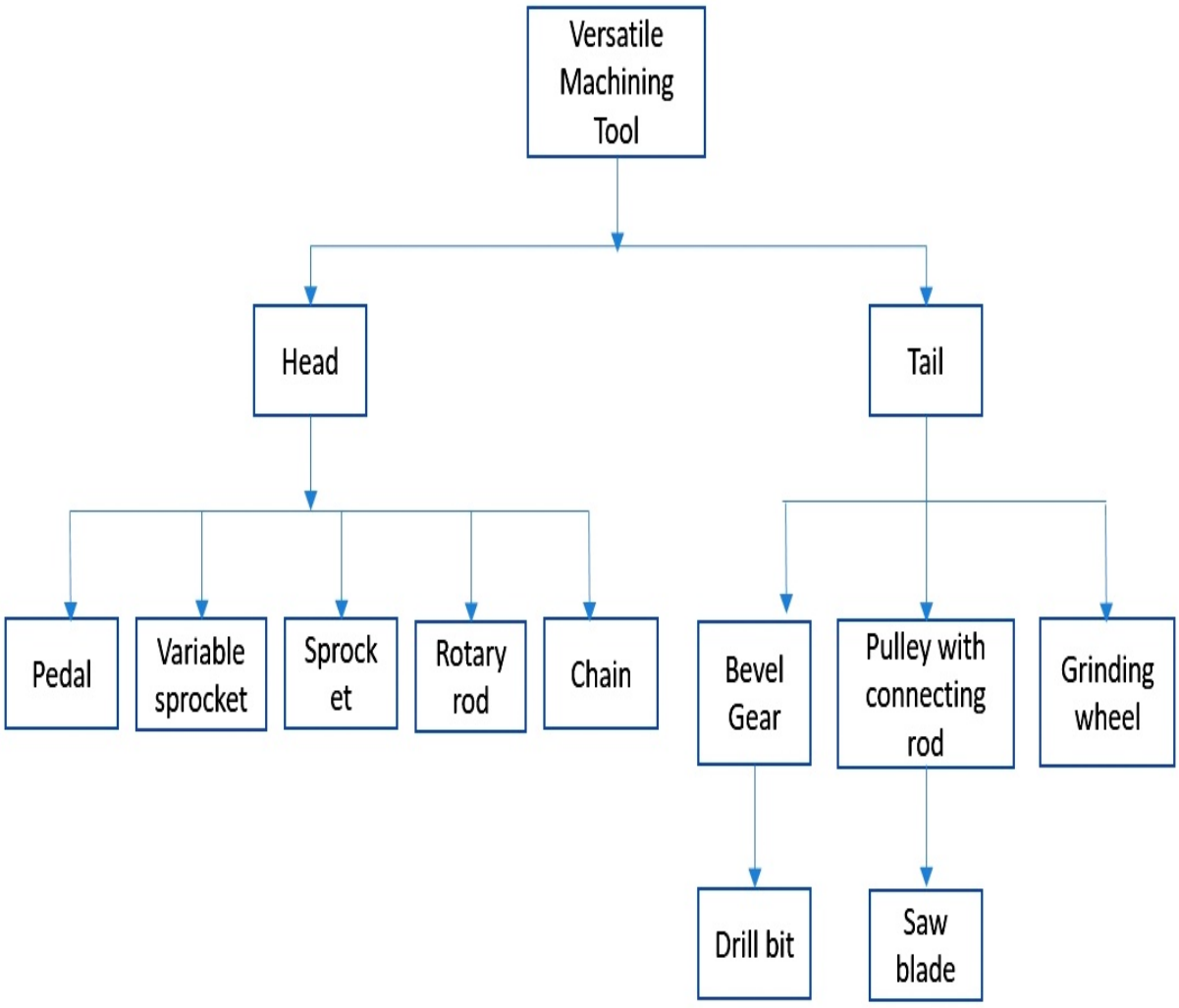
Black Box Model is a robust and complete method for modeling product's functionality. It is called "black-box" because its internal form is deemed unknown. It allows us to focus on the greatest and overall need for a product. The Black Box initiated a technical understanding of our product based on its inputs and outputs, known as material, energy and information.



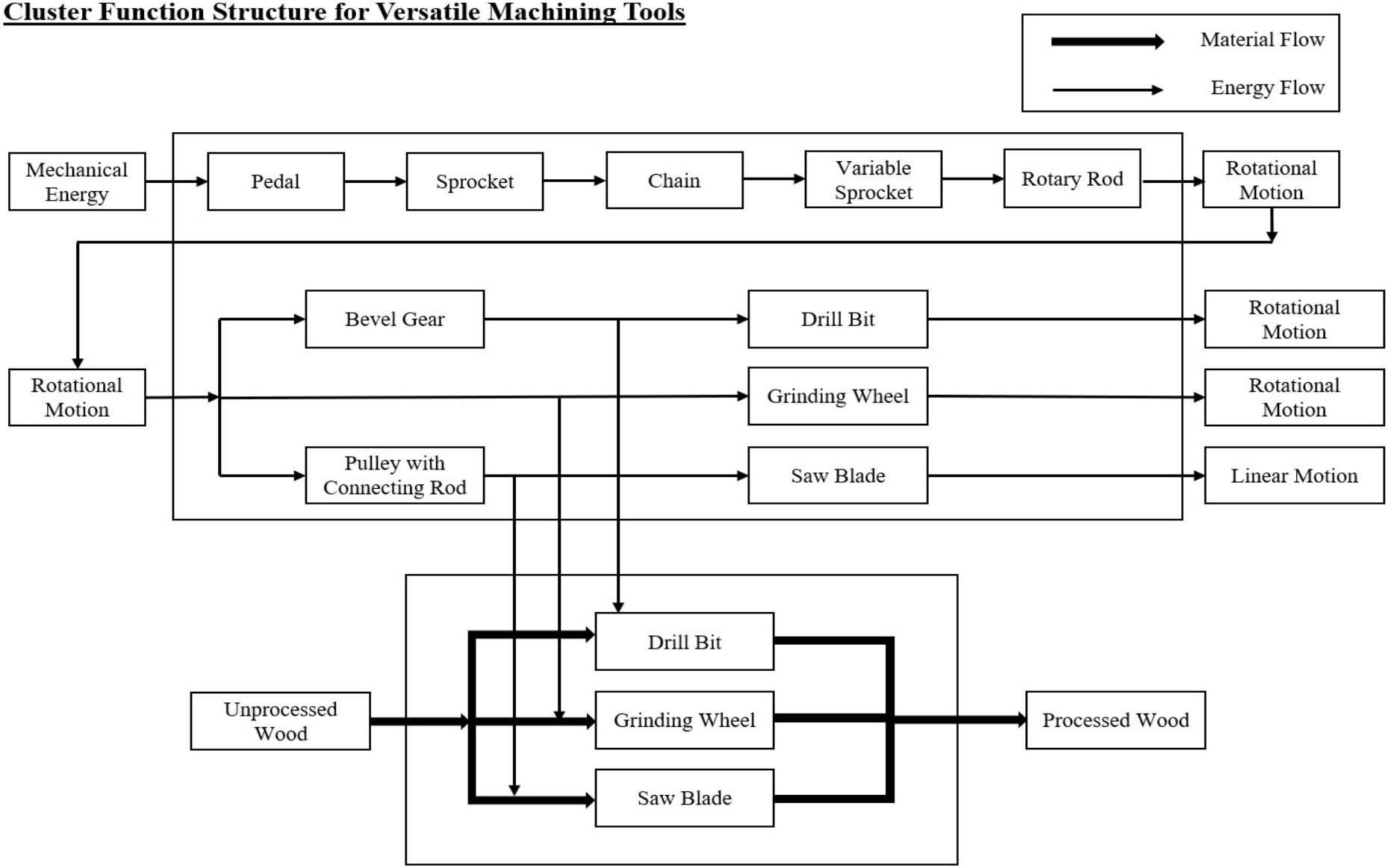
Component Hierarchy of Versatile Machining Tool

Functional decomposition takes something complicated and simplifies it. The individual elements of the process and their hierarchical relationship to each other are commonly displayed in a diagram called a functional decomposition diagram.

The main purpose of functional decomposition is to break up a large or complex business operation or function into smaller and more manageable parts. A large or complex mechanism is more easily understandable when breaking down using functional decomposition. During the analysis phase of a project to understand the function easily functional diagram is drawn. It can also be used during the planning, analysis and design phases of a project. The Functional Decomposition Diagram below shows how all the elements are inter-connected together.



Cluster Function Structure for Versatile Machining Tools



Chapter 8

Material Selection Process

Material Selection process using weighted average method

In case of **VERSATILE MACHINING TOOLS**, it is important for us to select the suitable materials to make it cost efficient, high fracture resistance due to cyclic loading and having high modulus of elasticity to resist bending. For material selection, it is necessary to find interrelations between various engineering parameters. To find these relations easily, systematically and logically Weighted Average Method is used. Which considers the objective weights of importance of the attributes as well as the subjective preferences of the decisions maker to decide the integrated weights of importance of the attributes.

Structural parts of Versatile Machining Tools:

Material selection is a step in the process of designing any physical object. In the context of product design, the goals are to minimize the cost and consider all engineering parameters for the betterment of the products.

In Versatile Machining Tools, material selection processes are done in this chapter for some vital parts.

Selected parts are: (parts names are same as mentioned in chapter -6)

- Body Frame
- Hand support
- Seat Stand
- Rotary rod
- Pedal connector

Here Digital Logic Method & Performance Index calculation system will be used for material selection.

