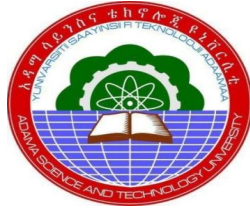


ADAMA SCIENCE AND TECHNOLOGY UNIVERSITY
School Of Mechanical, Chemical and Material Engineering



Thesis/Project title:-

**Designing and Manufacturing Aluminum Profile Cutting
Machine**

*A Thesis/Project submitted in partial fulfillment of
the requirements for the award of the degree of
Master of Science*

In

Manufacturing Technology Teachers Education

By

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Department of Mechanical and Vehicle

June 2015

Adama

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Advisor	Signature	Date

CANDIDATE DECLARATION

We hereby declare that the work which is being presented in this project entitle “***Designing and Manufacturing Aluminum Profile Cutting Machine***”, is our original work and has not been presented for a diploma / degree of any other Institution/University and we have acknowledged and referenced all materials used in this work.

Candidate	Signature	Date
1. Birhane Assafa	_____	_____
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4. Zeleke Amdine	_____	_____

This is to certify that the above declaration made by the candidates is correct to the best of my knowledge and belief. This project has been submitted for examination with my approval.

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Advisor	Signature	Date

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ABSTRACT

Aluminum work is a current expansion for building construction work in Ethiopia. Now a days industries need different and fast technologies in order to fabricate doors, windows, staircase, hand rails and supports, railings for verandas, partitions, structures and corridors in Ethiopia. The problem of SME and private sector on Aluminum profiles cutting operation is done traditionally fabrication product of Aluminum profiles and assembly, this operation process leads to using without clamp (holding work piece by hand), the machine when work easily hot, no work peace supporter, no safety guard of chip, limited to 0-90° adjust cutting angles and when cut by itself unexpected angle formed so on. These machines have side effect that cause burn, injury, unsatisfied of operator on work due to safety guard (chip scatter), loss concentration on work and is not accurate joint of Aluminum profiles parts.

The objective of this research to solve those problem, Aluminum profiles cutting machine with a capability of making perfect cutting operations and joint on Aluminum work area is required to be designed and manufactured that operates electrically. The scope of project has designed and analysis of Aluminum profile cutting machine, fabrication of the machine and testing the machine for its functionality.

To achieve this, an observation has been made in the selected cities (Adama SMEs, private sector of Aluminum work, distributes Aluminum profiles and Adama small and micro enterprise office) and data are collected via observation, semi-structured interviews, group discussions, and questionnaire surveys with key actors along the value chain. Based on the data analyzed, an improved Aluminum profiles cutting machine has designed and manufactured to improve the efficiency of the users.

Type of material for machine assigned for shaft, pulley, key, U-channel will be respectively mild steel, Aluminum Duralumin alloy, Carbon steel, Mild steel as economical and strength to hold all load acting on the machine.

The result of this project electrical operated Aluminum profiles cutting technology is studied out with a suspended inner shaft structure which is to be driven using belt drive mechanism. And also maximum cutting size capacity 100x77mm, the guider slide 220mm, measure and cut angle 0-180° Generally, this research to has solved the problem of SMEs and privet sector on the fabrication of aluminum work, to show an alternate direction how possible to design and manufacture cost competent Aluminum profile cutting machine equipped with safety cover and having work holding clamp, adjustable angle of cut and graduation of degree. So that cutting machine designed and material selection and manufacture part, assembling and expected testing done. This machine is helpful for the enterprises in making accurate cutting angle and assembly on the door and window frames by minimizing production time, reducing material wastage and improving the quality of the product fabrication and assembly.

Key Words: - Manufacturing, design, Aluminum profile, cutting, SME, Profile

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LIST OF ABBREVIATIONS, SYMBOLS AND ACRONYMS

SME: -	Small Micro Enterprise
Φ : -	Diameter
Al: -	Aluminum
M: -	Metric
&:-	And
α :-	Alpha
b :-	Bett
AISI:-	American Iron & Steel Institute
SAE:-	Society of Automotive Engineers
ASTM: -	American Society for Testing & Material
AA: -	Aluminum Association
PM: -	Preventive maintenance
N: -	Newton
N-m:-	Newton meter
mm:-	Millimeter
M:-	Metric thread
ISO: -	Standard of International Organization
W: -	Watt
KW:-	Kilowatt
Mpa:-	Mega Pascal
KN:-	Kilo Newton
M: -	Meter
Kg:-	Kilogram
CAD: -	Computer Aided Design
N/mm ² :-	Pascal
Rpm: -	Revolution per minute
Hrs:-	Hours
Eth.birr:-	Ethiopian birr

CHAPTER ONE: - NTRODUCTION

1.1 Background

Adama town lies on the eastern part of Ethiopia 100 km from Addis Ababa. It is one of the big city in Ethiopia in which large number of private and government organizations involved in manufacturing, service giving and construction sector. Small scale metal manufacturing enterprises which are owned by individual entrepreneurs and firms owned by shareholders currently involved in fabrication of window, frame, door, stairs and furniture using local human labor.

The evolutionary process of blacksmith has contributed to the creation and development of modern metal works. Generally, the development process of Adama metal works depends on the economic growth of local area and the country in general. Basically the demand for metal work products are a function of various economic variables, among them urbanization rate, population growth rate, income level etc. and development of other economic sectors such as construction, agriculture, industry etc. are also positively affect the growth of metal works.

Small scale metal manufacturing Enterprises play a crucial role in the social and economic development of a country. It is recognized that this sector provides not only employment opportunities to an increasing number of people but it is also an effective means of fighting poverty and improving income inequality.

The activities which are carried out frequently in small scale metal manufacturing enterprises in a daily basis are welding, drilling, grinding, cutting, bending and sheet metal work. These activities are implemented by local human labor with low technical skill and knowledge. The project is focused on the problem of Aluminum profile cutting while making windows, staircases, frames and doors with different profiles. Almost all of Aluminum profiles cutting tasks are taking place by trial and error without using appropriate tools and equipment which leads to wastage of materials and production time as well as decrease the quality of the product.

Aluminum profile is one of the most important semi-finished products used in the Aluminum industry, and Aluminum profile technology in construction industries is therefore an important engineering discipline within the area of mechanical engineering [29].

Aluminum profiles are building material products made from Aluminum. The products are used for doors, windows, stair case etc. Aluminum products are popular because they are light, strong and they do not rust. They are commonly used for modern commercial buildings [29].

The major end user of aluminum profiles and frames is the building construction sector. The reason is the product is a structure which is to be fitted to windows and doors. Although various types of profiles and frames are manufactured locally the source of aluminum profiles and frames is mainly from import.

The demand for aluminum frames and profiles is related with the expansion of the building industry. As stated in other relevant project ideas, there has been a huge expansion in the building industry during the last 10-14 years in almost all parts of the country. Along with it, the uses of aluminum frames and profiles have been also expanding. Today, it is common to see many residential houses, and multistory buildings being fitted with aluminum frames and profiles. As a result of increased demand for these products, many enterprises which produce the frames and profiles are established in Addis Ababa. As indicated above, the demand for aluminum frames and profiles is directly related to the construction activities. The national plan has forecasted that construction sector will grow as annual average growth rate of 14.9%. To arrive at a conservative estimate a 10% annual growth rate is adopted for aluminum frames and profiles [6].

Having more than a quarter of the country's population and similar size of the economy as well as increase in building construction, there is enough demand for aluminum profiles and frames which can justify the establishment of aluminum profiles and frames making plant in Amhara region[11].

The project is expected to find solution for the problem occurred in small scale metal manufacturing enterprises in making metal work products of different Aluminum profiles by trial and error in the fabrication process. Based upon this idea the project is aimed to design and manufacture Aluminum profiles cutting machine to address the problem of the enterprises in fabricating and assembling Aluminum profiles products with different shape and size. Boundless creativity, maximum flexibility and proven reliability offer a broad spectrum of possible solutions for the task in question.

Aluminum profiles cutting machine is fabricating variety of profile geometries and sizes that allow optimal adaptation to prevailing technical and economic conditions [29].

This paper has designed to improve the manufacturing process in assembling and fabricating door, window, frame, furniture and stairs with different profiles. In small scale enterprises by designing and manufacturing of Aluminum profiles cutting machine using the principle of machine tool cutting. So that this project gives answer to what this exceptional range of construction profiles was designed for the profiles to be cut in to length and assembled.

1.2 Statement of the problem

Productivity growth with efficient use of resources is a precondition for increasing people's living standards and maintaining competitiveness in the globalized economy. Small scale metal manufacturing enterprises have a great potential to generate employment for the majority of the urban labor force. They are also important sources of income for those people who could not find employment in other sectors.

It is clear that the larger the number of the small scale enterprises especially those engaged in manufacturing are the more likely to produce new jobs. Expansion of the small scale metal manufacturing enterprises would help development of entrepreneurial, technical and managerial skills of the organization. Since small scale metal manufacturing enterprises tend to be labor intensive and use low level of capital, expansion of these sector is necessary to increase employment and income growth and allowing for sustainable increment of productivity through improvement in technology.

Small scale metal manufacturing workshops nowadays highly involved in fabrication of metal furniture, building doors, windows, stairs etc. of different design according to needs of the customer using semi-finished metal products such as Aluminum profiles and Aluminum sheet metal imitation frames. In the manufacturing process the enterprises have faced with certain challenges in fabricating the above metal work products with different profile of angle. Having this limitation, try to apply Aluminum profiles cutting processes to get the desired profile while making metal work products by traditional methods. Manufacturing of metal of work products in the absence of the right manufacturing process, the right equipment and machinery, the correct material and sufficient skill leads to low product quality, inefficient and uneconomical way of

production system, decreases customer satisfaction and finally has a negative impact on the development of the enterprises.

The major problem to study on the SME's in the aluminum fabrication process problem faced like Aluminum profile joining window and door is mostly fabricated by power hack saw, portable grinding machine, manual hacksaw cutting process, and other metal cutting machines having the following problems.

- Poor ergonomic consideration work
- High cost of labor and spare parts;
- High initial investment cost;
- dimension errors
- Need skilled operator
- High machine setting up and measuring time
- Unappropriate cutting angle.
- Poor profile assembly joint
- The Motor easily hot

In order to improve such manufacturing system to a better standard, have used of appropriate Aluminum profiles cutting machines and manufacturing process is essential. Therefore this project is aimed to change the existing production system by design and manufacturing of Aluminum profiles cutting machine. Commonly, Hacksaw, portable cutting grinder machine is used to cut Aluminum profile at different construction sites, those leads a lot of problem of cut, an error of sizes, shapes, and not good assembly at the end. Generally the design and manufacture of Aluminum profile cutting machine replace those old machine to reduce the error of cut. This machine has designed to cut Aluminum profile at different angle; which guided on the table saw provided with graduation angle and guide way.

1.3 Objective

1.3.1 General objective

The main objective of this project has designed and manufacture Aluminum profile cutting machine for small scale metal manufacturing enterprises of Adama city in order to maximize the productivity, quality of product and reducing wastage of material, human labor, time and power

consumption on work of different profile in fabrication for perfect cutting of aluminum profile used for building construction works.

1.3.2 Specific objective

- Identify the problem of small scale enterprises encountered on the fabrication process using Aluminum profile cutting principles.
- To design detail analysis of Aluminum profile cutting machine.
- To manufacture the Aluminum profiles cutting machine parts.
- To select material for design according to purpose of the parts.
- To select Manufacturing Technology process of machine parts.
- To select jigs and fixtures to enable manufacturing of machine parts.
- To assemble the product according to sequence of component or sub-assemble.
- To finish and paint assemble machine.
- To test the functionality of Aluminum profiles cutting machines.

1.4 Significance of the project

The main contribution of this project is to design and construct the electrical power operated Aluminum profiles cutting machine used for small micro enterprise which replaces the conventional Aluminum cutting machine. In this aspect the project helps the SMEs to use electrical power with low maintenance cost, local technology with less noise and no environmental pollution.

Specifically, the project is useful for the manufacturing enterprises as well as for the community in the following aspects:-

- ✓ Improve customer satisfaction by providing quality products;
- ✓ Minimizing cost of product so as to provide products with low price;
- ✓ It increases productivity by reducing the time required for Aluminum profiles cutting;
- ✓ It increases employee efficiency by reducing unnecessary working steps;
- ✓ Enterprises can get high profit by minimizing material wastage;
- ✓ Enterprises own option with modern manufacturing process;
- ✓ Enhancing technology transfer;
- ✓ Reduce the foreign currency for importing Aluminum profiles and cutting machine;
- ✓ Local resource utilization;

- ✓ Develop knowledge and skill of production and assembly of Aluminum profiles;
- ✓ Develop optimum production capacity of Aluminum profiles machine.

1.5 Advantage of the project

- Saves time in preparation and assembly;
- Reduce machining time;
- Reduce operator stress and tension on the predetermined specification and design.

1.6 Limitation of the project

Due to the unpopularity of the project in Ethiopia especially in the project area the availability of the references related to the study was Challenge to attain the objective.

- As schedule the budget is not released on time.
- It Works only where electric power is available,
- Shortages of budget and time constraints.

1.7 Scope of the project

The project has designed for perfect cutting of Aluminum profile in to size especially to fabricate windows, doors, frames, stairs cases, structures and partitions in Enterprises of Adama city. On this area, the fabrication system of small scale metal manufacturing enterprises is assessed. In this project, attention is focused to evaluate the manufacturing system of small scale metal manufacturing enterprises in Adama city especially in Aluminum profiles cutting process while producing building doors, windows , stairs cases, frames and furnitures using imitation frames with the following tasks:-

- ❖ Design and analysis of Aluminum profiles cutting machine;
- ❖ Fabrication of the machine;
- ❖ Testing the machine for its functionality.

1.8 Organization of the project

This thesis is composed of seven chapters. The first chapter presents the problem addressed related Aluminum profiles cutting machine and is including about background, problem statement, objectives, scope and significance of the project. Chapter two discusses related literature on Aluminum profiles cutting machine, related machines and problem on the existing machine and gap indication for the problem. The third chapter presents the research methodology employed to achieve the thesis objective including instrument development, sample selection, data collected and data analysis. Chapter four introduces the design analysis and material selection of critical components. Chapter five addressed manufacturing process by the process and Operation sheet for critical components, Procedures of assembling components and maintenance of the project. The sixth chapter computes the total cost by adding costs of raw materials and standard items, labor cost for manufacturing and assembling components, Electrical power consumption cost and Machine Depreciation Cost to manufactured parts required for fabricating the project. And also explains how the project works efficiently and technical feasibility like Operational, Economic, Efficient and Affordable concerning this project. In the last chapter, findings are discussed; conclusions and recommendations are given to over the entire thesis project.