Some Dimensionless parameters - α, β, Υ

Weighting Factor = α

Scaled property,

For maximum, $\beta = \frac{numerical\ value\ of\ property}{maximum\ value\ in\ list} * 100$

For minimum, $\beta = \frac{minimum\ value\ in\ list}{numerical\ value\ in\ property} * 100$

Material Performance Index, $\Upsilon = \sum \alpha\beta$

Table: Digital Logic Method for Body Frame, Seat Stand, Hand Support:

Properties	Positive decision Number, N=n(n-1)/2 = 6(6-1)/2=15															Positive Decisions	Weighting Factor
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15		
Cost	1	0	1	0	1											3	0.2
Density	0					0	1	0	0							1	0.07
Modulus of Elasticity		1				1				1	0	1				4	0.26
Machinability			0				0			0			0	1		1	0.07
Availability				1				1			1		1		1	5	0.33
Co-efficient of thermal Expansion					0				1			0		0	0	1	0.07
Total Number of Decisions																15	$\sum \alpha = 1$

Table: Material properties for Body Frame, Seat Stand, Hand Support:

Properties	Materials	
	Aluminum	Mild steel
Cost ($/kg)	1.8	0.50
Density (Mg/m^3)	2.7	7.8
Modulus of Elasticity (GPa)	70	210
Machinability [1]	4	0.52
Availability (thousand metric tons)	64336 [2]	1808600 [3]
Co-efficient of thermal Expansion (10^{-6} / ˚C)	33	14

Table: Calculation of Performance index table:

Selection criterion	Weighting factor,(α)	Aluminum		Mild Steel	
		Scaled property,(β)	Weighted score,(αβ)	Scaled property,(β)	Weighted score,(αβ)
Cost	0.20	28	5.6	100	2
Density	0.07	100	7	35	2.45
Modulus of Elasticity	0.26	33	8.58	100	26
Machinability	0.07	100	7	13	.91
Availability	0.33	04	1.32	100	
Co-efficient of thermal Expansion	0.07	42	2.94	100	7
Material Performance Index, ϒ			∑αβ = 32.44		∑αβ = 38.36

Result: For Body Frame, Seat Stand and Hand Support Mild Steel 1020 will be selected.

Table: Digital Logic Method for Rotary Rod & Pedal Connector:

Properties	Positive decision Number N = n(n-1)/2 = 7(7-1) = 21																					Positive Decisions	Weighting Factor
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21		
Cost	0	0	1	0	0	0																1	.05
Density	1						0	1	0	0	0											2	.1
Modulus of Elasticity		1					1					1	0	1	0							4	.19
Machinability			0					0				0				0	1	0				1	.05
Availability				1					1				1			1			1	1		6	.28
Co-efficient of thermal Expansion					1					1				0			0		0		0	2	.1
fatigue						1					1				1			1		0	1	5	.23
Total Number of Decisions																						21	∑α=1

Table: Material properties Rotary Rod & Pedal Connector:

Properties	Materials	
	Aluminum	Mild steel
Cost ($/kg)	1.8	0.50
Density (Mg/m^3)	2.7	7.8
Modulus of Elasticity (GPa)	70	210
Machinability [1]	4	0.52
Availability (thousand metric tons)	64336 [2]	1808600 [3]
Co-efficient of thermal Expansion (10^{-6} / $^{\circ}C$)	33	14
Fatigue ($MNm^{-3/2}$)	28	140

Table: Calculation of Performance table:

Selection criterion	Weighting factor,(α)	Aluminum Alloy (7075-T6)		Mild Steel (1020)	
		Scaled property,(β)	Weighted score,(αβ)	Scaled property,(β)	Weighted score,(αβ)
Cost	0.20	28	5.6	100	2
Density	0.07	100	7	35	2.45
Modulus of Elasticity	0.26	33	8.58	100	26
Machinability	0.07	100	7	13	.91
Availability	0.33	04	1.32	100	
Co-efficient of thermal Expansion	0.07	42	2.94	100	7
Fatigue	.23	20	4.6	100	23
Material Performance Index, ϒ			∑αβ = 37.44		∑αβ = 61.36

Result: For Rotary Rod & Pedal Connector, Mild Steel 1020 will be selected.

References

[1] http://bit.ly/2PoMbdH

Average: $MA_{Al} = (4.80+3.20)/2 = 4$, $MA_{MS} = (0.64+0.40)/2 = 0.52$

[2] http://bit.ly/2IPqEdc

[3] http://bit.ly/2UPK5cY

Table: Material Selection for Different parts

Parts	Selection Criteria	Available Material	Selected Material
Body Frame, Seat Stand and Hand Support	- Density - Modulus of Elasticity - Machinability - Availability - Co-efficient of thermal -Expansion	- Mild Steel 1020 - Aluminum Alloy 7075-T6	Mild Steel 1020
Rotary Rod & Pedal Connector	- Density - Modulus of Elasticity - Machinability - Availability - Co-efficient of thermal Expansion - Fatigue	- Mild Steel - Aluminum Alloy 7075-T6	Mild Steel

Result

Through the means of the systematic procedures of weighted average method, among the alternatives we have selected the suitable materials for our product VERSATILE MACHINING TOOLS. Now we can move to the next stage of product design, which is to select appropriate manufacturing criterion for different parts and processes. Weighted average method is going to be implied there too.

Chapter 9

Manufacturing Process Selection

Introduction

Manufacturing Process selection refers to the strategic decisions of selecting different kind of production process to have in a manufacturing plant. The process flow in an organization refers to how a factory organizes material flow using one or more of the process technologies including the job shop, batch shop, assembly line, and continuous flows. The process chosen depends on the customization of the product as well as the volume required in the market. The relationship between the process structures and volume requirements is depicted on a product process matrix.

Qualitative analysis for manufacturing process:

Table: Manufacturing process analysis for different parts-

Operation	Properties considered	Process considered	Process selected
Joining operation	• Quality • Easy to operate • Operating time • Good finishing • Low cost	• Arc welding • Tig welding • Mig welding	Arc welding
	• Quality • Operation time	• Drilling machine	

Boring operation	• Good finishing • Cost • Eco friendly	• Lathe machine	Drilling machine
Facing and Turning operation	• Quality • Operation time • Good finishing • Low cost • Eco friendly	• Lathe machine • Drilling machine	Lathe machine

Quantitative analysis for manufacturing process:

1. Joining Operation:

This operation was done to attach all the other components of the product with the main body frame.

Table: Possible manufacturing process combination for main body frame

Serial no	Properties Considered	Decision numbers									
		1	2	3	4	5	6	7	8	9	10
1	Quality	1	1	0	0						
2	Easy to operate	0				0	1	1			
3	Operation time		0			1			0	0	

4	Good finishing			1			0		1		1
5	Low cost				1			0		1	0

Table: Weighting factors for body frame

Property	Positive decisions	Weighting factors
Quality	2	.2
Easy to operate	2	.2
Operation time	1	.1
Good finishing	3	.3
Low cost	2	.2
Total	10	1.0

Table: Scaled values of properties and performance index

Numerical value:

Very high	5
High	4
Medium	3
Low	2
Poor	1

Mfg. Process	Properties				
	Quality	Easy to operate	Operation time	Good finishing	Low cost
Arc	3	5	5	2	5

Tig	4	2	2	3	3
Mig	4	3	4	5	2

Welding process	Quality	Easy to operate	Operation time	Good finishing	Low cost	Performance index
Arc	75	100	100	40	100	77
Tig	100	40	40	60	60	62
Mig	100	60	60	100	40	76

Result: The rating was done between 100 scales and so after final calculation the rating point of Arc welding is the largest value. So, Arc welding is selected for the manufacturing of body frame.

2. Boring Operation:

This operation is done to increase the diameter of a previously drilled hole.

Table: Possible manufacturing process combination for boring operation

Serial no	Properties Considered	Decision numbers									
		1	2	3	4	5	6	7	8	9	10

1	Quality	1	0	0	0						
2	Operation time	0				0	0	1			
3	Good finishing		1			1			0	0	
4	Cost			1			1		1		0
5	Eco friendly				1			0		1	1

Table: Weighting factors for boring operation

Property	Positive decisions	Weighting factors
Quality	1	.1
Operation time	1	.1
Good finishing	2	.2
Cost	3	.3
Eco friendly	3	.3
Total	10	1.0

Table: Scaled values of properties and performance index

Mfg. Process	Properties				
	Quality	Easy to operate	Operation time	Good finishing	Low cost
Lathe machine	4	3	4	3	5
Drill Machine	5	5	3	5	3

Mfg. process	Quality	Operation time	Good finishing	Cost	Eco friendly	Performance index
Lathe machine	80	60	100	60	100	82
Drilling machine	100	100	75	100	60	83

Result: The rating was done between 100 scales and so after final calculation the rating point of Drilling machine is the largest value. So, Drilling machine is selected for boring operation.

3. Facing & Turning

Table: Possible manufacturing process combination for facing & turning operation

Serial no	Properties Considered	Decision numbers									
		1	2	3	4	5	6	7	8	9	10

1	Quality	1	1	1	1						
2	Operation time	0				0	0	1			
3	Good finishing		0			1			1	1	
4	Low cost			0			1		0		0
5	Eco friendly				0			0		0	1

Table: Weighting factors for boring operation

Property	Positive decisions	Weighting factors
Quality	4	.4
Operation time	1	.1
Good finishing	3	.3
Low cost	1	.1
Eco friendly	1	.1
Total	10	1.0

Table: Scaled values of properties and performance index

Manufacturing Process	Properties				
	Quality	Easy to operate	Operation time	Good finishing	Low cost
Lathe machine	5	5	3	5	3
Drill Machine	4	3	4	3	5

Mfg. process	Quality	Operation time	Good finishing	Low cost	Eco friendly	Performance index
Lathe machine	100	100	75	100	60	88.5
Drilling machine	80	60	100	60	100	84

Result: The rating was done between 100 scales and so after final calculation the rating point of Lathe machine is the largest value. So, Lathe machine is selected for facing and turning operation.

Chapter 10

Cost Analysis

Introduction

A cost benefit analysis (also known as a benefit cost analysis) is a process by which organizations can analyze decisions, systems or projects, or determine a value for intangibles. The model is built by identifying the benefits of an action as well as the associated costs, and subtracting the costs from benefits. When completed, a cost benefit analysis will yield concrete results that can be used to develop reasonable conclusions around the feasibility and/or advisability of a decision or situation.

Cost Analysis:

Machine & Associated Costs:

Drill Press: (Brand name: SKIL, China, Model No: 3320-01)

Buying Cost: 9550 Tk
Life: 5 years
Salvage: 2500 Tk
Quantity: 1
Considering salvage value, buying cost = 9550 - 2500 (P|F, 5.78%,5) = 7663 Tk

Circular Metal Cutter (CHOP SAW): (Brand name: PORTER-CABLE, USA, Model No: PCE700)

Buying Cost: 12800 Tk
Life: 5 years
Salvage: 4000 Tk
Quantity: 1
Considering salvage value, buying cost = 12800 - 4000 (P|F, 5.78%, 5) = 9780 Tk

Arc welding machine: (Brand name: AMICO, USA, Model No: SF-200A):

Buying Cost: 15690 Tk
Life: 3 years
Salvage: 5000 Tk
Quantity: 1

Considering salvage value, buying cost = 15690 - 5000 (P|F, 5.78%, 3) = 11466 Tk

Cost of furniture, computer & other accessories:

Total Furniture & accessories cost for office: 45000 Tk

Life: 10 yrs.

Salvage: 5000 Tk

Considering salvage value, buying cost = 45000 - 5000 (P|F, 5.78%, 10) = 42150 Tk

Computer cost: 50000 Tk

Life: 10 yrs.

Salvage: 5000 Tk

Considering salvage value, buying cost = 50000 - 5000(P|F, 5.78%, 10) = 47150 Tk

Costs of raw materials (per unit):

Mild Steel Angle:

Raw material required =50 Kg
Market price of raw material = 47.60 tk/kg
Total Raw Material cost = 2380 Tk

Manufacturing costs of different operations (per month):

1. **Measuring**

   Labor cost

   No of workers = 2

   Wage/labor = 6,000 Tk

   Total labor cost = 12,000 Tk.

2. **Cutting Labor cost**

   No of workers = 2

   Wage/labor = 7,000 Tk

   Total labor cost = 14,000 Tk.

3. **Turning operation**

   Labor cost

   No of workers = 2

   Wage/labor = 6,000 Tk.

   Total labor cost = 12,000 Tk.

4. **Assembly & Joining operation**

   Labor cost

   No of workers = 5

   Wage/labor = 8,000 Tk.

   Total labor cost = 40,000 Tk.

5. **Finishing operation**

   Labor cost

   No of workers = 2

   Wage/labor = 5000 Tk.

   Total labor cost = 10,000 Tk.

6. **Coloring Operation**

   Labor cost

   No of workers = 2

   Wage/labor = 5,000 Tk.

   Total labor cost = 10,000 Tk.

7. **Packaging Operation**

   Labor cost

   No of workers = 3

   Wage/labor = 7,000 Tk.

   Total labor cost = 21,000 Tk

   Total raw material: 2380 Tk. Per unit

   Total labor cost: 1,20,000 Tk. Per month

   Total unit of Production per year: 1,500

Total raw material cost per year: (1,500×2380) = 3570000 Tk.

Total labor cost per year: 1,20,000×12 = 14,40,000 Tk.

Purchasing Cost

Below is a list of parts which we are going to purchase

Serial No	Name of the components	Quantity	Price per unit (Tk)	Cost (Tk)
1	Bearing	4	130	520
2	Sprocket	2	150	300
3	Metal chain	2.028 m	400	811.2
4	Grinding Wheel	1	1407.95	1407.95
5	Cycle Seat	1	260	260
6	Bevel Gear & Pinion	1 pair	2660	2660
7	Padel	1 pair	500	500
8	Hacksaw Blade	1	250	250
9	Wooden wheel	1	-	-
			Total	6710

Total purchasing cost per year = 6710 × 1500 = 1065000 Tk

Manufacturing Cost

1. **Direct Material Cost**

Raw Material Cost: 1065000 Tk

Purchasing Cost: 1065000 Tk.

Direct material cost per year: (3570000 + 1065000) = 1065000 Tk

2. **Direct Labor Cost**

Labor Cost per year = 14,40,000 Tk.

Post	No. of post	Salary/person	Total(Tk.)
Production Manager	1	50000	50000
Manufacturing Engineer	1	35000	35000
Design Engineer	1	35000	35000
Assembly Manager	1	32000	32000
Guard(G4S)	2	7000	14000

Quality control Manager	1	25000	25000
Supply chain Engineer	1	25000	25000
Factory Space Rent			70000
Utilities Factory			50000
Power consumption			30000

Total = 366000 Tk

Total manufacturing overhead per year: (366000 × 12) = 43,92,000 Tk.

Total manufacturing Cost per year: (1065000+ 1440000 + 4392000) Tk = 15334500 Tk

Selling and Administrative Expenses:

Administrative Cost

Cost Item / Post	**No. of post**	**Salary/person**	**Total(Tk.)**
Chief Executive Officer	1	60,000	60,000
Security Manager	1	25,000	25,000
HR Manager	1	30,000	30,000
Accountant	1	25,000	25,000
Secretary	1	12,000	12,000
Clerk	2	7,000	14,000
Guard(G4S)	2	5,000	10,000
Office rent			20,000
Maintenance			10,000
Power Bill			6,000
Water Bill			2,000

Total = **2,14,000 Tk.**

Selling Expenses

Cost Item / Post	No. of post	Salary/person	Total(Tk.)
Marketing Executive	2	12000	24000
Advertising			20000
		Total	44000

Total Selling and Administrative expenses per month: (214000 + 44000) = 258000 Tk

Total Selling and Administrative expenses per year: (258000 × 12) = 3096000 Tk

Total unit of production per year: 1,500

Break Even Analysis

Fixed cost

Machine cost = 28900 Tk

Furniture and accessories cost = 43,400 Tk

Computer cost: 48,400 Tk.

Labor cost = 14,40,000 Tk

Fixed manufacturing overhead cost = 4392000 Tk

Fixed selling & administrative cost = 3096000 Tk

Total amount of fixed cost: 9048700 Tk. per year.

Variable cost (for the 1,500 products in the first year)

Raw material cost = 3570000 Tk

Purchasing cost per year = 1065000 Tk

Total variable cost per year: (3570000+ 1065000) = 4635000 Tk.

Total variable cost per unit production: (4635000 ÷ 1,500) = 3090 Tk.

Selling price per unit: 3090 + 40% of 3090 = 4326 Tk

The equation for Break Even Analysis:

At Beak Even Point,

Selling price × break-even unit (x) = Fixed cost + Variable cost

Total amount of fixed cost: 9048700 Tk

The total variable cost per unit: 3090 Tk

Selling price per unit: 4326 Tk

So the equation stands as:

$$4326\,x = 9048700 + 3090\,x$$

This yields $x \approx 7321$ units.

So the Break Even quantity is 7321 units for the first year.

Payback period is almost 4 years 11 months.

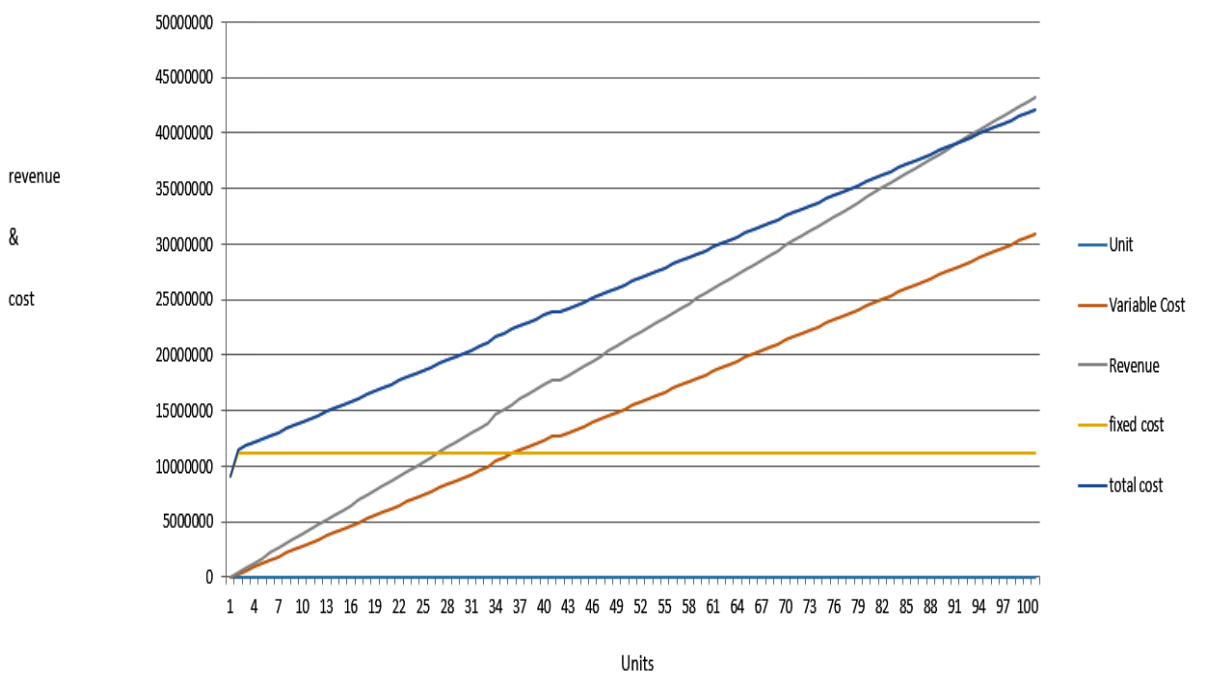


Fig: Graphical Representation of the Break-Even Analysis

Conclusion

Some of the costs used during cost analysis were estimates of actual value since we are not certain about their cost. But the estimates are reasonable and we have tried our best to show different types of costs related to the mass production of our product as extensively as possible. After the analysis, we can see that break-even quantity for our product is 4,042 units. The interpretation of that figure is: if sales amount is exactly 4,042 units cumulatively during the third year we will break even, i.e. total revenue will be equal to total cost. If sales amount is more than 4,042 units, we will have profit; otherwise loss. Another important point to be noted here is break-even analysis is based on some assumptions. Some of them are: variable cost per unit is the same regardless of the volume produced, fixed costs do not change with volume changes, the revenue per unit is the same regardless of volume etc. In real life not all of these assumptions hold correctly.

Chapter 11

Sensitivity Analysis

Introduction

The objective of cost analysis and sensitivity analysis is to understand the process of predicting the cost of products. Elements of traditional engineering economics are melded with manufacturing process modeling, life cycle cost management concepts, and selected concepts from environmental life cycle cost assessment to form a practical foundation for predicting the real cost of products.

By changing various parameters by 10% we have calculated the effect of the corresponding parameter on the Break-even quantity of product.

1. Sensitivity of Direct Material:

Total direct material cost per year = 10,65,000Tk
After 10 % increase total direct material cost= 10,65,000 Tk +10 % of 10,65,000Tk
= 11,71,500Tk

So, per unit direct material cost = (11,71,500 ÷ 1500)
=781Tk

Variable cost per unit = (11,71,500 +35,70,000) ÷ 1500 = 3161Tk

At Break Even Point
Selling price × unit of production, (x) = Fixed cost + Variable cost

4326 x = 9048700 + 3161 x

So, x ≈ 7768

Δx= {(7768-7321)/7321} *100
=6.10 %

From calculation we can see that, direct material cost is sensitive.