CHAPTER TWO:-REVIEW LITERATURE

2.1 Introduction

Materials like metals and wood are often cut using sawing machines. Metal sawing is like any other metal processing method and it is governed by similar cutting requirements. Sawing is used because of its some characteristics advantages like speed of cutting, low wastage of material, good quality of dimensional accuracy and low power consumption.

Saw is a multipoint cutting tool, which is used in sawing operation. In this operation a large number of teeth move through the work piece, each successive tooth deepens the cut made by its predecessor tooth. Feed is given either to the saw or the work piece. Straight or curved profile may be cut by controlling the direction of feed motion. Most of the stock materials are received in its standard size and shape. Therefore, the stock material is required to be cut to convenient length before being fed to the machine tool for its further processing. Not only in length, but quite often we may have to cut the bar stock in all direction to bring it roughly to the required shape and size. This may save lots of processing time. All these requirements and the economic considerations have made the power driven metal cutting saws almost indispensable now-a-days [15].

2.2 Classification of Sawing Machines

Metal sawing is one of the inevitable operations of metal shaping. Metal sawing cuts the metal into two or more pieces as per the requirement with exact dimensional accuracy. It is categorized into different categories depending upon the profile of saw tooth. Different machine tools are available to run the saw in a predetermined manner. In general the sawing machines are classified as [24]:

- Reciprocating saw (Power Hacksaw)
- Band saws
- Circular saw

Before describing each of the above sawing machinists will be better to understand the common components of any type of sawing machines.

The common components of a sawing machine are:

- (a) The saw (saw blade)
- (b) Machine
- (c) Fixture holding the saw

- (d) Driving mechanism
- (e) Work table
- (f) Feed mechanism.

Saw

The saw or saw blade is the one of the most important component of a sawing machine. Saws are characterized by their material, tooth form, teeth set, tooth spacing and size. Good quality metal cutting saws are made of high carbon or high speed steel. However, some circular saws may have inserted cemented carbide teeth.

Hack saw (power saw) and band saws are generally made solid. Circular saws may make solid or segmental with several teeth on each segment or with individual tooth inserts. Diamond tooth blades are used for machining of ceramics or likewise hard materials. The geometry of the teeth is singular to that of the single point tools. Two commonly used forms for saw blades. The straight tooth form is suitable for finer pitches whereas the undercut face tooth forms are used for coarser pitches. Undercut tooth form is better from design point of view, because the cutting edges are backed up by more metal. It is very difficult to have this tooth form if teeth are very small in size [24].

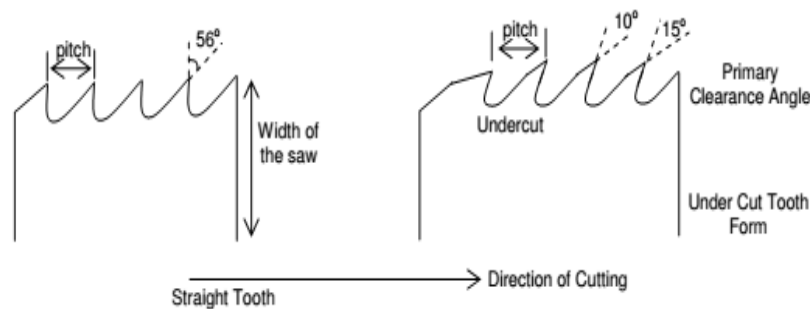


Fig 2.1 Tooth forms

Saw teeth are given an offset to the side known as tooth set to produce cuts which are wider than thickness of the back of the blade or disc. This enables the saw to move freely without friction. There are three common type of saw. Tooth set refers to how the teeth are bent or offset to one side of the other and the amount of the offset. The set makes the cut or kerf wider than the blade thickness so that the blade will not stick or bind.

Common types of tooth sets are described below.

I. Straight Set

When the teeth are offset alternatively to the right and left, it is called straight set or alternated set. This set is most suitable for non-ferrous metals and non-metals.

II. Wavy Set

It is also called circular set. In this case several teeth are offset in one direction and then several other teeth are offset in opposite direction. This set is employed with small teeth. It is used for sawing thin sheet sand sections.

III. Raker Set

It consists of one tooth is offset to the left, the next tooth is offset to the right then third tooth is unbent. This form is repeated in raker set. This set is used for cutting ferrous metals unless the metal thickness is too thin.

There is a specialty of circular saw that, it is made with alternate high and low teeth, straight and beveled teeth. These profiles help in breaking the chips, permit load distribution and allow some teeth to take finishing cuts.

In addition to the tooth form some other parameters concerned with saw characteristics are described below.

Blade Material

Generally blades are made of carbon steels, tungsten alloy steel, high speed tungsten steel, molybdenum steel and cemented carbide. Most of the saws are solid; however, some saws have the teeth of hard material backed by flexible steel. A few of the saws have tipped or (brazed) inserted bits as teeth.

Tooth Spacing (Pitch)

Tooth spacing or pitch has a significant influence on the performance of saw. The space between the teeth provides room for chips removed during the cutting operation. Smaller pitches are said finer pitches and larger pitches are said coarse pitches. Coarse pitches are required for longer cuts required in case of softer materials to accommodate the larger chips. Fine pitches are recommended for harder materials. To cut the thin sections a fine pitch is again recommended, the idea is two or more teeth should remain in contact with work piece, at a time, to prevent stripping of the teeth.

For band saws the pitch should be very fine is 0.75mm for hack saw or power saw the recommended value of pitch is 1.5 mm. Coarse band saw and power saw may have a pitch as

high as 12 mm. In case of circular saws value of pitch may vary from 5 mm for small saws to 50 mm for larger diameter saws. The large diameter saws with large pitch value are used for cutting of softer materials.

Cutting Speed of a Saw

Cutting speed for sawing is determined by the same considerations as for any other machining operation. Normally power driven hack saws are equipped with 3 or 5 speeds in their working mechanism. The speed of a saw is expressed as number of strokes per minute with high carbon steel blade; the higher speed should be used in cutting mild steel and other soft materials with HSS blade all materials can be processed at appreciable higher speeds. The cutting speed can also express as meter per second (MPs). In this expression length of a blade also matters a lot along with number of strokes per unit time.

Feed Rate of the Blade

Feed rate in case of sawing is the movement of the saw into the work piece at right angle to the direction of cutting. It is expressed in mm/sec or mm/stroke. Feed rate determines the depth of cut taken by each other, it should be so adjusted that the force exerted by the work piece on the saw in the opposite direction of feed is as high as the blade would permit without any damage to it. Higher the feed rate higher will be the force exerted by the work piece on the blade. Feed rate is a big problem in case manual sawing, it is not possible to maintain a definite and uniform feed rate, so manual sawing is considered inferior from feed point of view.

Machine Size and Specifications

Different types of sawing motions are required for cutting action. Depending upon the cutting actions three types of sawing machines are there. Reciprocating or power hack sawing, circular sawing and bend sawing. The size of a machine is usually designated by the maximum size of the bar stock of any geometry (work piece) that can be accommodate for processing other parameters that specify a machine are detailed below.

Length of Blade

Minimum and maximum length of the blade can be accommodated on a machine.

Maximum Length of Stroke

Stroke length of the blade can be set to any value but maximum up to active length of the blade.

Number of Strokes per Minute

Different discrete values of number of strokes per minute are available in a machine in a range. As we know that number of strokes per minutes and stroke length together decides the cutting speed of the work.

Power of Motor

A sawing machine is also identified by its power of the motor used to provide different movements to all of its motive parts as prime mover. Motor should be enough powerful to provide desired movements to all the motive parts simultaneously. Power of motor is normally expressed in H.P. or K.W. (horsepower or kilowatts).

Type of Drive and Lift

The other important parameter used to specify a machine is type of drive. That means how the power is transferred to various motive parts from prime mover. Type of power transmission may be belt drive, gear drive, etc. Type of lift should also be specified for a machine which may be manual hydraulic pneumatic, etc.

2.2.1 Power Hack Saw

These machines are also unknown as heavy duty power hack saw or production hack saws. These are heavier in construction and are provided with some additional accessories. In these machines work table may hydraulically operate. The work piece is rigidly clamped on the work table in vice built in there. A number of rods, bars or other sections can be grouped together and clamped to cut them simultaneously to the desired size. A special purpose fixture having a stop can be designed on the work table to maintain the dimensional accuracy of work piece efficiently. This can avoid the repetitive measurement exercise during its operation.

In these machines, most of the operations like moving the stacked stock to required length each time, clamping of stacked material, raising of saw frame after cutting is over, circulation of cutting fluid, etc. are hydraulically controlled. Some of the power saws maintain these controlling operations very accurately as these are computer numerically controlled. A line diagram indicating construction of a reciprocating power saw (heavy duty) [5].

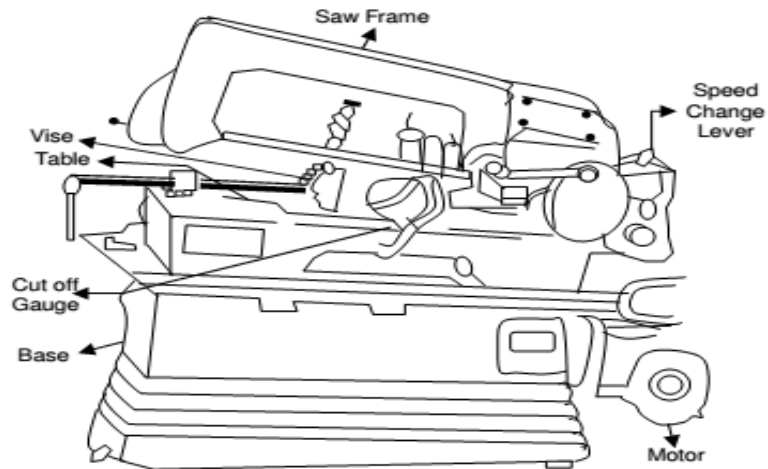


Fig 2.2. Reciprocating power hack saw

2.2.2. Band Saw Machines

Band saw consist of endless saw blade sued to a greater extent for cut off and straight sawing operations for metals since they enable the width of the kerf to be substantially reduced. They are used in special power band sawing machines. A continuous saw blade runs over the rims of two wheels on the machine. Normally two types of band saw machines are used. These are vertical band saw and horizontal band saw.

2.2.2.1 Vertical band saw machine

Line diagram of main parts of a vertical band saw machine is shown in figure 2.3 different parts are described below.

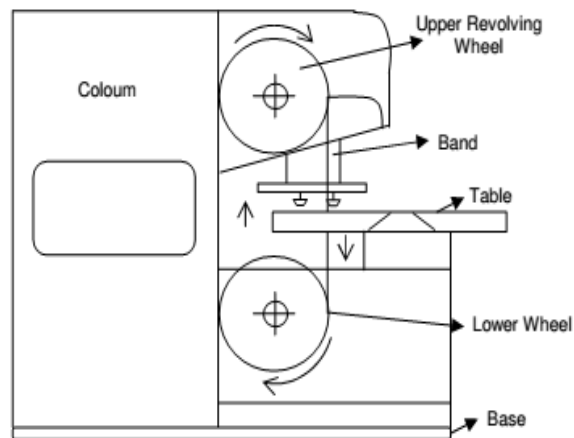


Fig.2.3 vertical band saw

2.2.2.2 Horizontal band saw

It is also named as cut off band saw machine. Its line diagram indicating construction of working. It also carries two revolving wheels which have their axis in horizontal plane. A endless band saw is loaded over the two wheels. A tension control mechanism is there by varying center distance between the wheels slightly. Two guides are available on the path of the band to avoid abnormal bending angle and breakage.

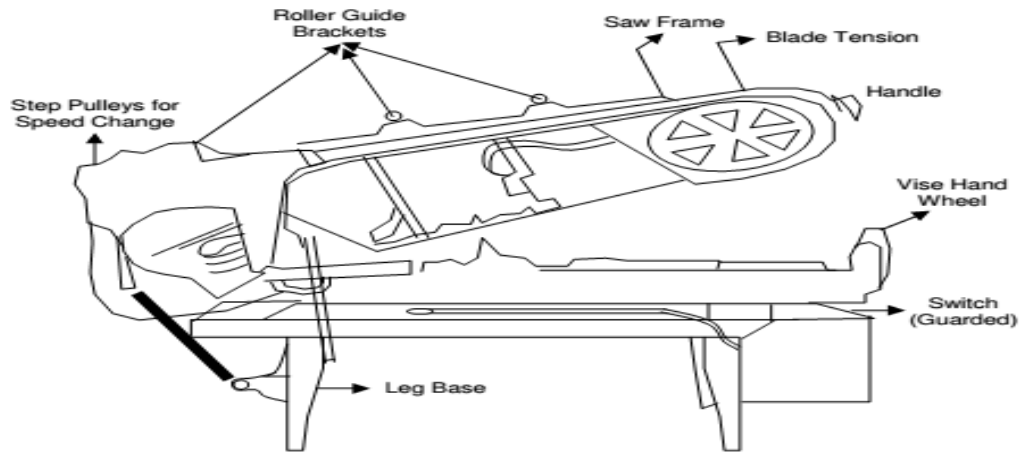


Fig.2.4 Horizontal band saw

2.2.3. Circular Saw

The circular saw was invented around the end of the 18th century as a rip saw to convert logs into lumber timber) in sawmills and various claims have been made as to who invented the circular saw. Before the design was invented logs were sawn by hand using a pit saw or using powered saws in a sawmill using an up-and-down saw with a reciprocating motion. The rotary nature of the circular saw requires more power to operate but cuts faster because the teeth are in constant motion. The sound of the circular saw is different from the sound of an up-and-down saw and earned it the nickname buzz-saw.

Sawmills first used smaller diameter circular saws to re saw dimension lumber such as lath and wall studs and for edging boards. As the technology advanced large diameter saw blades began to be used for the head saws and to cut clapboards.

Claims to the invention of the circular saw include:

- A common claim is for a little-known sail maker named Samuel Miller of Southampton, England who obtained a patent in 1777 for a saw windmill. However the specification for

this only mentions the form of the saw incidentally, probably indicating that it was not his invention.

- Gervinus of Germany is often credited with inventing the circular saw in 1780.
- Walter Taylor of Southampton had the block making contract for Portsmouth Dockyard. In about 1762 he built a saw mill where he roughed out the blocks. This was replaced by another mill in 1781. Descriptions of his machinery there in the 1790s show that he had circular saws. Taylor patented two other improvements to block making but not the circular saw. This suggests either that he did not invent it or that he published his invention without patenting it (which would mean it was no longer patentable).
- Another claim is that it originated in Holland in the sixteenth or seventeenth century. This may be correct, but nothing more precise is known.
- The use of a large circular saw in a saw mill is said to have been invented in 1813 by Tabitha Babbitt, a Shaker inventor, after she noted the inefficiency of the traditional saw pits used by the sawyers in her community and sought an improvement.
- The Bar ringer, Manners and Wallis factory in Rock Valley Mansfield, Nottinghamshire also claims to be the site of the invention [15].

2.3 Survey on Existing Machine

2.3.1 Small and micro enterprises and private sector in Adama town

At Adama city on SMEs and privates which produce aluminum work products. But all of them have no comfortable uses Aluminum profiles cutting machine rather than they used existing working methods of Aluminum profile cutting using without clamp (holding work piece by hand), no work piece supporter, no safety guard of chip ,limited to 0-90°, when cut by itself unexpected angle formed and on work time not consider ergonomic.



Sources: - Gada SME's
Fig.2.5Grinding cutting



Source; - KAS Engineering Fabrication & Installation of Aluminum
Figure 2.6 Metal cutting

With the bases of the above survey we decided Design and Manufacture Aluminum Profile Cutting Machine. This machine operates electrically and resolves the shortages of machine that we have observed in our survey especially in SMEs and privet sector in Adama city and its surrounding.

Aluminum profiles cutting machine is produce a variety of profile geometries cutting to size and angle cutting allows optimal adaptation to fundamental technically and economically [29].

Aluminum profile cutting machine used for cutting processes operated electrical system by sliding the cutter blade, the work piece, clamped with the guide at the required cutting angle or straight (to the size), the angle graduation from 0-180⁰ and it has safety guard. The machine easily move from one place to other work site.

CHAPTER THREE: MATERIAL AND METHODOLOGY

3.1 Introduction

This chapter presents the research methodology employed to achieve the thesis objective including instrument development, sample selection, data collected and data analysis.

For the purpose of the project to be successful, experimental research method is used to identify key issues and key variables. Experimental research might involve a literature search or conducting focus group interviews. The experiment of new phenomena can help our need for better understanding and test the feasibility of a more extensive study, or determine the best methods to be used in a subsequent study. For these reasons, exploratory research is broad in focus and provides definite answers to specific research issues [7].

3.2 Target population

Target population is from the city of Oromia Regional Government which is East Shoa zone of Adama city. From this city are selected randomly 15 respondents of Aluminum profiles cutting workers.

3.3 The study setting

The study was conducted in Adama city, Oromia state, Ethiopia. At this time building construction work like, doors, windows, stair cases and partitions are worked by aluminum profile.

3.4 Sample selection

Sampling involves selecting relatively small number of elements from the large defined group of elements and expecting that the information gathered from small group allow generalization to be made about the larger group of population.

The sampling units are the defined target population elements available for selection during the sampling process. In this research, Adama city Aluminum profile workers are selected purposely as the total population since the result can be considered for the whole Aluminum workers in the country.

A total of 15 of Aluminum workers are randomly selected from the population of 20 Aluminum workers including SMEs at Adama city that are currently working in the field of Aluminum work.

The reason why Adama city is selected for this study is because the city is nearer to the University and due to limited budget the researchers couldn't include other places. The sampling is selected by using systematic random sampling method. The sample ratio can give sufficient information because it is taken 75% out of total population.

3.5 Method, sources of data and Data collection technique

Various methods and tasks will be conducted to accomplish this study. Data are collected from both primary and secondary sources. From the primary data sources direct observations imported machines the cut Aluminum profile interview, questionnaires and observation etc.

From the Secondary data collection data will be collected from books, journals such as published and unpublished documents collected from pertinent institutions as well as different research papers studied by former researchers for the development of aluminum profile manual cutting machine.

3.5.1 Data Gathering techniques

Three data gathering techniques have been used to understand current problems of Aluminum profile cutting machine and the need for this machine; Data has been collected by questionnaires (closed and open questionnaires), interviewing and direct observation. After the quantitative and qualitative data are gathered from those sources, Aluminum profile cutting machine is designed and manufactured as a solution to facilitate Aluminum profile products and to avoid exhausting, Error of cut and time consuming of Aluminum profile cutting activities.

3.5.1.1. Survey questionnaire

It is designed the survey questionnaire for assessing about Aluminum profile cutting machine in selected areas. This questionnaire was distributed to different SME and private worker live in Adama city and other professional users for their comments and suggestions before finalizing it. The questionnaire was finalized taking into account the above suggestions under the guidance of our advisor. Twenty questionnaires were distributed to the randomly selected users. The composition of the persons who were participated in the response of the questionnaire includes: Aluminum profile cutting workers, technical workers, and others who work in related area.

The objectives of the questionnaire are:

- To identify the problems related with Aluminum profile cutting machine.
- To assess attitudes and tendency towards Aluminum profile cutting machine.
- To know how many Aluminum profile workers use Aluminum profile cutting machine.
- To compare the efficiency of the existing machine with current reverse engineering Aluminum profile cutting machine.

The survey questionnaire contains about nineteen questions requiring two types of answers.

- a. The first type uses options from the alternatives (objective)
- b. Subjective type questions, which need brief answer.

3.5.1.2 Interview

The interview included from different private sectors and Small Micro Enterprise workers. Structured interviews (face to face) conducted with different Aluminum profile workers (the existing Aluminum profile cutting machine). Most of the interview questions conducted are similar to the questions in the questionnaire. This helped us to cross check the response given by the respondents on both methods of assessment.

3.5.1.3 Direct observation

We have used this method for collecting the required data and information from different documents. We have observed the existing working methods of Aluminum profile cutting method using cutter from Aluminum profile workers and working area. Also we have observed to identify the problems that faced during cutting process as well as visited some Aluminum profile products that made from the existing cutting processes.

The data collected was analyzed using experimental method statistics such as percentage (%).the data obtained from the SMEs as private worker was compared with the relevant design analysis as ergonomic consideration.

3.5.2 Subjective Evaluation

Subjective evaluation is carried out based on statistical analysis by gathering SMEs as private worker opinion towards traditional machine used. They were asked to evaluate the characteristics of machine. The purpose of this to assess the traditional machine used to cut. All of the question were opened and closed.

3.5.3 Objective evaluation

- Design analysis
- Fabrication

- Testing the machine

3.6 Data Analysis

3.6.1 Quantitative data analysis

This analysis is important to get full information from the respondents. The questionnaires also prepared for the respondent by closed and opened types.

Table 3.1 Analysis of personnel (sex, age, working experience and qualification) sated

No		Value	Percent (%)	Remark
	Sex	F	3	20
		M	12	80
		total	15	100
	Age 20-50	15	100	

Table 3.2. Analysis of questionnaire filled by respondent and the result

No	Questionnaire	No.of respondent/ sample size	Yes	No
1	At this time, is there a need Aluminum profiles cutting machine on the market?	15	86.66%	13.33%
2	The hand tools or machine you are using in your shop, are not they suitable for all workers?		73.33%	26.66%
3	To solve the above problem raised (2 question) on aluminum cutting area, what was the way to improve the fabrication system?		66.66%	33.33%
4	What is your opinion about Aluminum profiles cutting machine will be design and manufacture at Adama Science and Technology University with affordable price?		100%	
5	Are you using hand tools for cutting process of Aluminum profile products? This is due to either machines are not available with fair price or hand tools better than those machines?		60%	40%
6	Have you feeling in order to substitute the product in to local area manufacturing of aluminum building construction work?		86.66%	13.33%
7	Have you ever bought and used Aluminum profiles cutting machines?		73.33%	26.66%
8	In working Aluminum doors, Window, stair case, structures and partitions perfect cutting system increase quality?		100%	

The findings indicate that, there is lack of Aluminum profile cutting machine and currently this machine is highly wanted by the Aluminum profile workers at Adama city.

3.6.2 Qualitative data analysis

This analysis is important to get wide and in depth information from the respondents. The questionnaires also prepared for the respondents open & closed that he/she can describe freely much information on the space provided. It helps to get realistic information from respondents because the researchers are not to interfere the participant's idea.

The respondents, as they replied according to their experiences, there were no comfortable used Aluminum profiles cutting machine rather they used traditional working methods of Aluminum profile cutting :- Using without clamp(holding work piece by hand)

- No work piece supporter
- No safety guard of chip
- limited to 0-90° and
- When cut by itself unexpected angle formed so on.

These machines have side effect that cause burn, injury, unsatisfied of operator on work due to lack safety guard (chip scatter), loss concentration on work and is not accurate joint of Aluminum profiles parts.

According to them, the reasons why the respondents are using these machines due to have no opportunity to select extra machine on the market. To improve Aluminum profiles products joint, they understand Aluminum profiles cutting machines are very important.

After studying the above need assessment developers arrived on decide to design and manufacture Aluminum profiles cutting machine having 0-180° adjusting cutting angle.

CHAPTER FOUR: DESIGN AND MATERIAL SELECTION

This chapter introduces the design analysis and material selection of critical components for electrical operated Aluminum profile cutting machine.

4.1. Design

4.1.1. Introduction

From the study of existing ideas, a new idea has to be conceived. The idea is then studied keeping in mind its commercial success and given shape and form in the form of drawings. In the preparation of these drawings, care must be taken of the availability of resources about money, men and materials required for the successful completion of the new idea into an actual reality.

In designing a machine component, it is necessary to have a good knowledge of many subjects such as Mathematics, Engineering Mechanics, Strength of Materials, Theory of Machines, Workshop Processes and Engineering Drawing.

4.1.2. Classifications of Machine Design

The machine design may be classified as follows:

1. Adaptive design.
2. Development design.
3. New design.

4.1.3. Design concept selection

The manufacturing of aluminum profile cutting work by belt drive and pulley system [16].

- The machine is electrically operated
- The rotational motion with average angular velocity has transferred to shaft; this has delivered from the rotation of the motor.
- On the motor shaft large pulley of the diameter has attached.
- On the driver shaft small pulley of diameter has attached.
- The force generated from the electric power has transferred to shaft by the belt drive has attached to another axially suspended shaft.
- Therefore we get speed has created on the smallest pulley.
- This smallest pulley is rotated with high speed and it transfers this motion to the cutting blade
- Finally these cutting blades rotate clockwise direction to make.

4.1.4. General design consideration

- Type of load and stresses caused by the load;
- Motion of the parts or kinematics of the machine;
- Material selection
- Form and size of the parts;
- Ergonomically consideration; and
- Use of standard parts and safety operations; etc.

4.1.5. General Procedure in Machine Design

1. Recognition of need;
2. Synthesis (Mechanisms);
3. Analysis of forces;
4. Material selection;
5. Design of elements (Size and Stresses);
6. Modification;
7. Detailed drawing;
8. Production.

4.1.5. Critical component for the design

The main part of the project includes;-power, pulley, shaft, blade, belt, bearing, key and bolt.

4.1.5.1. Estimation of motor power

This project has designed to cut Aluminum profile height 77mm, width of 100mm and length of 6000mm to obtain a required length and angle of cut based on the need of users(SME's)who fabricate and assembly Aluminum products during or survey [29]. Since Duralumin Aluminum alloy is a family of non-ferrous material and has a tensile strength of up to 400Mpa, so the recommended consumption of power to be three phase AC motor having 2800 RPM and 4kw power by considering functional requirements and the availability of Ethiopian Electrical power so as to the required energy and to work for 6-15 hours per day continuously [26].

4.1.5.2. Design of pulley and V- belt

Pulleys are used to transmit power from one shaft to another by means of belts. Since the velocity ratio is the inverse ratio of the diameters of driving and driven pulleys, therefore the

pulley diameters should be carefully selected in order to have a desired velocity ratio.

The pulleys must be in perfect alignment in order to allow the belt to travel in a line normal to the pulley faces[19].

The basic parameters required for drive selection are given below:

- Distance between axes of pulley (C)
- AC electric motor power(P)
- Motor rotation speed (n_1).
- Output rotational speed (n_2)
- The rated power of the driving motor
- The service factor based on the type of driver and driven load.
- length of the belt (L_p)
- Diameter of the smaller pulley(d)
- Diameter of the large pulley(D)
- The correction factor for belt length.
- The correction factor for the angle of wrap on the smaller pulley
- The number of belts
- The initial tension on the belt

Two different diameters of pulleys with larger diameter on the motor driver shaft and smaller driven diameter on the cutter shaft is designed to increase the RPM of cutter shafts to have continuing feed of the aluminum profile piece. For the case of this design, the V-belt ratio recommended 1-15 so, it is decided to have a velocity ratio of 1:2 based on motor rpm and to increase the speed by two times of main shaft because of cutting Aluminum profile (due to soft material) need high speed.

Now from the design concept selection small diameter of pulley and velocity ratio (V_r), it is possible to calculate the large pulley diameter on the main shaft.

$$V_r = \frac{d}{D} \quad \text{Where, } D - \text{is diameter of larger pulley on the motor shaft;}$$

d – is diameter of small pulley on the driven shaft;

$$\frac{1}{2} = \frac{71\text{mm}}{D}, \quad D = 2 \times 71 = 142\text{mm}$$

Therefore, for doubling the main shaft speed sufficient.

So, select the following data from the standard table of appendix 3 for the design purpose.

- Belt width of section A=13mm
- Belt thickness of section A=8mm
- Motor power of section A =5 HP
- Service Factor of section=1.8
- Minimum pulley pitch Diameter=71mm
- Large pulley diameter =142mm
- belt Center distance 426mm

Now by taking 2800 RPM of motor (on larger pulley), the speed in rpm of the smaller pulley (on the driven shaft) to estimate the ratio of n_2 is given by:-

$$\frac{n_1}{n_2} = \frac{d}{D} \dots\dots\dots \text{equation 4.1}$$

$D \times n_1 = d \times n_2$,where n_2 – is rpm of smaller pulley

n_1 - is rpm of larger pulley

$$n_2/D = n_1/d \quad n_2 = n_1 D/d$$

$$n_2 = 2800 \text{RPM} \times 142 \text{ mm} / 71 \text{mm} = 5600 \text{ rpm}$$

Comment alumunium profile due to soft material high speed is recommended so, satisfy with design.

For any type of the belt drive it is always desirable to know the length of belt required. It will be required in the selection of the belt. The length can be determined by the geometric considerations. However, actual length is slightly shorter than the theoretically determined value.