2. Sensitivity of Direct Labor:

Total direct labor cost = 14,40,000 Tk

After 10 % increase total direct labor cost per year = 14, 40,000 Tk + 10% of 14, 40,000 Tk

= 15,84,000 Tk

So, per unit direct material cost = (15, 84,000+46, 35,000) ÷ 1500 Tk = 4146 Tk

At Beak Even Point,

Selling price × unit of production, (x) = Fixed cost+ Variable cost

$4326\,x = 1584000 + 4146\,x$

$x=8800$

$\Delta x= \{(8800-7321)/ 7321\} * 100$

$=20.20\ \%$

From calculation we can see that, direct labor cost is relatively sensitive.

3. Sensitivity of Fixed Manufacturing Overhead:

Total fixed manufacturing overhead = 43,92,000 Tk

After 10 % increase total manufacturing overhead per year = 48,31,200Tk

Total fixed cost becomes = 9048700 Tk + 43,92,000 of 10% Tk

= 94,87,900 Tk

At Beak Even Point,

Selling price × unit of production, (x) = Fixed cost+ Variable cost

$4326\,x = 94,87,900 + 3161\,x$

So, $x = 8145$

$\Delta x= \{(8145-7321)/7321\} *100$

$=11.24\ \%$

From calculation we can see that, fixed manufacturing overhead cost is relatively sensitive.

4. Sensitivity of Variable Manufacturing Overhead:

Total variable manufacturing overhead cost = 43,92,000 Tk

After 10 % increase it becomes = 43,92,000 Tk

Total variable cost becomes = 46,35,000 Tk + 43,92,000 × 0.1 Tk

= 50,74,200 Tk

So variable cost per unit = 50,74,200 ÷ 1500 = 3,383 Tk

At Beak Even Point,

Selling price × unit of production, (x) = Fixed cost+ Variable cost

4326 x = 9048700 + 3383 x

So, x = 9596

Δx= {(9596-7321)/7321} *100 =31.07 %

From calculation we can see that, variable manufacturing overhead cost is much sensitive.

5. Sensitivity of Selling & Administrative Cost:

Total selling & administrative cost per year = 30,96,000 Tk

After 10 % increase it becomes = 34,05,600 Tk

So total fixed cost per year = (34,05,600 Tk + 4635000)/1500=5361 Tk

At Beak Even Point,

Selling price × unit of production, (x) = Fixed cost+ Variable cost

4326 x = 9358400 + 5361 x

x=9004

Δx= {(9004-7321)/7321} *100

=22.98 %

From calculation we can see that, selling & administrative cost is relatively sensitive.

Result of Sensitivity Analysis

The results we got from sensitivity analysis:

Direct material cost is sensitive.

Direct labor cost is relatively sensitive.

Fixed manufacturing overhead cost is relatively sensitive.

Variable manufacturing overhead cost is much sensitive.

Selling & administrative cost is relatively sensitive.

Conclusion

We can conclude that we have made Cost analysis, Break Even analysis and Sensitivity analysis for our product for developing a better product design approach. Cost analysis helped us estimate the payback period by examining the break-even point. Sensitivity analysis helped us determine which parameters are sensitive (i.e. change in that parameter results in large change in break-even point) and which are not.

Chapter 12

Plant Layout

Plant layout design of a new manufacturing facility for the production of "Versatile Machining Tools"

Introduction

Facility Location is the right location for the manufacturing facility which will have sufficient access to the raw material, workers, transportation, market and customer.

Successful facility location decisions may lead to drastic cost reductions as well as an improvement in the customer service levels. An unsuccessful facility location decision may lead to inefficient operations and additional costs which drastically affects the competency and effectiveness of the overall operation. A production unit is the place where all inputs such as raw material, equipment, skilled labors, etc. come together and manufacture products for customers. One of the most crucial factors is determining the right facility location for that production unit.

Location of the industry for Versatile Machining Tools:

For the production of **Versatile Machining Tools**, the selected location is situated in ***Keranigan***, Bangladesh. Different factors have affected our decision of moving the factory out of Dhaka but in the close proximity of it. The different factors that we have considered are listed below.

Customer Proximity:

We have selected the location closer to the area in which the customers of our product are mostly available. As our product is a machining device and this area has so many local

manufacturing companies that needs machining devices consist of drilling, sawing, and grinding, etc. And our product has these three operational tools. So, this location full fill the customer proximity requirements.

Distance:

Keranigan is the best place for transportation of raw materials and workers. Because it is situated beside the Buriganga river. And we all know transportation through river is very easy and very cheap.

Availability of Cheap Labor:

It's expected to find cheap and skilled labor in the proximity of our selected location which has motivated us in order to select the location for our industry.

Suppliers & Availability of Raw Material:

The raw materials of our product & the suppliers are available in this area. Though our industry near the river so that the raw material supply and transport becomes smooth and easy for us.

Environmental Policy:

Now a days everybody is concern about environmental safety factor. During manufacturing of our product there will be no harmful impact in the environment.

So, these are all the factors that has been considered by thorough analysis in order to select the facility location of our plant. We expect that the facility that we have selected will be most suitable for our product.

Rules of Plant Layout:

(i) Minimum Movement:

Materials and labor should be moved over minimum distances; saving cost and time of transportation and material handling.

(ii) Effective of Space Utilization:

All available cubic space should be effectively utilized – both horizontally and vertically.

(iii) Flexibility:

Layout should be flexible enough to be adaptable to changes required by expansion or technological development.

(iv) Interdependence:

Interdependent operations and processes should be located in close proximity to each other; to minimize product travel.

(v) Overall Integration:

All the plant facilities and services should be fully integrated into a single operating unit; to minimize cost of production.

(vi) Safety:

There should be in-built provision in the design of layout, to provide for comfort and safety of workers.

(vii) Smooth Flow:

The layout should be so designed as to reduce work bottlenecks and facilitate uninterrupted flow of work throughout the plant.

(viii) Economy:

The layout should aim at effecting economy in terms of investment in fixed assets.

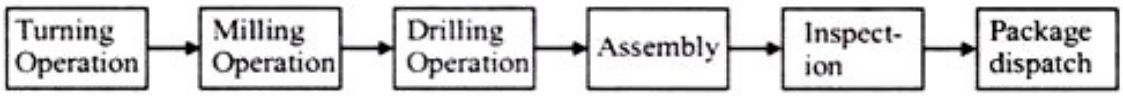
Types of Plant Layout:

Two basic plans of the arrangement of manufacturing facilities are – product layout and process layout. The only other alternative is a combination of product layout and process layouts, in the same plant.

(a) Product Layout (or Line Layout):

In this type of layout, all the machines are arranged in the sequence, as required to produce a specific product. It is called line layout because machines are arranged in a straight line. The raw materials are fed at one end and taken out as finished product to the other end.

Special purpose machines are used which perform the required jobs (i.e. functions) quickly and reliably.



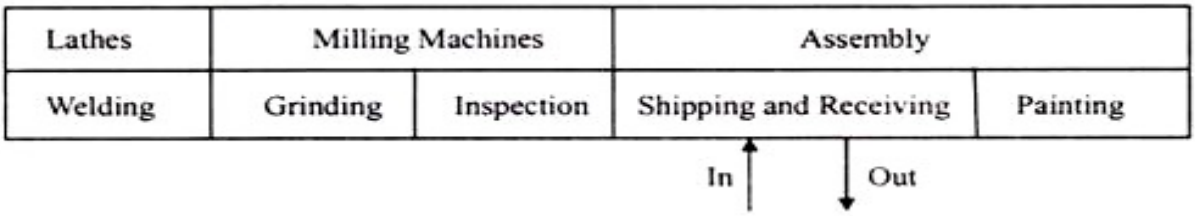
Suitability of product layout:

Product layout is suitable in the following cases:

1. Where one or few standardized products are manufactured.
2. Where a large volume of production of each item has to travel the production process, over a considerable period of time.
3. Where time and motion studies can be done to determine the rate of work.
4. Where a possibility of a good balance of labor and equipment exists.
5. Where minimum of inspection is required, during sequence of operations.
6. Where materials and products permit bulk or continuous handling by mechanical parts.
7. Where minimum of set-ups is required

(b) Process Layout (or Functional Layout):

In this type of layout, all machines performing similar type of operations are grouped at one location i.e. all lathes, milling machines etc. are grouped in the shop and they will be clustered in like groups.



Suitability of process layout:

Process layout is suitable in the following cases, where:

1. Non-standardized products are manufactured; as the emphasis is on special orders.
2. It is difficult to achieve good labor and equipment balance.
3. Production is not carried on a large scale.
4. It is difficult to undertake adequate time and motion studies.
5. It is frequently necessary to use the same machine or work station for two or more difficult operations.
6. During the sequence of operations, many inspections are required.
7. Process may have to be brought to work, instead of **"vice-versa"**; because materials or products are too large or heavy to permit bulk or continuous handling by mechanical means.