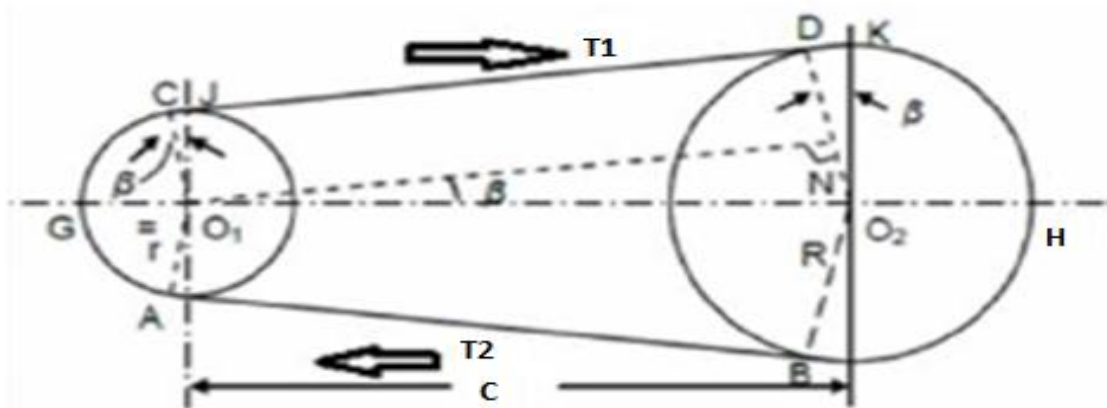


Figure 4.1 Belt drives (From Engineering Data book for v – belt.)

Steps to calculate belt

1. Calculate horsepower

$$HP = \frac{4KW}{746W} = 5HP$$

Where, HP - horse power

$$1HP = 746W$$

The belt of A-shape is chosen [19].

Formula for a recommended distance of axis or center distance is given by:

$$(D + d)/2 + 50 \leq A \leq (2 \times (D + d)) = 213/2 + 50 \leq A \leq 2 \times (213) = 156.5 \leq A \leq 426$$

so, for the design A is chosen ~ **426mm**. Therefore large

2. Select the pulley diameters

- Choose the minimum pulley diameter = 71mm (appendix 4)
- Find the speed ratio = $n_1/n_2 = 5600/2800 \text{ RPM} = 2$
- Calculate the pitch diameter of large pulley

$$DP = R_s \times dp \quad 2 \times 71 \text{ mm} = 142 \text{ mm}$$

Where, DP - Pitch diameter of large pulley

dp - Pitch diameter of small pulley

R_s - Speed ratio

3. Determine the V-belt Length

from the belt drive shown on figure 4.1, First above the Angle of a slope of the belt is calculated as follow,

By geometry, $\angle O_2 O_1 N = \angle C O_1 J = \angle D O_2 K = \beta$ equation 4.2

Arc BHD = $(\pi + 2\beta) R$, and

Arc CGA = $(\pi + 2\beta) r$

$$AB = CD = O_1 N = O_1 O_2 \cos \beta = A \cos \beta$$

$$\sin \beta = (D - d) / A = (180 - 90) / 460 = 0.1956$$

$$\beta = \sin^{-1}(0.1956) = 11.28^\circ$$

then length of the belt is calculated as follow,

$$L = 2C + 1.57(D + d) + \frac{(D - d)^2}{4C} \text{ equation 4.3}$$

Where:

L = Pitch Length of Belt

C = Center Distance

D = Datum or Pitch Diameter of Large pulley

d = Datum or Pitch Diameter of Small pulley

β = be the angle subtended by the tangents AB and CD with $O_1 O_2$.

$$L = 2(426) + 1.57(142 + 71) + ((142 - 71)^2 / (4 \times 426))$$

$$= 852 + 334.41 + 2.96$$

$$= \underline{\underline{1189.37\text{mm}}}. \text{ Therefore large length.}$$

From the standard table of appendix 2, A it is close to the datum length of A47=1200mm

Therefore, belt specification for this machine is A47; L1200mm V-belt is selected based on the following table. These data are suitable and ISO standard because it describes the relations of center distance, pulley diameters and belt dimensions. In addition, it guides to select standard sizes and appropriate movements.

Calculate the exact center distance of the pulleys after the belt length has been determined.

$$C = \frac{b + \sqrt{b^2 - 2(Dp - dp)^2}}{4} \dots\dots\dots \text{equation 4.4}$$

$$\text{Where: } b = Lp - 1.57(Dp + dp)$$

$$= 1200\text{mm} - 1.57(142 + 71)$$

$$= 1200\text{mm} - 334.41\text{mm}$$

$$= 865.59\text{mm}$$

$$C = \frac{865.59 + \sqrt{(865.59)^2 - 2(142 - 71)^2}}{4}$$

$$= \underline{\underline{431.33\text{mm}}}$$

Therefore, this 431.33mm exact center distance sufficient for design

4. Angle of contact of belt on each pulley

The angles are important because commercially available belts rated with on assumed contact angle of 180°. This will occur only if the drive ratio is 1:1 (no speed change). The angle of contact on the smaller of the two pulleys will always be less than 180°, requiring a lower power rating.

The tensile force in the belt maximum on the tight side of the belt. The bending of the belt around the pulley, maximum at the tight side of the belt bends around the smaller pulley.

$$\angle AGC = \theta_1 = 180^\circ - 2\sin^{-1}\left[\frac{D-d}{2C}\right] \dots\dots\dots \text{equation 4.5}$$

$$\angle BHD = \theta_2 = 180^\circ + 2\sin^{-1}\left[\frac{D-d}{2C}\right] \dots\dots\dots \text{equation 4.6}$$

Where θ_1 = contact angle of belt on small pulley

θ_2 = contact angle of belt on large pulley

L = Belt length

C = center distance between pulleys

d = small pulley diameter

D = large pulley diameter

Contact angle of small pulley (θ_1)

$$\theta_1 = 180 - 2\sin^{-1}\left[\frac{D-d}{2C}\right]$$

$$\theta_1 = 180 - 2\sin^{-1}\left[\frac{142-71}{2 \times 426}\right]$$

$$\theta_1 = 170.4^\circ$$

Contact angle of larger pulley (θ_2)

$$\theta_2 = 180 + 2\sin^{-1}\left[\frac{D-d}{2C}\right]$$

$$\theta_2 = 180 + 2\sin^{-1}\left[\frac{142-71}{2 \times 426}\right]$$

$$\theta_2 = 189.56^\circ$$

Therefore, the contact angles for small and large pulley are good.

5. Selection of a belt number

To find the size of the drive, number of belts, and a force acting on the low-speed shaft.

considering functional requirements and the availability of Ethiopian

Electrical power, so as a drive fan work for 6- 15 hours per day continuously.

- Transmission ratio (i) = $d/D = 71/142 = 0.5$ by taking $k_i = 1.15$ from transmission ratio factor.

Table 4.1 Transition ratio factor k_i (in accordance with PN-ISO 4184: 2000)

i	$\leq 0,55$ $> 1,8$	0,56 0,83 1,21 1,8	0,84 0,95 1,05 1,2	0,95 1,05
k_i	1,15	1,10	1,05	1,00

b. Belt length factor

Coefficient of length k_L for A-shape belt and length of belt 71mm is obtained from “belt length factor diagram”. Appendix 5, for this design taking k_L for A section =1.1 from the table

c. Belt contact factor (k_f) is given by: $D-d/c = (142-72)/426=0.985$

Accordance with “Belt contact factor” diagram on appendix 6, value of k_f is taken as $0.985 \sim 0.99$ which is equal to $177^0 = 0.05$, so, the value of k_f is 0.99

d. belt velocity (v)

$$v = \pi D n_1 / 60000 = (3.14 \times 142 \times 2800) / 60000 = 20.8 \text{ m/s}$$

e. Service factor (k_s) for this design is 1.8 from table of appendix 6.

6. Belt number (Q)

$$\text{Number of belt} = \frac{\text{Design HP}}{\text{Standard Transmission} \times \text{Coefficient of arc of contact} \times \text{Coefficient of Belt Length}} \dots \text{eq. 4.7}$$

$$Q = \frac{P_d}{n_1 k_L k_f}$$

Where, $P_d = 4000/746 \sim 5 \text{ HP}$

$$= \frac{5}{1.15 \cdot 1.03 \cdot 0.99} = 2$$

n_1 -rated power transferred by one belt

k_f -coefficient of contact factor

k_L - coefficient of belt length

7. Tension in the belt

$$P = (T_1 - T_2) V \dots \text{equation 4.8}$$

Where T_1 - is tension on the tight side of belt

T_2 – is tension on the slack side of belt

V – is velocity of the belt in small pulley

P – is power from the above design = $4 \times 10^3 \text{ W}$

$$\text{That is } V = \frac{\pi D N}{60} \dots \text{equation 4.9}$$

$$V = \frac{\pi \times 142 \times 2800}{60,000}$$

$$V = 20.8 \text{ m/s}$$

$$\text{There fore } T_1 - T_2 = \frac{P}{V}$$

$$T_1 - T_2 = \frac{4 \times 10^3}{20.8} = 192.3 \text{ N}$$

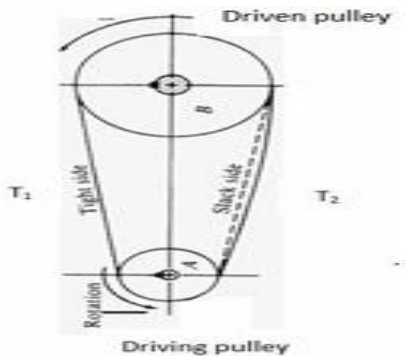


Fig 4.2 Belt tension

Therefore, belt tension is sufficient.

$$2.3 \log \left(\frac{T_1}{T_2} \right) = \mu \theta \operatorname{cosec} \beta \dots \dots \dots \text{equation 4.10}$$

Where, μ - is Coefficient of friction between the smaller pulley and

V- Belt by taking $\mu = 0.12$ from table.

θ - is contact angle on small pulley in radian that is 170.4°

$$= 2.97 \text{ rad}$$

$$2.3 \log \left(\frac{T_1}{T_2} \right) = e^{0.12 \times 2.97 \operatorname{cosec} 36}$$

$$\operatorname{Log} \left(\frac{T_1}{T_2} \right) = \frac{0.12 \times 2.97}{2.3} = 0.155$$

$T_1/T_2 = 1.43$ by taking anti log of 0.155

$$T_1 = 1.43 T_2$$

Therefore by combining the two equations, that is

$$1.43 T_2 - T_2 = 192.3 \text{ N} \quad T_2 = 192.3 / 0.43 = 447 \text{ N in the slack side}$$

$$T_1 = 1.43 T_2 \quad T_1 = 1.43 \times 447 = 640 \text{ N in the tight side}$$

4.1.5.3. Cutter blade forces analysis

According to experiment of porankiewicz et al the tangential force (F_t) is generally associated with the rotational effort (torque) to cut the work piece. Normal forces may affect the cutter locus during the initial phase of the cut which forms the resultant machined work piece surface. By convention, positive normal cutting forces are defined as those which push the cutter tip and work piece apart. Opposite forces pull the Aluminum profile and cutter together [24].

In case of circular saw, identically as in analytical models for milling, can be expressed as [3]:

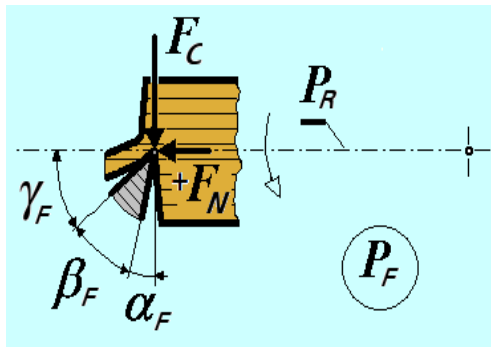
$$F_c = a_p$$

$$F_c = a_p \cdot W_c \cdot k \cdot c_r \cdot c_\delta \cdot c_p \cdot c_{ap} \cdot c_{vc} \cdot c_{mc} \cdot c_T \text{ (N)} \dots \dots \dots \text{equation 4.11}$$

$$F_c = -7.37 + A_1 + 15 \times 61 \times \phi v - 2.6 \times \phi v^3 + 1.31 \times P + 0.2 \times v c + A_2 \dots \dots \text{equation 4.12}$$

$$\text{When: - } A_1 = a_p (0.38 \times D - 224.5 \times Y F) \dots \dots \dots \text{equation 4.13}$$

$$A_2 = M_c (0.3 \times \phi v - 0.01 \times T) \dots \dots \dots \text{equation 4.14}$$



Where: F_C - Cutting force
 F_N - Normal cutting forces
 P_F - Working Plain;
 P_R - Tool reference plain

Source: Porankiewicz et al. (2011). "Saw cutting forces," Bio Resources [23].

Figure 4.3 shows main and normal cutting force

$$F_c = (-7.37 + A1 + 15.61\Phi Gvc - 2.6\Phi Gvc^3 + 1.31\rho ce + 0.2vc + A2) \frac{St}{4.25} \dots \text{equation 4.15}$$

Calculate kerf /circular pitch/

In finding the relief value K, the relief angle is taken as 10° to 15° . A large relief angle increases the height and reduces the strength of the teeth. The fillet radius is taken I to 3 mm. The flute angle O is taken from 18° to 30° . The tooth base thickness C should be equal to (0.8 to 1) H for strength considerations. The fillet radius at the root of the cutter is made $r = 0.5$ to 2 mm.

The angle of the flute groove x is made 60° to 65° for finishing cutters S is taken equal to (1.3 to 1.8) H for roughing cutters S is made equal to (1.8 to 2.5) H.

Where, S - is kerf (circular pitch of the teeth) [6].

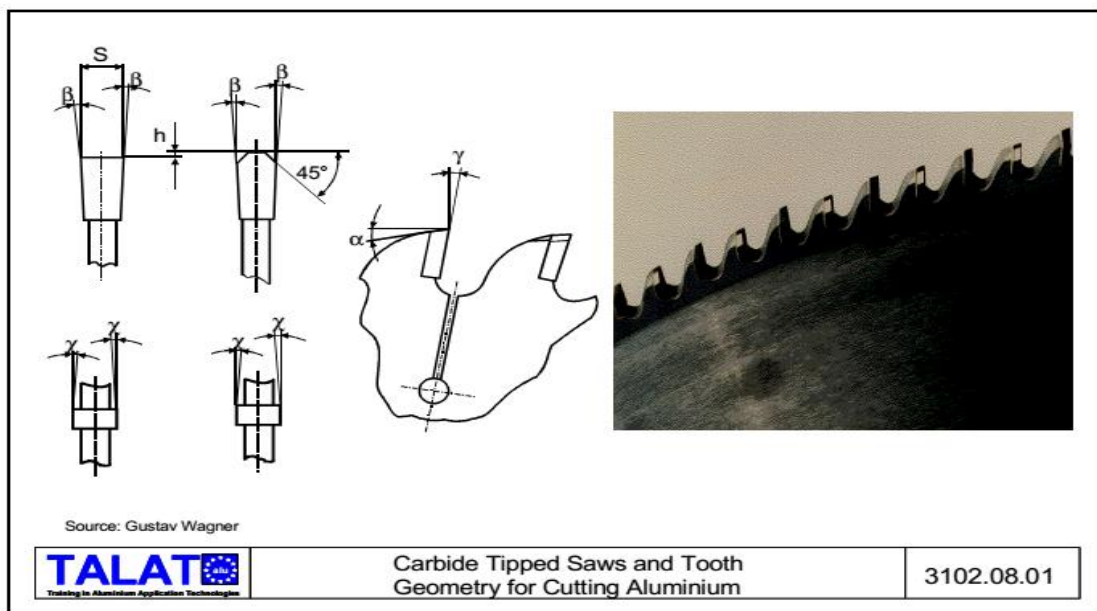


Fig 4.4. Carbide tipped saws and Tooth Geometry for cutting Aluminum

Either circular or band saws are widely used for cutting aluminum although the latter are obviously winning in popularity, especially for sawing compact cross-sections.

Nowadays, the circular saws used are mostly carbide-tipped.

$$Z = \pi D / S \dots\dots\dots \text{equation 4.16}$$

Where, D = diameter of the blade

Z = No teeth of blade

H = tooth height.

S = kerf (circular pitch of the teeth)

Given Z=54 teeth

D=300mm

$S = \pi D / Z = 3.14 \times 300 / 54$

= 7.44mm

Therefore, the recommended kerf 5-50mm so, 7.44 is sufficient.

In practice, the profile of the relieving curve used on form relieved milling cutters is the Archimedean spiral. In relieving along an Archimedean spiral, uniform rotation of the milling cutter about its axis corresponds to a uniform translator motion of the relieving tool. As has been explained earlier the relief value K is found as [4]:

$$K = \frac{\pi D_c}{Z} \tan \theta \dots\dots\dots \text{equation 4.17}$$

Given Z=54 teeth

Dc=300mm

$\theta = 10^\circ$ to 15° = select 15°

$K = 3.14 \times 300 \times \tan 15^\circ / 54 = \mathbf{5mm}$

$$\sin \theta = \frac{Z}{R+K} \dots\dots\dots \text{equation 4.18}$$

Where K = Distance knife protrudes from the head

R = Radius of body

θ = Cutting angle

$\theta = \sin^{-1} Z / (R+K)$

$= \sin^{-1} 54 / (150+5)$

= 20° Therefore, acceptable.

In the case of circular sawing, identically as in analytical models for milling, the instantaneous uncut chip thickness $h_j(\phi)$ at a certain location of the cutting edge can be approximated as follows [1]:

$$h_j(f) = f_z \sin f_j \dots \dots \dots \text{equation 4.19}$$

Where: f_z is feed per tooth,

F_j is the angular position of the j -tooth (immersion angle), and its value changes as follows:

$$F_z = 0.3 \text{ mm}$$

$$\Phi_p = 2\pi/Z = 3.14 \times 2/54 = \underline{\underline{0.116 = 7^\circ}}$$

$$\Phi_j = \Phi + (j-1) \Phi_p - \tan \beta Z/R \quad j=1, 2, 3, \dots, Z$$

$$= 45 + (10-1)7 - (\tan 20^\circ \times 54/150)$$

$$= 108^\circ - 0.013(7.4^\circ) = 100.5^\circ$$

$$h_j(\phi) = 0.3 \text{ mm} \times \sin 100.5^\circ$$

$$= \underline{\underline{0.29 \text{ mm}}}$$

$$A_1 = (0.38\rho - 224.5gf) h_j(f)$$

$$\text{Given } \rho_{Al} = 2700 \text{ kg/m}^3 = 2.7 \text{ gm/cm}^3$$

$$\gamma_f = 10 - 20^\circ = 10^\circ$$

$$h_j(\phi) = 0.29 \text{ mm}$$

$$= (0.38 \times 2700 - 224.5 \times 0.176) 0.00029 \text{ m}$$

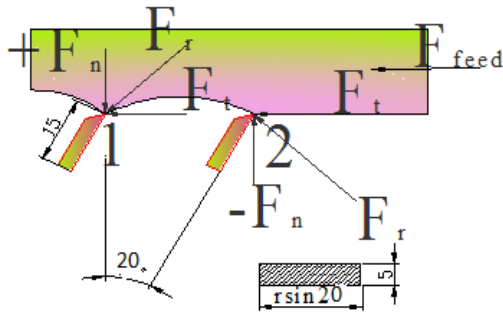
$$= 0.028 \text{ m} = 28 \text{ mm}$$

$$F_c = (-7.37 + A_1 + 15.61\Phi Gvc - 2.6\Phi Gvc^3 + 1.31\rho ce + 0.2vc + A_2) \frac{St}{4.25}$$

$$= (-7.37 + 28 \text{ mm} + 15.61 \times 100.5^\circ - 2.6 \times 100.5^\circ + 1.31 \times 0.5 + 0.2 \times 0.028 \times 1000 + 0) 7.44/4.25$$

$$= (272 - 84.22 + 14 + 0.655 + 56) 7.44/4.25$$

$$= \underline{\underline{136 \text{ N}}} \text{ Therefore, the resisting force of work piece small.}$$



Where F_n - normal force
 F_r – Radial force
 F_t – Tangential force
 F – Feed

Figure 4.5 Normal and tangential cutting forces during rotary machining of Aluminum

Note: - cutting force arrows represent force on tool tip

➤ Basic parameters

- Motor power $P = 5 \text{ HP} = 4 \text{ KW}$
- $N = 2800 \text{ RPM}$
- Driver pulley diameter $D = 142 \text{ mm}$
- Driven pulley diameter $d = 71$
- Coefficient of friction $\mu = 0.12$
- Shaft material AISI No.1020 , $\sigma_y = 320 \text{ Mpa}$, $\sigma_u = 600 \text{ Mpa}$

✓ Rime velocity

$$V_1 = 20.8 \text{ m/s}$$

✓ Belt tensions ratio

$$\text{Log}_e \frac{T_1}{T_2} = \mu \cdot \theta \dots \dots \dots \text{equation 4.20}$$

$$\text{But } \theta = \frac{(180 - 2\alpha)\pi}{180} \text{ rad and}$$

$$\alpha = \sin^{-1} \frac{r_1 - r_2}{x} \text{ Where } x \text{ is datum length} = 1000 \text{ for A39 } \frac{1}{2} \text{ V- belt}$$

$$\theta = 2.96 \text{ rad}$$

$$\alpha = 5.2 \text{ rad}$$

$$\frac{T_1}{T_2} = 1.4$$

✓ Velocity ratio

$$\frac{N_2}{N_1} = \frac{d_1}{d_2} \dots \dots \dots \text{equation 4.21}$$

$$N_2 = 5600 \text{ rpm}$$

✓ Turning force torque (M_t) transmitted to shaft

$$P = \frac{2\pi N M_t}{60}$$

$$M_t = \frac{60P}{2\pi N} \dots \dots \dots \text{equation 4.22}$$

$$= \frac{60 \times 4000}{2\pi \times 2800} = 13.65 \text{ Nm}$$

- ✓ Belt forces on the shaft D=45mm
 $T_2 = 447\text{N}$ refer from page 32
 $T_1 = 640\text{N}$

i. Main shaft force

- ✓ Tangential cutting force

$$F_t = \frac{Mt}{S_t} \dots\dots\dots \text{equation 4.23}$$

$$\begin{aligned} \text{Where } S_t &= \text{saw kerfs } 7.44\text{mm} \\ &= 13.65 \times 1000 / 7.44 \\ &= 1.8\text{KN} \end{aligned}$$

- ✓ Radial cutting force

$$\begin{aligned} F_r &= F_t \tan 20^\circ \\ &= 0.7\text{KN} \end{aligned}$$

- ✓ Maximum bending stress

$$\begin{aligned} \sigma &= \frac{Mt \cdot y}{I} \\ &= \frac{32M}{\pi D^3} = \frac{32 \cdot 13.65}{\pi \cdot 0.045} = 3.1\text{KPa} \end{aligned}$$

- ✓ Normal load act on the blades

$$\begin{aligned} w &= \frac{F_t}{\sin \theta} \\ w &= \frac{0.7\text{KN}}{\sin 20} = \underline{\underline{2.1\text{KN}}} \end{aligned}$$

- ✓ Maximum bending moment of shaft ends

$$\begin{aligned} M &= wxL \\ M &= 2.1\text{KN} \times 0.433\text{m} \\ \mathbf{M} &= \underline{\underline{0.91\text{KN.m}}} \end{aligned}$$

4.1.5.4. Design of shaft

Shaft is a rotating solid part which is used to transmit power from the electric motor through belt and pulleys to driven shaft by means of key: the power is delivered to the shaft by some tangential force and the resultant torque (twisting moment) set up with in the shaft permits the

power to transmit to the driven shaft. The required torque to transmit power to the driver shaft is obtained by using the following relation [28].

To know that power transmitted (in watts) by the shaft

$$P = \frac{T}{\omega}, \omega = \frac{60}{2\pi n} \dots \dots \dots \text{equation 4.24}$$

Then twisting moment is obtained by: $T = \frac{Px60}{2\pi n}$

Where T- is twisting moment in N-m

n- Speed of shaft in RPM = 2800RPM=46.67 revolution per second

p- Power required = 4kw

$$T = \frac{Px60}{2\pi N} = \frac{4000Wx60}{2x\pi x2800r.pm} = \frac{4x1000Wx60}{2\pi x46.67} = \mathbf{818.86N.m}$$

The shafts may be designed on the basis of

1. Strength, and
2. Rigidity and stiffness.

Designing shafts on the basis of strength

- (a) Shafts subjected to twisting moment or torque only,
- (b) Shafts subjected to bending moment only,
- (c) Shafts subjected to combined twisting and bending moments, and
- (d) Shafts subjected to axial loads in addition to combined torsional and bending loads.

The material used for ordinary shafts is carbon steel of grades 40C8, 45C8, 50C4 and 50 C12.

Table 4.2 Mechanical properties of steels used for shafts [16].

Indian standard designation	Ultimate tensile strength, MPa	Yield strength, MPa	Remark
40c8	560-670	320	Used for shafts, gears stud bolts, spd le, washer etc. for light stressed
45c8	610-700	350	Used for lead screws, feed rods bigger gears, bigger shafts etc...
50c4	640-760	370	
50c12	700 Minimum	390	

From this mechanical properties of steels used for shaft, we choose 40c8 materials because our project is derived from simple mechanism by considering its yield strength of **320MPa**

The stress included in the shaft is:

- Shear stress due to transition of torque(due to torsional load)
- Bending stress (compression) due to force acting up on the shaft.
- Stress due to combined torsional and bending loads

Maximum permissible working stress for transition shafts

According ASME code for commercial steel shaft, the maximum permissible shear stress is taken as 40-42MPa for shafts with key and 55-56MPa for shafts without key.

For shaft purchased under definite physical specification, the permissible shear stress (allowable shear stress) is 25% of yield strength but not over 18% of ultimate strength in tension for shafts with key ways

$$\tau = 0.25\sigma_y \text{ or } \tau = 0.18\sigma_u \quad \text{where, } \tau = \text{permissible shear stress}$$

$$\sigma_y = \text{yield strength}$$

$$\sigma_u = \text{ultimate tensile strength}$$

For this design the permissible shear stress is $\tau = 0.25 \times \sigma_y = 0.25 \times 320 = \mathbf{80MPa}$.

In designing shafts on the basis of strength, the following cases may be considered.

1. Shafts Subjected to Twisting Moment Only

In this case, then the diameter of the shaft may be obtained by using the torsion equation.

We know, [26]:

$$\frac{T}{J} + \frac{\tau}{r} \dots\dots\dots \text{equation 4. 25}$$

Where, T = Twisting moment (or torque) acting upon the shaft,

J = Polar moment of inertia of the shaft about the axis of rotation,

τ = Torsional shear stress, and

r = Distance from neutral axis to the outer most fiber = d /2;

We know that for round solid shaft, polar moment of inertia,

$$J = \frac{\pi}{32} X d^4 \dots\dots\dots \text{equation 4.26}$$

The equation (i) may now be written as

$$\frac{T}{\frac{\pi}{32} X d^4} + \frac{\tau}{\frac{d}{2}} \text{ or } T = \frac{\pi}{16} X \tau X d^3 \dots\dots\dots \text{equation 4.27}$$

From this equation we can determine the diameter of the shaft of round solid shaft (d) as;

$$d = 3 \sqrt[3]{\frac{16XT}{\pi\tau}} \dots\dots\dots \text{equation 4.28}$$

2. Shaft subjected to bending moment only.

When the shaft is subjected to a bending moment only, then the maximum stress (tensile or compressive) is given by the bending equation.