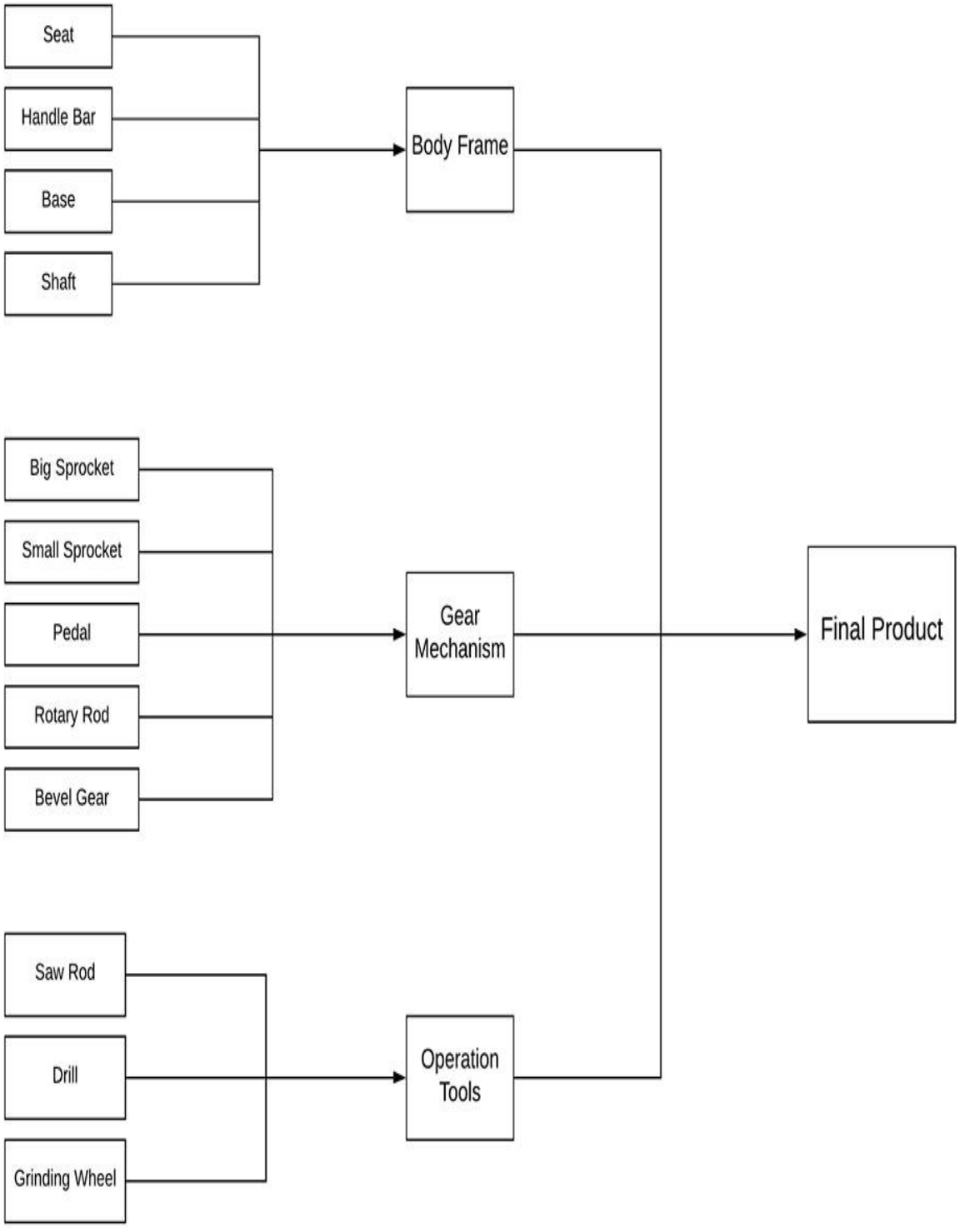
(c) Combination Layout:

In practice, plants are rarely laid out either in product or process layout form. Generally, a combination of the two basic layouts is employed; to derive the advantages of both systems of layout. For example, refrigerator manufacturing uses a combination layout.

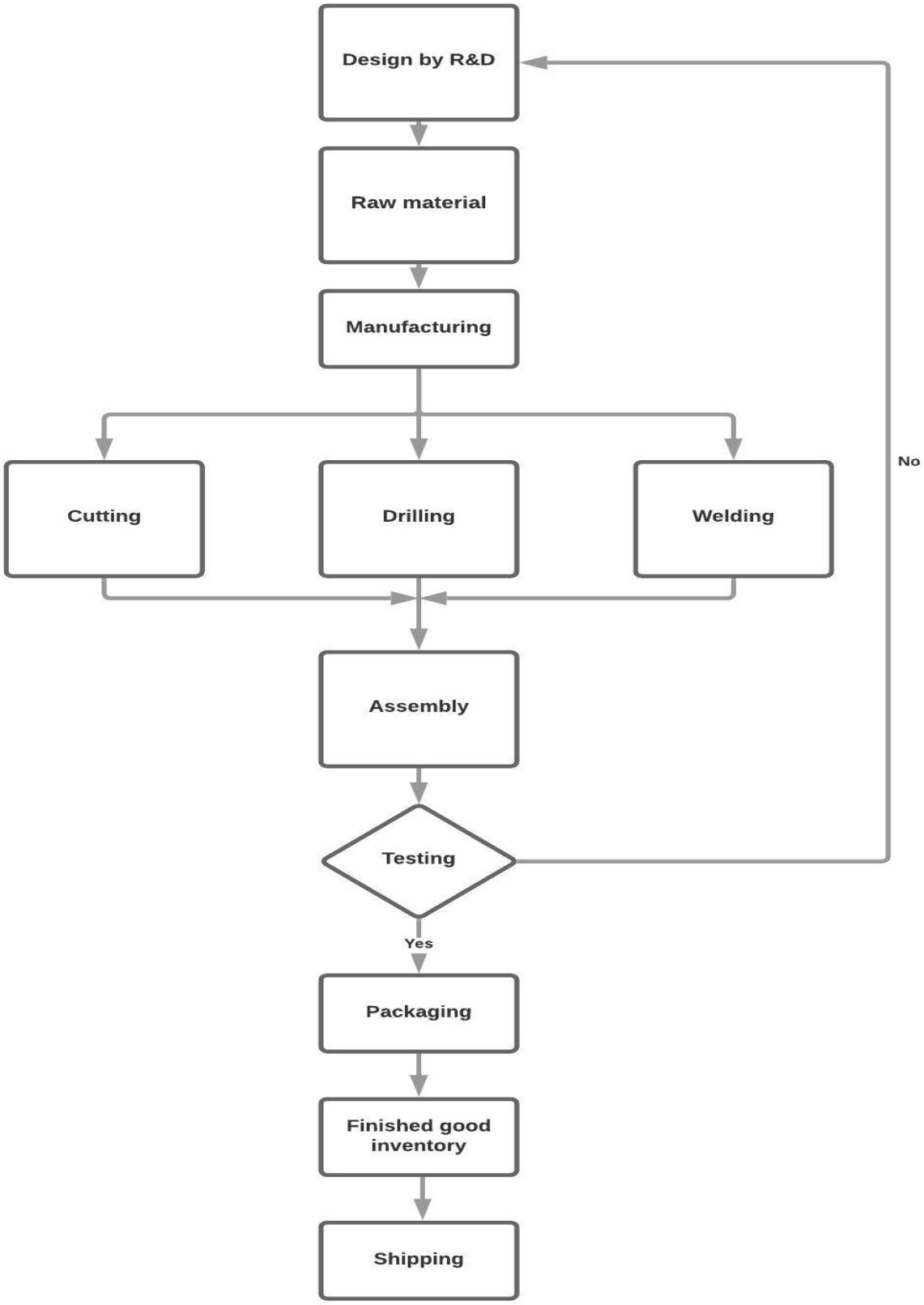
Process layout is used to produce various operations like stamping, welding, heat treatment being carried out in different work centers as per requirement. The final assembly of the product is done in a product type layout.

(d) Fixed Position Layout:

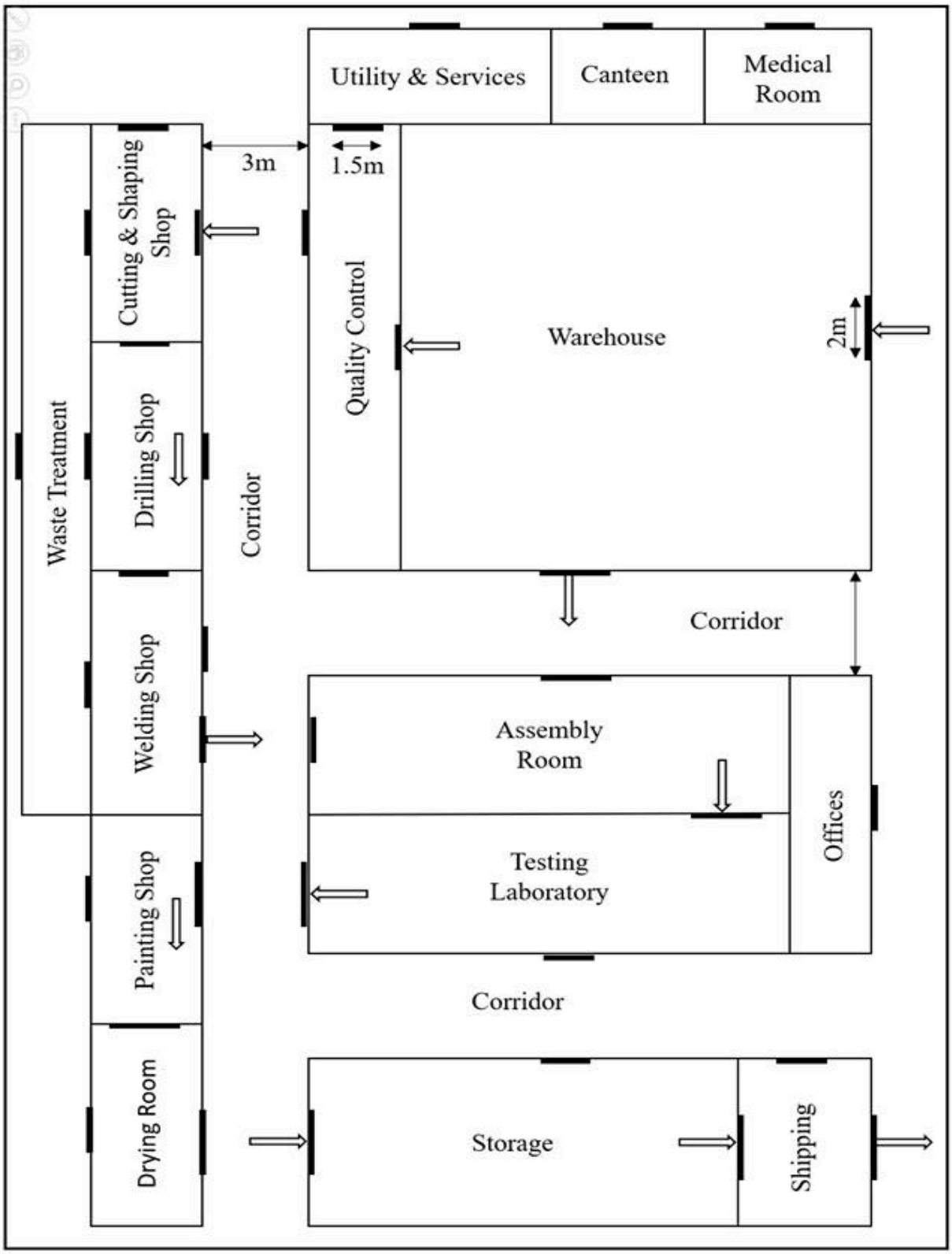
It is also called stationary layout. In this type of layout men, materials and machines are brought to a product that remains in one place owing to its size. Ship-building, air-craft manufacturing, wagon building, heavy construction of dams, bridges, buildings etc. are typical examples of such layout.