We know that

$$\frac{M}{I} = \frac{\sigma_b}{r} \dots\dots\dots \text{equation 4.29}$$

where M=bending moment acting on the shaft

I=moment of inertia of cross sectional area of the shaft

σ_b = Bending stress

r= radius of the shaft=d/2

For solid shaft moment of inertia

$$I = \frac{\pi d^4}{64} \dots\dots\dots \text{equation 4.30}$$

Substituting this value in to bending equation we have

$$\frac{M}{\frac{\pi d^4}{64}} = \frac{\sigma_b}{\frac{d}{2}} \text{ or } M = \frac{\pi}{32} \sigma_b d^3 \rightarrow d = 3 \sqrt{\frac{32M}{\pi \sigma_b}} \dots\dots\dots \text{equation 4.31}$$

3. Shaft subjected to combined twist moment (T) and bending moment (M)

When the shaft is subjected to combined twist moment (t) and bending moment (m), the shaft must be design on the bases of the two moments simultaneously. Two types of theories have been subjected to account the elastic failure of the shaft when it is subjected two various combined stress the two types of theories are;

- Maximum shear theories: used for this design because it is used for ductile materials such as mild steel
- Maximum normal stress theory: used for brittle materials such as cast iron According Maximum shear stress theory, the maximum shear stress in the shaft is given by

$$\tau_{\max} = \frac{1}{2} \sqrt{\sigma_b^2 + 4\tau^2} \dots\dots\dots \text{equation 4.32}$$

Where, $\tau_{\max}$ – maximum shear stress

σ_b – bending stress

τ – Shear stress

Substituting the value of τ and σ_b from torsio equation and bending equation we have

$$\tau_{\max} = \frac{1}{2} \sqrt{\left(\frac{32M}{\pi d^3}\right)^2 + 4\left(\frac{16T}{\pi d^3}\right)^2} \Rightarrow \sqrt{M^2 + T^2} = \frac{\pi}{16} \tau_{\max} d^3 \dots\dots\dots \text{equation 4.33}$$

Where, d – Shaft diameter

M – Moment

T – Twisting moment

The expression $\sqrt{M^2 + T^2}$ is known as equivalent twisting moment and is denoted by T_e . The equivalent twisting moment T_e may be defined as the twisting moment, which when acting alone produces the same shear stress (τ) as the actual twisting moment. By limiting the maximum shear stress ($\tau_{\max}$) equals to the allowable shear stress (τ) for the shaft material equation above can be written as:

$$T_e = \frac{\pi}{16} \tau d^3 \dots\dots\dots \text{equation 4.34}$$

A little consideration will show that the maximum bending moment acts on the pulley. A groove angle (α) of pulley ranges from 34-38°. For this design we take $\alpha = 36^\circ$

The twisting moment, $T = \underline{818.86 \text{ N-m}}$ Refer from page **36**

Therefore, tangential force (F_t) on the pulley is given by, $F_t = \underline{1.8 \text{ kN}}$

The normal load (W) acting on the groove of pulley is given by, $W = \underline{0.7 \text{ kN}}$

Here from the above figure, the critical part of the shaft which is exposed to maximum bending moment is at the point where the pulley is mounted.

Bending moment M is given by normal load (W) x Perpendicular distance (L)

$$M = W \times L \quad \text{where, } L = 433 \text{ mm} = 0.433 \text{ m}$$

$$700 \text{ N} \times 0.433 \text{ m} = \underline{303.1 \text{ N-m}}$$

From equivalent twisting moment equation we know that

$$T_e = \sqrt{M^2 + T^2} = \sqrt{(303.1)^2 + (818.86)^2}$$

$$= 873.2 \text{ N-m}$$

$$= \underline{873.2 \times 10^3 \text{ N-mm}}$$

The equivalent twisting moment is given by

$$T_e = T_e = \frac{\pi}{16} \tau d^3 \dots\dots\dots \text{equation 4.35}$$

where, τ is permissible stress = **80 MPa** for shaft diameter (d) to be design.

By re-arranging this equation yields $d^3 = 16 T_e / \pi \tau$

$$d = \sqrt[3]{\frac{16 T_e}{\pi \tau}} = \sqrt[3]{\frac{16 \times 873200}{\pi \times 80}} = 44 \text{ mm} \sim 45 \text{ mm}$$

Therefore to have better strength ,standard design specification and more safe, the driven shaft diameter d is designed by rounding off this value to **45mm**.

From above calculation of shaft, belt and cutting force the shaft like stepped shaft.

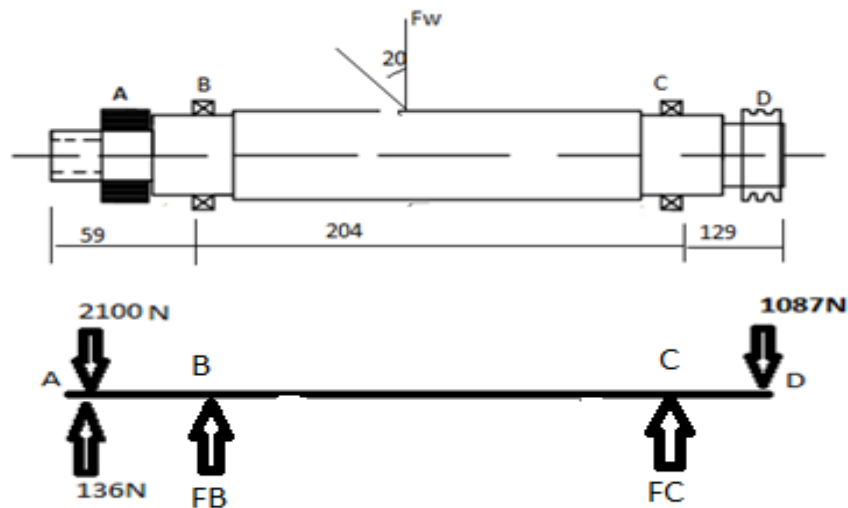


Fig 4.6 Free body diagram of shaft

From above free body diagram calculate FB, FC, Horizontal bending moment, Vertical bending moment and Resultant bending moment.

$$2100\text{N} + 1087\text{N} = 136\text{N} + \text{FB} + \text{FC}$$

$$\text{FB} + \text{FC} = 3051\text{N}$$

$$\text{FB} = 3051\text{N} - \text{FC}$$

$$\text{FC} = -4516.8\text{N} \text{ and } \text{FB} = 7567.8\text{N}$$

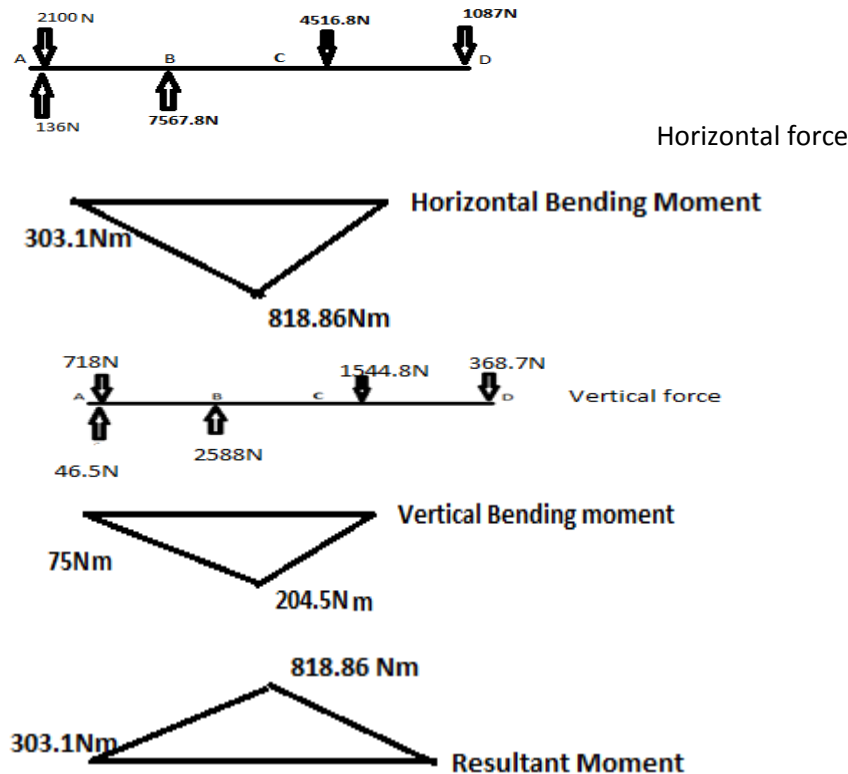


Figure 4.7 load and bending moment diagram for the shaft

4.1.3.5. Design of key

A key is a piece of mild steel inserted between shaft (key way) and hub or boss of the pulleys(key way) to connect these parts in order to prevent relative motion between them. It is always inserted parallel to the axis of the shaft. Keys are used as temporary fasteners and are subjected to considerable crushing and shear stresses. The most widely used method of torque transfer is by the use of keys. Keys transmit torque by the mechanism.

A longitudinal groove called a keyway is machined into the shaft and a corresponding groove into the bore of the hub. The key fits simultaneously into both grooves, locking them together.

A square key is provided half in the key way of the shaft and half of its part in the key way of the hub or boss of the pulley. a square key is that its width and thickness are equal, i.e., $b=h$ [10].

a. Design of Square Key

Design specification of the key is calculated based on shaft diameter as follows:

Square sunk key: The only difference between a rectangular sunk key and a square sunk key is that its width and thickness are equal, i.e.

$$w = t = d / 4$$

$$= 45/4 = 11.25 \text{ mm} \sim 11 \text{ mm}$$

- Diameter of the shaft = 45 mm.
 - Width of the key, $w = 11 \text{ mm}$
 - Thickness of key, $t = 11 \text{ mm}$
 - The shear stress of the material is $40 \text{ Mpa} = 40 \text{ N/mm}^2$
 - The crushing stress of the key material = 70 N/mm^2
- [18]

b. Design Analysis

A key has two failure mechanisms: 1) it can be sheared off, and 2) it can be crushed due to the compressive bearing force shown below figure.

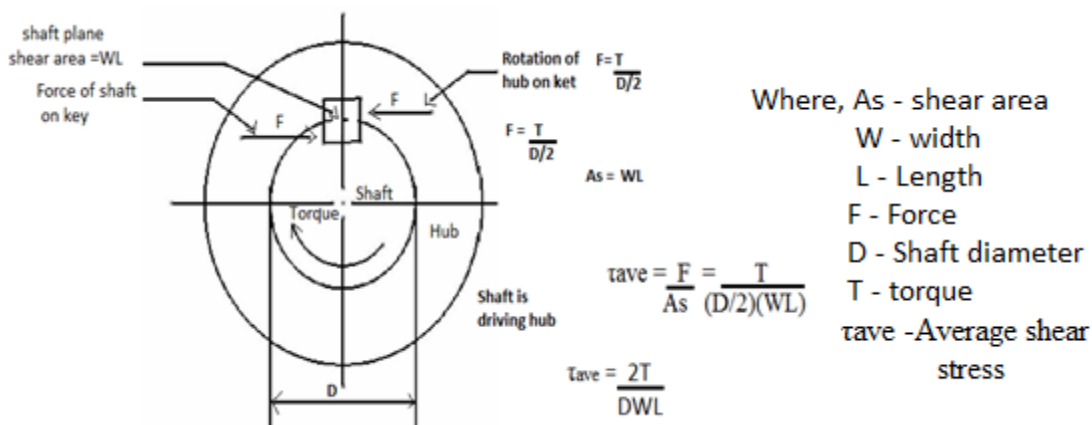


Figure 4.8 Forces exerted on the key

The length of the key is obtained by considering the key in shearing and τ crushing.

Shearing of key

Let L = Length of key. Considering shearing of the key, developers know that shear strength or torque transmitted of the key,

Shear force F = Area of resisting shear $\times$ shear stress

$$F = L \times w \times \tau \dots\dots\dots \text{equation 4.36}$$

$$T = (F \times d)/2, T = (L \times w \times \tau) \times d/2$$

$$L = (2 \times 818680) / (45 \times 11 \times 40 \text{ N/mm}^2)$$

$$L = \underline{\underline{68 \text{ mm}}}$$

Crushing of key

Shear force $F = \text{Area of resisting crushing} \times \text{crushing stress}$

$$F = L \times t/2 \times \sigma_c \dots\dots\dots \text{equation 4.37}$$

We know that $T = F \times d/2$

$$T = L \times t/2 \times \sigma_c \times d/2$$

$$818.86 \times 10^3 \text{ N-mm} = (L \times 11 \times 70 \text{ N/mm}^2 \times 45)/2$$

$$L = 68.22 \times 10^3 / 10 \times 3 \times 70 = \mathbf{47.3 \text{ mm}}$$

Taking the larger of the two values, developers have length of key.

$$L = 68 \text{ mm}$$

4.1.5.6 Bearing selection

There are two types of rolling contact bearings. The ball and roller bearings consists of an inner race which is mounted on the shaft or journal and an outer race which is carried by the housing casing. In between the inner and outer race, there are balls or rollers. A number of balls or rollers are used and these are held at proper distance by retainers so that they do not touch each other. The ball bearings are used for light loads and the roller bearings are used for heavier loads.

Since medium loads for Aluminum profile cutting are required ball bearings are used for Aluminum Profile Cutting Machine. In addition, the machine is designed on small scale ball bearings can efficiently run the machine assembly. There is only radial load (W_r) on the bearing as there is no load applied to shift the plane of rotation of the balls.

We select deep groove ball bearings, as the balls are symmetrically located by the use of a retainer or case. The deep groove ball bearings are used due to their high radial load capacity and suitability for high running speeds [28].

Bearing selection for the driven shaft would be shown below figure.

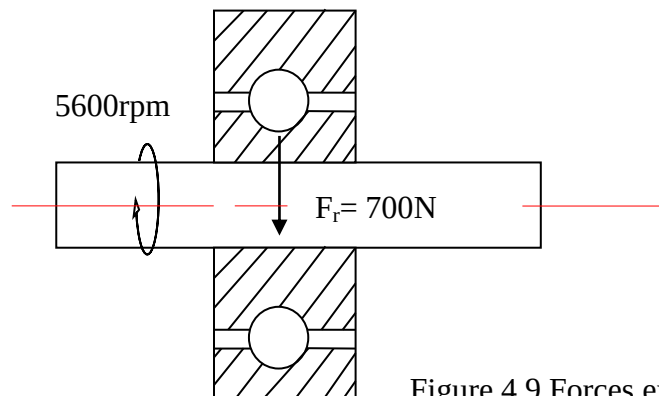


Figure 4.9 Forces exerted on the Bearing

Decision and assumptions:-

1. a conservative design for light to moderate impact is required
2. a compressive design for 8hr per continuous service is required
3. a 90% reliability is required
4. a radial bearing ($\alpha = 0^\circ$) should be chosen
5. ball bearing life varies inversely with $\frac{10}{3}$ power of the load

Design analysis:-

- Only radial load (F_r) is applied
- From bearing catalogue $k_a = 1.5$ (moderate impact) and 8hrs every working day has 30000 hr. life. The shaft rotates at 5600rpm.

Hence, life corresponding to radial load (F_r), or life required by the application

$$L = \text{rpm} \times \text{hr. life} = 5600 \text{rpm} \times 30000 \text{hrs} \times 60 \text{min/hr.} = 1.008 \times 10^{10} \text{ rev}$$

From standard catalogue for standard 90% reliability life corresponding to rated capacity ($L_R = 90 \times 10^6 \text{ rev}$)

The required value of rated capacity,

$$C_{\text{rew.}} = F_r \left(\frac{L}{L_R} \right)^{0.3} \dots \dots \dots \text{equation 4.38}$$

Where, F_r - radial load

L_R - reliability life

L -life radial bearing

$$= 700 \text{N} \left(\frac{1.008 \times 10^{10} \text{ rev}}{90 \times 10^6 \text{ rev}} \right)^{0.3} = 2.88 \text{kN}$$

From the standard catalogue, the appropriate radial bearing would be: bearing basic number 209
bore = 45mm, outer diameter = 85mm, and width = 19mm.