Seat
Handle Bar
Base
Shaft
Body Frame
Big Sprocket
Small Sprocket
Pedal
Rotary Rod
Bevel Gear
Gear Mechanism
Final Product
Saw Rod
Drill
Grinding Wheel
Operation Tools

Process Flow Chart:



Plant Layout (2D):



Plant Layout (3D):

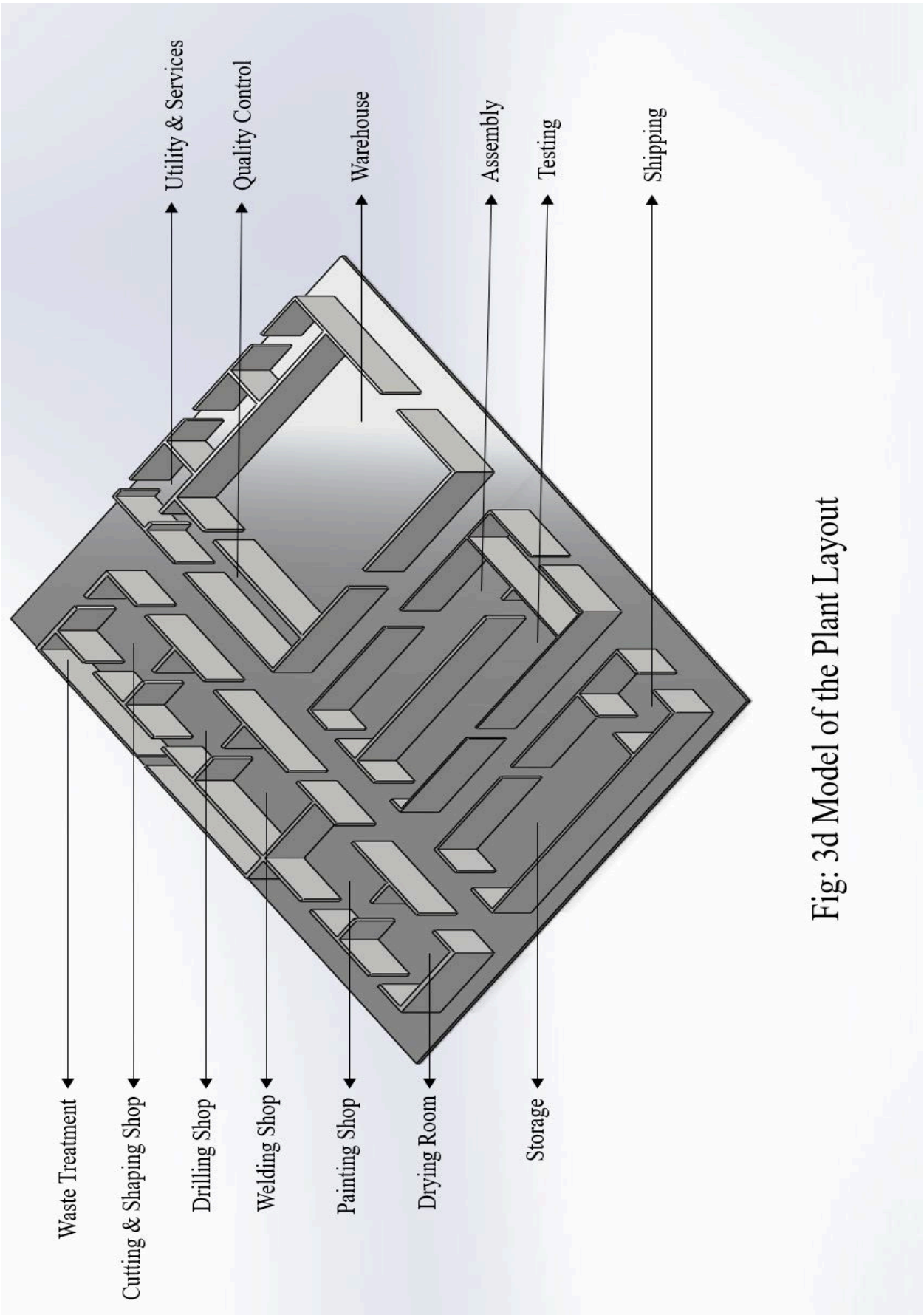
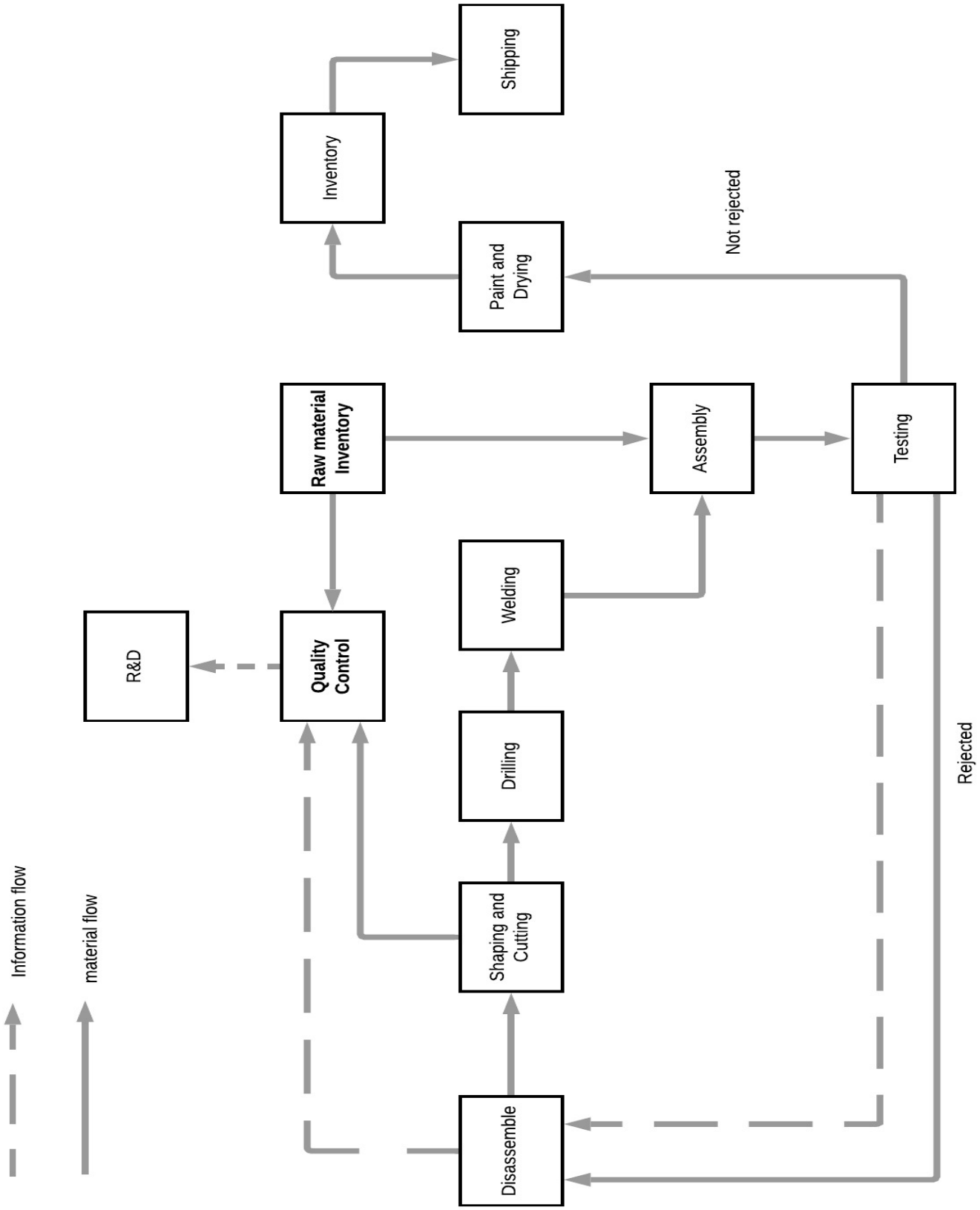


Fig: 3d Model of the Plant Layout

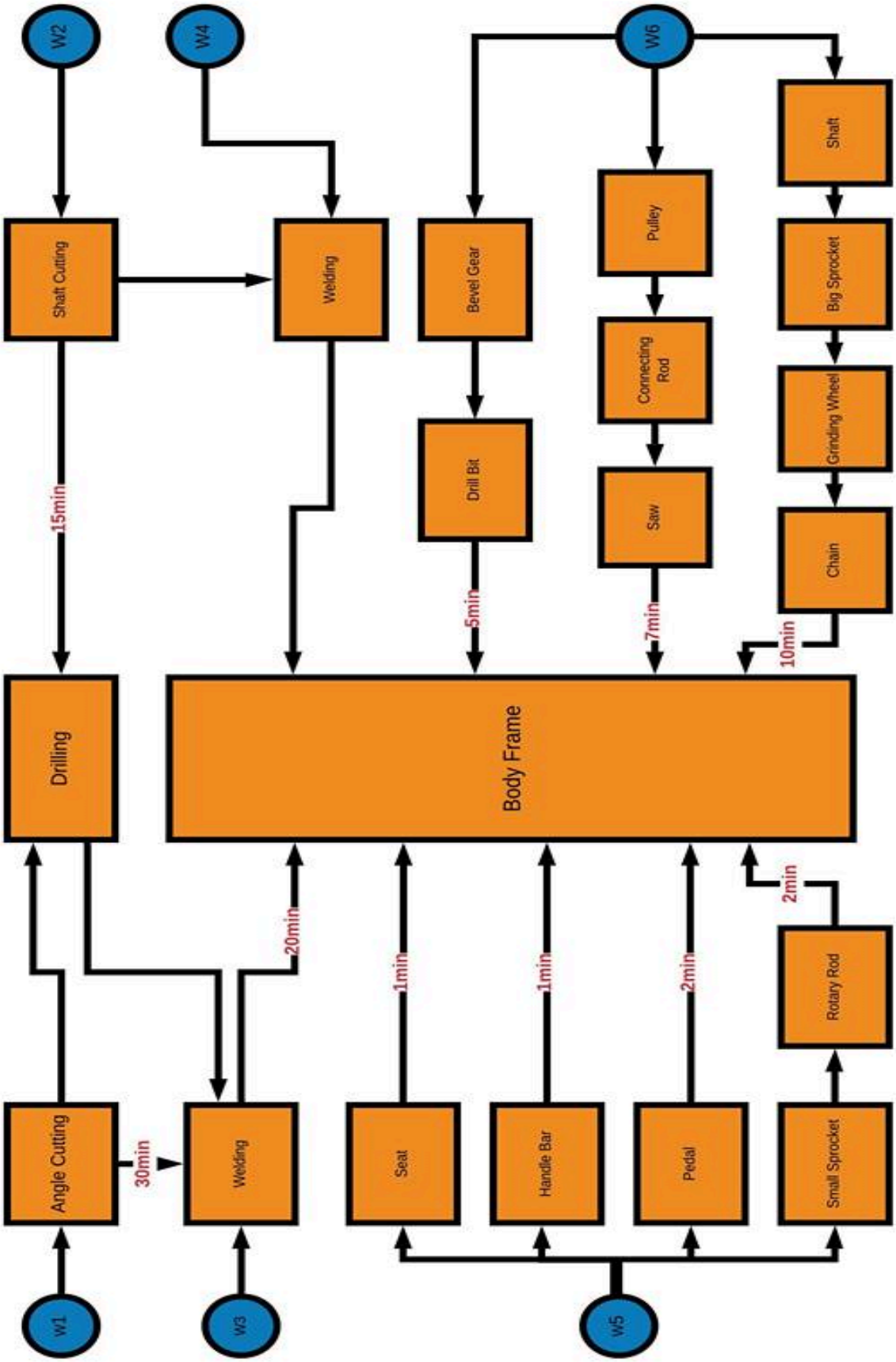
Cluster Analysis of Process Layout:



Unit	Name of Unit	Dimension	Purpose
1	Gate 1	20ft	For entering vehicle For entering Employees
2	Warehouse	6000sqft	For keeping raw materials and purchased goods
3	Cutting and Shaping shop	700sqft	For cutting and shaping of raw materials
4	Welding shop	700sqft	For joining materials
5	Drilling shop	700sqft	For drilling materials
6	Assembly area	1500sqft	For assembling all the materials
7	Painting shop	700sqft	For painting after assembly
8	Drying room	700sqft	For drying after painting
9	Finished Goods Inventory	6000sqft	For keeping before shipping
10	Shipping area	2000sqft	For shipping and loading
11	Quality Control	150sqft	Ensuring Product quality
12	Testing Laboratory	1500sqft	For fatigue, hardness, elasticity testing
13	R&D department	150sqft	To find the most optimized design
14	Utility and services	200sqft	To provide materials in the shops if anything goes wrong
15	Canteen	1000sqft	To provide food to the employees
16	Medical room	150sqft	To provide medical service
17	Offices	120x6sqft	For administrative works
18	Waste Treatment	600sqft	To disposal of wastes
19	Guards room (2)	60x2sqft	For monitoring the security
20	Power room	100sqft	To provide power to the plant
21	Parking Lot	800sqft	For parking vehicles
22	Gate 2	20ft	For exiting vehicle For exiting Employees

Activities	machines	Process time In Minutes	Value added / non value added process
Material importing to workshop from inventory	Forklift	25	Non value added
Angle + shaft cutting process	Circular Metal Cutter (CHOP SAW	30	Value added
Drilling process	Drill Press	15	Value added
Joining process	Electric Arc welding machine	20	Value added
Temporary joint	Bolt joint	10	Value added
Assembly	Worker	22	Non value added
Quality check and testing	Worker	10	Non value added
Painting + drying	metal spray painting machine	25	Value added
Packaging	Worker	10	Non value added
		Total time = 167	

Process activities with time consideration:



Chapter 13

Floor Marking

Floor marking design of a new manufacturing facility for the production of "Versatile Machining Tools"

Introduction

What is floor marking?

Floor marking is the process of using visual cues such as lines, shapes, and signs on floors to make a space easier for people to navigate. These cues divide spaces, highlight hazards, outline workstations and storage locations, direct traffic, and convey important safety or instructional information. Floor marking is often part of a larger visual communication system that includes wall signs and labels.

Why use floor marking?

Floor markings are a common topic of discussion in the manufacturing and warehousing industries. If you don't know the benefits of floor markings or where to use them, this can be confusing. The following are some key reasons why so many facilities use industrial floor markings.

- **Organizational Improvement** - Any increase in organization at a facility will reduce wasted time and energy. Identifying storage or staging areas, for example, can quickly let people know where things need to be.

- **Finding First Aid Equipment** - In the event of an emergency, every second is critical. Having floor markings that can lead employees or emergency responders to things like fire extinguishers, emergency eye wash stations, first aid kits, and automated electronic defibrillators (AEDs) can minimize injury or even avoid deaths.

- **Lean** & **5S Methodologies** - When following the lean or 5S methodologies to eliminate waste in your facility, you can benefit from using proper floor markings. You can also follow the 5S floor marking color standards to maximize effectiveness.

- **Personal Protection Equipment** - Using floor markings to alert people to when PPE is necessary is very effective. For example, your facility may use a dotted red line to indicate respiratory protection is required beyond a set point.

- **Navigation Assistance** - Given the size and scope of many facilities, having floor markings to guide people can be very helpful. One color may lead to the nearest exit, another color to the main office, and so on.

- **Placement of Objects** - There are hundreds or even thousands of objects placed throughout most facilities. Things like pallets, inventory, garbage cans, and more. Using floor markings to indicate where they should be placed when not in use can help improve organization.

- **Traffic Direction** - Any areas where there are vehicles driving, the floor markings can act like lines on a normal road. They can let people know where they should be driving, which direction, and even at what speed. Just make a set of traffic standards and train everyone on them.

Floor marking applications:

- **Traffic routes -** Pedestrian and vehicular pathway markings are probably the most common use of floor marking tapes. Forklift collisions with workers are a major cause of workplace fatalities, which is a good indicator of how important clearly marked traffic routes are. Marking emergency exit routes is also important; exit floor markings can include directional arrows and glow-in- the-dark1 lines. Ideally, route markings should be so easy to understand that people can navigate safely through a facility without any prior training.
- **Hazardous area -** Employers often fail to protect workers from falls. The lack of safety resources is routinely one of OSHA's top cited violations. Communicate potentially hazardous areas with floor marking barriers and messages. Communicate hazards by: placing markings in front of a potentially hazardous piece of equipment like a conveyor; in an area that contains a known hazard like a high number of particulates in the air; and placing markings in front of electrical panels where arc flash is a risk.

- **Product and material storage -** Some facilities mark product and material storage areas. These can be temporary storage areas, such as products that are currently being worked on, or more long-term storage areas, such as raw material storage bins or finished inventory. The point of labeling these areas is to easily communicate to workers where resources should go and where to find them when they're needed. The reduction in worker confusion results in greater efficiency and safety. This use of floor marking and wayfinding can also be considered part of a lean manufacturing2 or 5S3 initiative.
- **Equipment & tools -** Many facilities have outlines around equipment and tools. For example, a white line of tape may be applied around the base of a portable machine or tool to let workers know where that object is supposed to be located. This ensures workers will never waste time searching for the resources they need. This use of floor marking also can fall under a 5S lean manufacturing program. A floor outline around a machine can also indicate if a part like a swinging arm extends beyond the equipment's footprint.

Benefits of floor making:

- **Organizational Improvement** - Any increase in organization at a facility will reduce wasted time and energy. Identifying storage or staging areas, for example, can quickly let people know where things need to be.
- **Finding First Aid Equipment** - In the event of an emergency, every second is critical. Having floor markings that can lead employees or emergency responders to things like fire extinguishers, emergency eye wash stations, first aid kits, and automated electronic defibrillators (AEDs) can minimize injury or even avoid deaths.
- **Lean and 5S Methodologies** - When following the lean or 5S methodologies to eliminate waste in your facility, you can benefit from using proper floor markings. You can also follow the 5S floor making color standards to maximize effectiveness.
- **Personal Protection Equipment** - Using floor markings to alert people to when PPE is necessary is very effective. For example, your facility may use a dotted red line to indicate respiratory protection is required beyond a set point.

- **Navigation Assistance** - Given the size and scope of many facilities, having floor markings to guide people can be very helpful. One color may lead to the nearest exit, another color to the main office, and so on.
- **Placement of Objects** - There are hundreds or even thousands of objects placed throughout most facilities. Things like pallets, inventory, garbage cans, and more. Using floor markings to indicate where they should be placed when not in use can help improve organization.
- **Traffic Direction** - Any areas where there are vehicles driving, the floor markings can act like lines on a normal road. They can let people know where they should be driving, which direction, and even at what speed. Just make a set of traffic standards and train everyone on them.

5S in floor marking:

Far more than colorful lines and simple geometric shapes that help mitigate hazards, floor marking is a useful organizational tool that can prove invaluable for anyone designing a straightforward 5S program. In the same way that floor marking can be used to delineate hazards within the workplace, it can also be used as a vivid visual reminder of where tools should be, where a workspace begins and ends, and how traffic should flow through an area. This allows floor marking to be used to not only improve safety, but to also enhance overall efficiency and reduce time and money losses related to confusion over how processes should flow and where tools and materials should be located.

1. Seiri (Sort)

The first pillar of 5S can be described as a cleaning effort. The goal is to make work easier and more efficient by leaving only crucial, must-have items in the workspace, such as tools and materials. Anything that is not used in the completion of a worker's prescribed task is removed. If these extraneous items can't be disposed of immediately, they should be placed into a dedicated Red Tag area for later disposal.

2. Seiton (Set in Order)

Though the second 5S pillar is concerned primarily with sorting all necessary items into appropriate places, the key to success here is repetition. It's not enough to simply put something

in the right place once; You must put it in the right place each time it's used. Through repetition, it becomes increasingly easy to find the right tool or materials as they're needed, which makes all tasks flow more smoothly.

Floor marking proves invaluable here, as it helps to create discrete locations for tools, materials, and anything else a worker may need. Outlining the position of objects in a workspace ensures that they'll find their way back in the event that they need to be used elsewhere in the facility.

3. Seiso (Shine)

This too is a pillar in which floor marking can shine (pardon the pun). The seiso pillar has two components: The cleaning of the workspace, and the maintenance of this cleanliness into the future. The core idea is that a clean workspace is less likely to fall into disorder, and that by focusing on maintaining a high level of cleanliness, workers are actively engaged in fighting off the chaos that inevitably creeps into any workspace over time. Floor markings can aid in these efforts by clearly blocking off areas for cleaning, storage, transit, and any other task that may occur in the workspace.

4. Seiketsu (Standardize)

The fourth S, seiketsu, is concerned with standardization. This is the pillar in which all of the progress created by the cleaning and organization efforts of the first three pillars is formalized into a set of procedures that can be utilized well into the future. Repetition of these procedures cements them into a worker's daily routine, driving further increases in efficiency, safety, and productivity. Thoughtful floor marking is useful here as it creates a vibrant, visual reminder of the processes that have been created, and the need to keep the workspace in order.

5. Shitsuke (Sustain)

Finally, we come to shitsuke, the last of the 5S pillars. The goal of shitsuke is instilling in workers and management a sense of self-discipline through which they can maintain the benefits created by the first four pillars. If employees are inherently motivated to take progressive action toward maintaining and improving their workspace, the workspace is far less likely to become chaotic, dangerous, and inefficient. Here, the floor markings you've placed as part of the prior four pillars, serve as unmistakable reminders of a facility's ongoing 5S efforts, and, in turn, keep workers and management focused on proactive maintenance and improving efficiency when possible.

Floor marking making methods:

- **Permanen**t:
- **Temporary**:

Choosing the best floor marking method:

Floor Marking Tape	Traditional Paint
No fumes	Fumes require ventilation, the wearing of PPE & possible shutdown
No time needed to dry	Needs time to dry
No spills	Spills likely
Up to 5 years, depending on traffic/exposure	Up to 7 years, depending on traffic/exposure
Preparation requires only cleaning floor	Extensive preparation time
Minimal application equipment required	May require brushes &/or rollers, taping, drop cloths etc.
No equipment required	Fumes require ventilation, the wearing of
Application does not usually interrupt work	Application will usually disrupt work for extended period
Can be quickly applied	Not designed for quick application

Method Selection:

The selected method for floor marking of the desired plant is temporary which is using Floor Marking Tape.

Reasons for method selection:

The production of the plant will not be high for the first few months or years. The warehouse, finished goods storage and other facilities have been initially kept for a considerable size for first few years. But there are rooms for enlargement at every section. The warehouse, and finished goods inventory can be large after few years. So, the marking will also be changed after some years. That's why floor marking tape will be used for floor marking method.

Tape Selection:

Different types of tapes have to be selected for different sections of the plant.

Tape	Section	Reason for Selection
Rigid	Warehouse.	Good for heavy demand environment.
Lite	Welding shop.	Good for hazardous area.
Flex	Assembly area, painting and drying area, finished good inventory, shipping area.	Good for medium demand environment.
Tread	Cutting and drilling shop.	Good for marking machinery.

Floor Marking process:

Standards and Assumptions:

OSHA clarifications: Floor marking is mentioned in OSHA 29 CFR 1910.22, titled "Walking-Working Surfaces." It reads: "Permanent aisles and passageways shall be appropriately marked." In a follow-up interpretation to this, OSHA clarified that this rule does not necessarily mean that floor markings are required (for example, a dirt floor would be near-impossible to apply tape or paint to), and that there are other methods of appropriately marking aisles and passageways. The interpretation pointed out that applying floor marking was typically the most convenient and inexpensive method of meeting that requirement.

Another important OSHA interpretation regards aisle-marking sizes:

- The lines used to delineate the aisles may be any color so long as they clearly define the area considered as aisle.
- The recommended width of aisle markings varies from 2" to 6". To ensure maximum visibility, any width 2" or more is considered acceptable.

- The recommended width of aisles is at least 3' wider than the largest equipment to be utilized, or a minimum of 4'.

Regulations of color: The United States has no specific regulations regarding floor marking colors, unless you are using floor marking to signal physical hazards or emergency safety equipment. OSHA standard 29 CFR 1910.144, titled the "Safety color code for marking physical hazards," sets requirements for using the colors red and yellow for very specific applications. While regulations are lacking, consistency is key. Maintaining a consistent floor marking color system will ensure the employees understand walking-working surfaces and potential hazards on the job.

Marking with Glow Tape: Glow-in-the-dark labeling materials allow for clearly marked exit pathways even in the event of power outages or smoky conditions. This technology is becoming increasingly popular in facilities. In some regions it is even legally required. The technical name for "glow" materials is photoluminescent. Phosphorescent tape is a specific kind of photoluminescent tape that absorbs energy from a light source during normal operating conditions and glows when that light source is removed. The light that phosphorescent tape provides is not enough to illuminate an area, but it is enough to make paths and doors visible when lights go out.

Color Codes:

Color	Sections
	Warehouse, Shipping area.
	Quality control, Testing area.
	Assembly area.
	Cutting and Shaping shop, Drilling shop.
	Painting and Drying area.
	Finished goods inventory, Warehouse.
	Waste treatment.
	Material moving carts walkway.
	Welding shop.

Implementations of 5s:

Sort: Every type of operations has a specific section in the plant. Where only the specific machineries required for the operation are kept, which will help to improve productivity.

Set in Order: Different colors have been used to mark the floor. Workflow has also been shown through arrows. Warehouse and machineries are also marked by the marking tapes so that they can be placed in perfect positions.

Shine: Wastes from different operations like cutting, drilling is to be shifted in waste treatment section, which has the objective of disposal of theses wastes. So, the work area will be clean and the morale of the workers can be lifted up.

Standardize: Floor tapes and marks are being placed perfectly so that every can know where they are going, what they are supposed to do in that section, if they have to be careful in that area or not. Which can help the workers to complete their routine work easily.

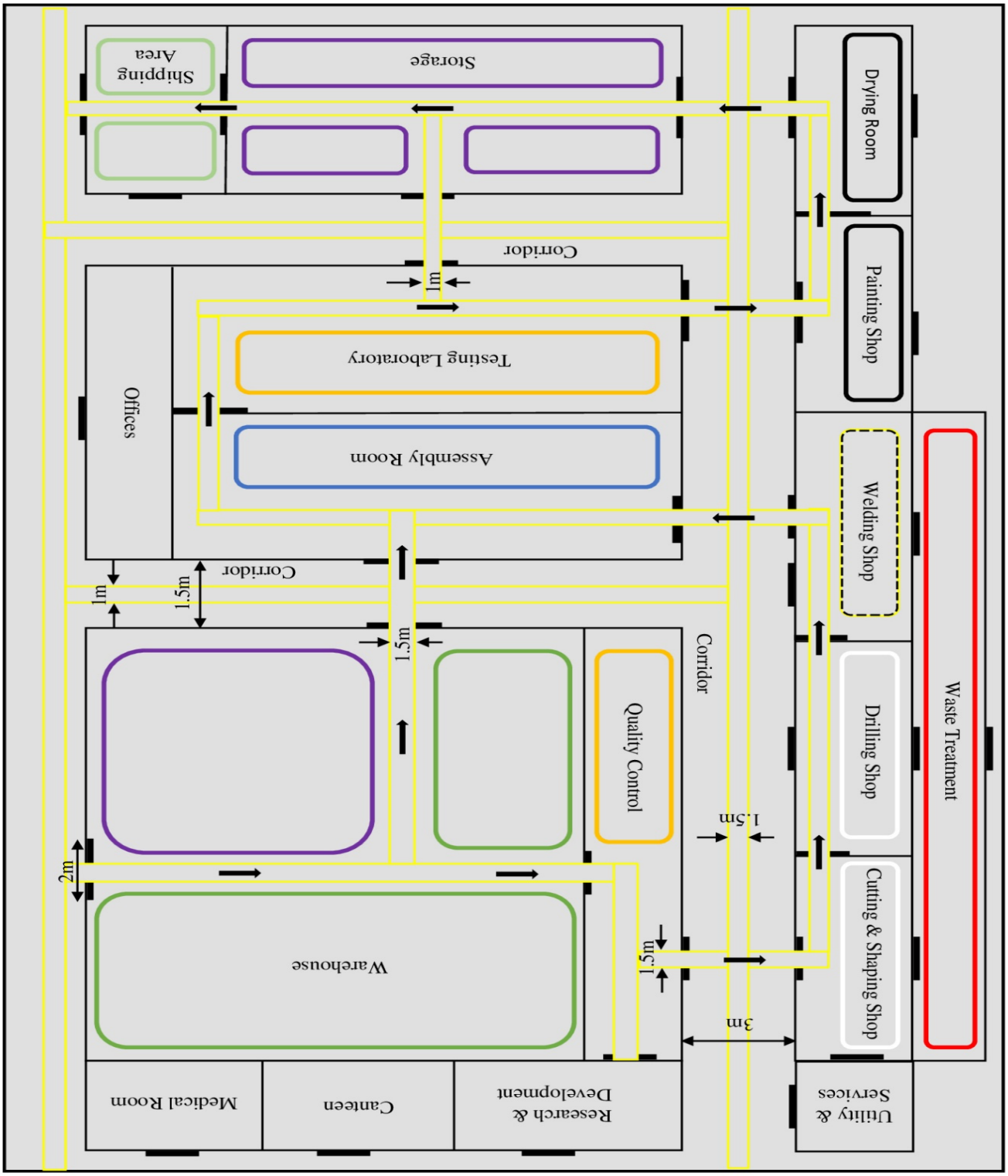
Sustain: All the specific sections for each operation, floor markings and signs will help to grow self-discipline in the workers, which will become an integral part of their working hours.

Discussion:

Different colors have been used for marking the floor of the plan. All of them have different size and each color serve different purpose.

- **Green:** It has been used for marking the warehouse and shipping area. In the warehouse, green color means there are required material for cutting and shaping which is mild steel. That will be used to made the body of the product.
- **Purple:** It has been used in the finished good inventory and warehouse. In warehouse, purple color means there are materials which will go directly to the assembly room which are gears, cutters, bolts, bearings, screws etc.
- **White:** It has been used to mark the machineries in cutting and drilling sections.
- **Yellow and Black stripes:** This color is generally used for marking the hazardous area like electric panel. In this plan it has been used to mark the electric panels of the welding area which can cause heath issues.
- **Blue:** It has been used to mark assembly area of the product in the plant.
- **Orange:** It has been used in the area where the materials are hold for inspection like quality control and testing area after the assembly.
- **Black:** It has been used for the painting and drying area.
- **Red:** In this area all the wastes from various operational processes are kept for disposal.
- **Yellow:** It has been used to mark the floor to show the pedestrian and equipment traffic lanes, aisles, and pathways. Different measurements are used for this color markings.
    - 1.5meter: 1.5m gap has been maintained where equipment traffic will be available.
    - 1meter: 1m gap has been maintained where only the pedestrian walkway is available.

Floor Marking:



Conclusion:

Marking the floor of the plant with different colors and signs doesn't only show the path but also creates a work environment which helps to increase the morale of the worker as well as the productivity. A perfect floor marking can be achieved by fulfilling the 5s. For this plan every pillar of the 5s have been achieved. By maintain the cleanliness of each and every section of the plant the morale of the worker can be lifted up, which can be achieved by floor marking. Many types of accidents and hazardous events can also be avoided by a proper floor marking of the plant. Without proper floor marking the efficiency will be lower of the worker and chances get bigger for accidents. Thus, floor marking is essential for a plant.