4.1.5.7. The standard bearing house

The bearing is inserted into the bearing house for supporting the shaft and facilitate its motion the bearing housing should have a property that resist the bearing stress and also it resist the torsion of the shaft due to rotational motion. The standard bearing house would be shown as below figure.

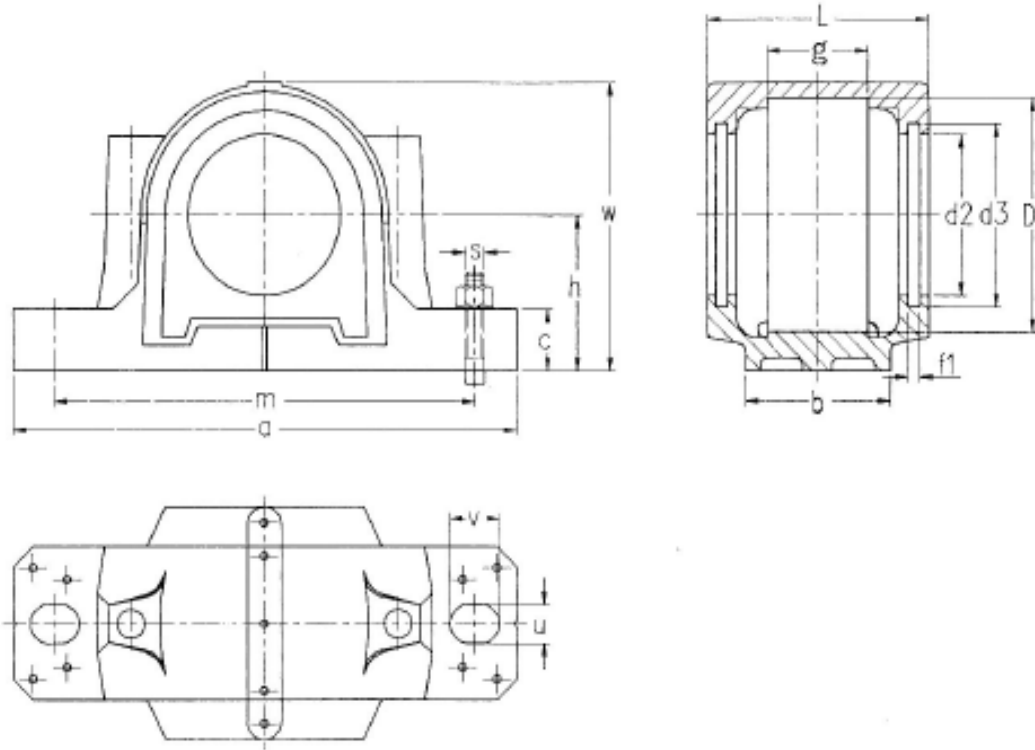


Figure 4.10. Standard bearing House

The standard bearing house with its bearing is selected for our project was bought from the local market. The selected bearing is self-centered type and can resist the load radial on the shaft. The size of the bearing and bearing house selected is based on the standard values indicated on the above table. As it was indicated on the standard table above, the housing number SNG510-608 is appropriate for the shaft diameter of 45 mm. So that, the selected bearing house for the project is the housing number of SNG510-608. From Appendix 10 [28].

4.1.3.8. Design analysis of bolts

A screw joint is mainly composed of two elements that are bolt and nut. A screw joints are widely used when the machine parts are required to be readily connected or disconnected without damage to the machine. Bolts and nuts are standard machine elements and their sizes have to be designed based on the loads applied on them, i.e., either tensile, shear or combined loads. The materials of the bolts and nuts have to be tough, strong, stiff and wear resistant [18].

Design of bolt fixing the driven shaft to its carriage

The load of driven shaft = 1664N, this load causes shearing effect on the bolt. Considering the standard bolt material has permissible shear stress of 518Mpa (heat treated medium carbon steel) with factor of safety 8.

$$\tau_{\text{allow}} = \frac{\tau_{\text{max}}}{f_s} = \frac{518\text{Mpa}}{4} = 129 \text{ Mpa}$$

We know that, shearing load carried by the bolt is

$$P_s = \frac{\pi}{4} d^2 \tau_{\text{allow}} \dots \dots \dots \text{equation 4.39}$$

$$d = \sqrt{\frac{4P_s}{\pi \tau_{\text{allow}}}} = \sqrt{\frac{4 \times 1664}{\pi \times 129}} = 4\text{mm, which is M6 coarse teeth.}$$

As a bolt fixing bearing housing of the driven shaft to its support beam is subjected to the same shearing load, it has to be fixed by M6 coarse teeth bolt.

4.1.5.9. Design analysis of welded joints in the machine assembly

A welded joint is a permanent joint which is obtained by the fusion of the edges of the two parts to be joined together. Welding is extensively used in fabrication as an alternative method for casting or forging and as a replacement for bolted and riveted joints [22].

Strength analysis of welded joint of the frame supporting the mechanism of the machine

The frame supporting the driven shaft, shaft supporting bearing, carriage and motor to which the body fixed is welded together by a closed butt weld. The butt joints are designed for tension or compression. In case of butt joint the length of leg or size of weld is equal to the throat thickness which is equal to the thickness of the plate.

Therefore, tensile strength of butt joint (square or single-V butt joint)

$$P = t \times l \times \sigma_t \dots \dots \dots \text{equation 4.40}$$

Where, t = throat thickness = side of plate = 3mm

l = length of weld = 40mm because the frame is 40 x 40 x 3mm in dimension

p = total load on the frame.

The total load, (p) on the machine

$$p = \text{load on the on the shaft} + \text{load on the belt} + \text{load on the blade} + \text{load on the pulley} \\ = 2100 \text{ N} + 1087\text{N} + 1664\text{N} + 1087\text{N} = 5937\text{N}$$

The tensile strength, σ_t of the joint
$$\sigma_t = \frac{P}{t \times l} = \frac{5937\text{N}}{3\text{mm} \times 40\text{mm}} = 49.48\text{N/mm}^2$$

4.2 Input specification

Researcher carried out in the privet and SMEs reveals that one of the comfortable machine for aluminum profile cutting. Primarily used for the cutting of all kinds of aluminum alloy window profile, may also uses for the cut of other Aluminum profiles.

From the above design analysis obtained the machine specification shown at the below table.

Table 4.3. Input specification

No.	Machine Component	Specification	Remark
1	Motor rotary speed.	2800RPM	
2	Max cutting height	77mm	
3	Max cutting width.	100mm	
4	Blade dimension	Φ254xΦ30x2.5mm	
5	Motor power	4kw	
6	Overall dimension	1120X600X900mm	

4.3. Material selection for critical component

4.3.1. Introduction

Selection of the appropriate material is an important consideration in engineering design; that is, for some application, choosing a material having a desirable or optimum property or combination of properties. Selection of the proper material can reduce costs and improve performance. Elements of this materials selection process involve deciding on the constraints of the problem and, from these, establishing criteria that can be used in materials selection to maximize performance. This is done by using digital logical method. In this case only two properties are considered at a time and properties or goals is compared and no shades of choice are required, only a yes or no decision for each evaluation [17].

Step to follow this method is:-

- Set the functional requirement for the part under consideration. This are used to set rating factors
- Rank the rating factors (properties) then determine the weighting factors;
- Calculate the total number of decision of properties;
- Write the most suitable candidate materials and enlist properties from standard data table/quantitative or qualitative data/;

- Normalize the outcome of the parts;
- Value outcomes and overall satisfaction of parts. The overall satisfaction shall at last ranked, and the ranked shows the result on the basis of the allocated weight factors which gives the best overall satisfaction for the functional requirements of the part.

Important formulas [21] :-

- Weighted-property value=numerical value of the property x weighting factor (α).
- Individual weighted-property values of each material=the sum of comparative materials performance index (φ).
- The total number of possible decisions is $N=n(n-1)/2$ equation 4.41
Where, n is the number of properties or goals under consideration [22].
- coefficient or weighting factor(a) =

$$\frac{\text{No. positive decision for each goal(m)}}{\text{total number of possible decisions(N)}} \text{ called properties} = \frac{\text{numerical value properties}}{\text{maximum value in the list}} \times 100$$
- The component or structural element selected to discuss is shaft, pulley, bearing, key and bolt, bearing house, stand frame and belt.

4.3.2. Material selection for shaft

Functional requirement of shaft

The main function of shaft is to transmit power. Shaft is subjected to a torsional stress and bending or combination to produce a high torque and friction with the pulley and bearing. Strength of the shaft will be considered in detail, and criteria will be developed for maximizing strength with respect to both minimum material mass and minimum cost and other parameters and properties that may be important in this selection process are also discussed briefly.

Properties requirement of the shaft

To fulfil the above functional requirement the shaft should have the following property requirement [11].

- Highly tensile strength.
- Highly yield strength.
- Wear resistance
- Corrosion resistance
- Modulus elasticity

From the property of material selected for shaft rating and weighting factor would be shown at below table.

Table 4.4 Determination of relative importance properties of materials using digital logic method

Properties	Number of possible decisions										Positive decision	weighting factor(a)
	1	2	3	4	5	6	7	8	9	10		
tensile strength		1		1		0		0			2	0.2
yield strength	1			0	1		1		0		3	0.3
Wear resistance			1						1	0	2	0.2
Corrosion resistance		0				1					1	0.1
young's modulus elasticity	0		0		0		0	1		1	2	0.2
Total positive decision											10	1

Based on the properties of material listed above the following candidate material for the shaft is selected at below table from standard design hand book.

Table 4.5 Different candidate material requirement for shaft

No	Material	Yield strength	Tensile strength	Wear resistance	Corrosion resistance	Modulus of elasticity
1	AISI No.1010 hot rolled	179	324	3	4	12
2	AISI No.1020 hot rolled	207	379	4	3	12
3	ASTM No.A570-A	170	310	2	1	13
4	ASTM No.A675 Grade -45	155	380	3	2	13

Depend on the properties of candidate material for normalized value of shaft could be taken from standard hand book shown as below table 4.6.

Table 4.6 Normalized value of shaft

No	Material	Yield strength	Tensile strength	Wear resistance	Corrosion resistance	Modulus of elasticity
1	AISI No.1010 hot rolled	86.5	85.3	75	100	92.3
2	AISI No.1020 hot rolled	100	99.7	100	75	92.3
3	ASTM No.A570-A	82.13	81.6	50	25	100
4	ASTM No.A675 Grade -45	74.9	100	75	50	100

Note: - During normalizing numbers 100 is given the maximum number for higher functional requirement of material and for the remaining number use cross multiplication to obtain similar results, but for lower requirements of material (for example specific gravity) 100 gives to the smallest no. & for the rest no. use the smaller no. multiplying by 100 divided the no. to obtain the required result.

Based on weighting factor multiply by the candidate material with normalized value of shaft to know make the rank of the material could be as shown below.

Table 4.7 Performance index (μ) (value outcome)

No	Material	Yield strength x(0.3)	Tensile strength x(0.2)	Wear resistance x(0.2)	Corrosion resistance x(0.1)	Modulus elasticity x(0.2)	Performance index(a)	Rank
1	SAE/AISI NO.1010 hot-rolled	25.95	17.06	15	10	18.46	86.47	2
2	SAE/AISI NO.1020 hot-rolled	30	19.94	20	0.75	18.46	89.15	1
3	ASTM NO.A570-A	24.64	14.32	10	2.5	20	73.46	4
4	ASTM NO.A675 Grade-45	22.47	20	15	5	20	82.47	3

Comment: - From the above result of material selection shows that AISI No.1020 hot rolled is the material for the shafts so mostly shafts are made of low -to- medium carbon steel one of these materials is mild-steel.

4.3.3. Material selection of pulley

Functional requirement of the pulley

The pulleys are used to transmit power from one shaft to another by means of V-belt. Since the velocity ratio is the inverse ratio of the diameters of driving and driven pulleys, therefore the pulley must select based on the availability of material. The pulleys must be in perfect alignment in order to allow the belt to travel in a line normal to the pulley faces. So, it used to increase or decreasing the speed by differentiating the same of the pulley.

Property of Material requirement for pulley [2]:

- possess optimum tensile strength
- have adequate yield strength
- Possess moderate heat capacity
- Coefficient of linear expansion lie at range of minimum value
- Density should meet value of safe operation
- Wear resistance
- Low specific gravity
- Good machinability
- Non-corrosive
- Much ductile
- Highly formed
- Highly surface finished
- Good Specific gravity
- Good Elastic modulus

Total number of decision, $N = \frac{n(n-1)}{2}$, Where rating factor, $n=4$

$$N = \frac{5(4-1)}{2} = 8$$

From the property of material selected for pulley rating and weighting factor would be shown at below table

Table 4.8 Determination of relative importance properties of materials using digital logic meth

Properties	Number of possible decisions								Positive decision	weighting factor(a)
	1	2	3	4	5	6	7	8		
yield strength		1		0	1		0		2	0.2
Specific gravity			1	1		0	1		3	0.3
Corrosion resistance		0		0		1	1		2	0.2
young's modulus elasticity	1		0		1			1	3	0.3
Total positive decision									10	1

Based on the properties of material listed above the following candidate material for the pulley is selected at below table from standard design hand book.

Table 4.9 Normalized outcome value

Material	Yield Strength (Mpa)	Elastic Modulus (GPa)	Specific Gravity	Corrosion Resistance"
AA 6061 T6 (UNS A96061	275	69.7	2.7	3
AA2024 T6 (UNS A92024)	393	72.4	2.77	3
AA 2014 T6 (UNS A92014)	415	72.1	2.8	3

Based on weighting factor multiply by the candidate material with normalized value of pulley to know make the rank of the material could be as shown below table 4.10.

Table 4.10 Performance index (μ) (value outcome)

Material	Yield Strength (Mpa)x0.2	Elastic Modulus (GPa)x0.3	Specific Gravity x0.3	Corrosion Resistance" x0.2	Weight factor	Ran k
AA 6061 T6 (UNS A96061	55	20.91	0.81	0.6	77.32	3
AA2024 T6 (UNS A92024)	78.6	21.72	0.81	0.6	101.73	2
AA 2014 T6 (UNS A92014)	83	21.63	0.84	0.6	106.07	1

Commernt:- Candidate materials to manufacture the pulleys selected are AA2014T6 (UNSA92014) Aluminum type. Duralumin Aluminum alloy is widely used for pulley and mechanical applications. Chief among its attractive properties are light weight, good corrosion resistance, relativeease of forming and machining, and pleasing appearance.

4.3.4. Material selection for bearing

Important considerations in the selection of bearing are as follows [2]:

- Direction of load relative to bearing axis. The various loads which a bearing may be required to meet are
 - a. Axial thrust load
 - b. Radial load
 - c. Combination of axial thrust and radial load.
- Intensity of loads. Ball bearings can sustain considerable loads. Roller bearings with their line contact are preferred for severe conditions and shock loads.
- Speed of rotation
- Thermal stability
- Shaft stiffness. Rigid bearings are used for stiff well aligned shafts and self-aligning bearings are used for shafts subjected to flexure or misalignment
- Class of accuracy of the machine

The distinguishing features of anti-friction bearings (ball bearing and roller bearings) compare to sliding bearings are as follows.

- (i) Low starting resistance
- (ii) Low frictional moments and heat generation
- (iii) High load capacity per unit width of bearing
- (iv) Less consumption of lubrication
- (v) Easy maintenance

Function of bearing

Bearing is used to support and make reliable rotation of shaft without drag to other materials. It minimizes the friction of shaft with other subjects. It permits a relative and smooth motion between the contact surfaces of the members, while carrying the load. Since there is a relative motion between the bearing and the moving element, a certain amount of power must be absorbed in overcoming friction, and if the surface actually touches, there will be a rapid wear.

Material requirement for the bearing

1. Compatibility
2. Comfort ability to compensate miss alignment

3. Load capacity
4. Fatigue resistance
5. Corrosion resistance
6. Thermal expansion
7. Compatibility
8. Thermal conductivity

Already, we have designed shaft diameter to be 45mm. therefore based on the diameter of shaft and the properties of bearing mentioned above, ball bearing with Bearing Basic Number 209, bore 45mm, outer diameter 85mm and width 19mm from the above table is selected for this project.

4.3.5. Material selection key

Functional requirement

A key is a piece of mild steel inserted between shaft and hub or boss of the pulleys to connect these parts in order to prevent relative motion between them. It is always inserted parallel the axis of the shaft. Keys are used as temporary fasteners and are subjected to considerable crushing and shear stresses. The most widely used method of torque transfer is by the use of keys.

Property of Material selection

Candidate materials for power transmission to shaft and pulley to connect parts typically should have good strength (especially fatigue strength), high stiffness, low cost and in some applications, good wear resistance. Steel materials meet the strength, stiffness, and cost criteria [8].

Total number of decision, $N = \frac{n(n-1)}{2}$, Where rating factor, $n = 5$

$$N = \frac{5(5-1)}{2} = 10$$

From the property of material selected for key rating and weighting factor would be shown at below table 4.11.

Table 4.11 Weighting factors for the key

Properties	Number of Decision										Weight factor
	1	2	3	4	5	6	7	8	9	10	
Ultimate strength (Mpa)	1	1	0	0							0.2
Yield strength (MN/m ²)			1	1	0	0					0.2
Modulus of elasticity (Gpa)					1	1	0	0			0.2
Density (g/cm ³)	0						1		0	0	0.1
Cost (birr/m)		0						1	1	1	0.3

Based on the properties of material listed above the following candidate material for the key is selected at below table 4.12 from standard design hand book.

Table 4.12 Candidate materials for the key

No	Material	Ultimate strength (Mpa)	Yield strength (Mpa)	Modulus of elasticity (Gpa)	Density (g/cm ³)	Cost (birr/m)
1	Structural steel ASTM A572	590	330	207	7.81	124
2	Carbon steel AISI 1080	965	524	207	7.81	168
3	Carbon steel SAE1045	742	518	207	7.81	156

Depend on the properties of candidate material for normalized value of key could be taken from standard hand book shown as below table 4.13.

Table 4.13 Normalized outcome

No	Material	Ultimate strength (Mpa)	Yield strength (Mpa)	Modulus of elasticity (Gpa)	Density (g/cm ³)	Cost (birr/m)
1	Structural steel ASTM A572	61.14	62.98	100	100	100
2	Carbon steel AISI 1080	100	100	100	100	73.81
3	Carbon steel SAE 1045	76.89	98.85	100	100	79.49

Based on weighting factor multiply by the candidate material with normalized value of key to know make the rank of the material could be as shown below table 4.14.

Table 4.14 Value of outcome and overall satisfaction

No	Material	Ultimate strength (Mpa)x(0.2)	Yield strength (Mpa)x(0.2)	Modulus of elasticity (Gpa)x(0.2)	Density (g/cm3)x(0.1)	Cost (birr/mx(0.3)	Performance index	Rank
1	Structural steel AISI 1080	12.23	12.6	20	10	30	84.83	3
2	Carbon steel AISI 1080	20	20	20	10	22.14	92.14	1
3	Carbon steel SAE 1045	15.38	19.77	20	10	23.85	89	2

Comment:- The above result shows that on the basis of allocating weighting factor carbon steel AISI 1080 gives the highest overall satisfaction among those materials. Therefore, this material is preferable for the production of the key.

4.3.6 Material selection for Bolt

Functional requirement

A screw joint is mainly composed of two elements that are bolt and nut. A screw joints are widely used when the machine parts are required to be readily connected or disconnected without damage to the machine.

Property of material requirement [12]

The material for bolt and nut production should possess high strength, fatigue resistance, high stiffness, tough and wear resistance.

Total number of decision, $N = \frac{n(n-1)}{2}$, Where rating factor, $n = 5$

$$N = \frac{5(5-1)}{2} = 10$$

From the property of material selected for bolt rating and weighting factor would be shown at below table 4.15.

Table 4.15 Weighting factors for the bolt

Properties	Number of Decision										Weight factor
	1	2	3	4	5	6	7	8	9	10	
Ultimate strength (Mpa)	1	1	0	0							0.2
Yield strength (MN/m ²)			1		0	0	0				0.1
Modulus of elasticity (Gpa)				1		1		0	0		0.2
Density (g/cm ³)	0						1	1		0	0.2
Cost (birr/m)		0			1				1	1	0.3

Based on the properties of material listed above the following candidate material for the bolt is selected at below table 4.16 from standard design hand book.

Table 4. 16. Candidate materials for the bolt

No	Material	Ultimate strength (Mpa)	Yield strength (Mpa)	Modulus of elasticity (Gpa)	Hardness (BHN)	Cost (birr/m)
1	Carbon steel SAE 1025	462	120	207	234	126
2	Carbon steel SAE 1045	655	197	207	414	142
3	Nickel alloy steel oil quenched	527	140	207	332	192

Depend on the properties of candidate material for normalized value of bolt could be taken from standard hand book shown as below table 4.17.

Table 4.17: Normalized outcome

No	Material	Ultimate strength (Mpa)	Yield strength (Mpa)	Modulus of elasticity (Gpa)	Hardness (BHN)	Cost (birr/m)
1	Carbon steel SAE 1025	70.5	60.9	100	56.5	100
2	Carbon steel SAE 1045	100	100	100	100	88.7
3	Nickel alloy steel oil quenched	80.5	71.1	100	80.2	65.6

Based on weighting factor multiply by the candidate material with normalized value of bolt to know make the rank of the material could be as shown below table 4.19.

Table 4.18: Values of outcome and overall satisfaction

No	Material	Ultimate strength (Mpa) x 0.2	Yield strength (Mpa) x 0.1	Modulus of elasticity (Gpa) x 0.2	Hardness (BHN) x 0.2	Cost (birr/m)x 0.3	Performance index	Rank
1	Carbon steel SAE 1025	7.5	6.09	20	11.3	30	74.89	2
2	Carbon steel SAE 1045	10	10	20	20	26.6	86.6	1
3	Nickel alloy steel oil quenched	8.05	7.11	20	16.04	19.68	70.88	3

Comment:- According to the above table, the material with higher overall satisfaction, is selected i.e. Carbon steel SAE 1045 are selected for bolt

4.3.7 Material selection for bearing house

Function requirement

Since the bearing is inserted into the bearing house for supporting the shaft and facilitate its motion the bearing housing should have a property that resist the bearing stress and also it resist

the torsion of the shaft due to rotational motion. The machinability of the part should be considered to have a shape of bearing [10].

Material Requirement

To satisfy the functional requirement for selecting bearing house, the material should have:--

- Better yield strength
- Better tensile strength
- Higher young's modulus of elasticity - high corrosion resistance
- it should be tough enough - it should be machine able
- it should be light in weight

Cast iron is selected for bearing house because it satisfies the above requirements.

4.3.8 Material selection for the Table stand frame

Function of frame

Used as support for the good appearance of machine .it has stand to sit on the ground and resist working loads.

Property requirement

The tensional moment of the motor, shaft and pulley have impact on the frame, it has to be tough enough to resist and absorb shock and vibration [8]

- Material requirement of frame
- It has to be tough
- It has to be hard
- Good weld ability
- Good in strength
- Highly shock resistance and vibration absorption.

The materials to be used for fabrication were selected after a careful study of the desired physical, mechanical and chemical and even aesthetic characteristics of a number of proposed materials. For this project, due to economic considerations and availability of raw materials, medium carbon steel (Angle Iron) was mostly used for stand frame parts; table top materials while Wood was chosen for the top table cover; for shaft, key, bolt and Nut used mild steel.

4.4. Ergonomic considerations

Ergonomics is the study of the interaction between people and machines and the factors that affect the interaction. Its purpose is to improve the performance of systems by improving human machine interaction. This can be done by ‘designing-in’ a better interface or by ‘designing-out’ factors in the work environment, in the task or in the organization of work that degrade human–machine performance.

The systems can be improved by designing the user-interface to make it more compatible with the task and the user. Therefore, ergonomics in system design should make the system work better by eliminating aspects of system functioning that are undesirable, uncontrolled or unaccounted for, such as

- ✚ Inefficiency – when worker effort produces sub-optimal output.
- ✚ Fatigue – in badly designed jobs people tire unnecessarily.

- ✚ Accidents, injuries and errors – due to badly designed interfaces and/or excess stress either mental or physical.
- ✚ User difficulties – due to inappropriate combinations of subtasks making the dialogue/interaction cumbersome and unnatural.

For ergonomics, the human is part of the system and must be fully integrated into it at the design stage. Human requirements are therefore system requirements, rather than secondary considerations. Modern ergonomics contributes to the design and evaluation of work systems and products. These activities should be seen as an integral part of the design and management of systems rather than ‘optional extras’.

So, in designing and manufacturing Aluminum profiles cutting machine we have included all considerations to make more suitable the interference between human-machine interaction systems in standing working posture [13].

CHAPTER FIVE

MANUFACTURING PROCESS, ASSEMBLY

5.1 Manufacturing process

A manufacturing process is a designed procedure that results in physical and/or chemical changes to a starting work material with the intention of increasing the value of that material.

A manufacturing process is usually carried out as a unit operation, which means that it is a single step in the sequence of steps required to transform the starting material into a final product.

Manufacturing operations can be divided into two basic types:-

- (1) Processing operations and
- (2) Assembly operations.

A processing operation: - transforms a work material from one state of completion to a more advanced state that is closer to the final desired product. It adds value by changing the geometry, properties, or appearance of the starting material. In general, processing operations are performed on discrete work-parts, but certain processing operations are also applicable to assembled items (e.g., painting a spot-welded car body).

An assembly operation: - joins two or more components to create a new entity, called an assembly, subassembly, or some other term that refers to the joining process (e.g., a welded assembly is called a weldment) [14].

5.2. Selection of manufacturing processes for mechanical applications

Proper manufacturing process selection is related to characteristics of materials, tolerances, surface finishes obtained and cost

The choice of a manufacturing process is dictated by various considerations such as [27]:

- Characteristics and properties of the work piece material
- Shape ,size and thickness of the part
- Tolerance and surface finish requirements
- Functional requirements or the expected service life of the computer
- Production volume (quantity)
- level of automation required to meet production volume and rate
- Costs involved in individual and combined aspects of the manufacturing operation.

5.2.1 Main shaft

It is a machine element used to transmit power from the smaller pulley to driving shaft through key and pulley. It has used to transmit power to the cutting blade. For this shaft manufacturing process the detail operation are shown below on the operation sheet table 5.1 & figure 5.1 with dimension

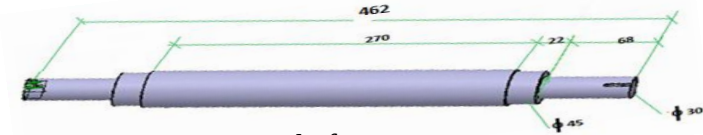


figure 5.1.mainshaft

Table 5.1 Operation list for main shaft

Operation list												
Part name: Cutter shaft				Quantity:1	Material: mild steel		Blank size: Ø52x5000mm		Part no:01			Drawing no:01
Revision no:				Date : 08/09/07			Page 1 of 11		Aluminum profile : group			
Op.no	Description	Machine tool	Tooling	Depth of cut	Speed		Feed	Time		Machine cost		Remark
					v(mv/min	n(rpm)	f(mm/min)	Setup time (hrs)	Machine time(hrs)	rate (bir/hr.	Cost (bir)	
001	Laying out and scribe	-	Tape rule ,caliper, scribe	-	-	-	-	0.08	-	2	0.16	
002	Cutting off 500mm bar stock to 440mm length	Power hacksaw	HSS	-	-	-	-	0.08	0.08	10	1.60	
003	Face one end to 435mm length	Lathe	HSS	2	98.12	625	0.2	0.08	0.16	12	2.88	
004	Face another end to 433mm length	Lathe	HSS	2	98.12	625	0.75	0.16	0.25	11	4.50	
005	Turn to Ø50mm	Lathe	HSS	4	133.45	850	0.5	0.16	0.08	9	2.16	
006	Turn to Ø 45mm at one end to 90mm length	Lathe	HSS	4	120.10	850	0.75	0.08	0.25	8	2.64	
007	Turn to Ø 45mm at other End to length of 90mm	Lathe	HSS/carbide LH	4	120.10	850	0.75	0.08	0.25	8	2.64	
008	Turn to Ø 30mm at one end to length 68mm	Lathe	HSS	5	80.08	850	0.25	0.16	0.16	6	1.92	
009	Turn to Ø 30mm at other End to length of 68mm	Lathe	HSS/carbide	5	80.08	850	0.5	0.16	0.16	6	1.92	
010	End Milling keyway hole of 11x11x68mm	Milling	HSS	4	9.15	265	0.25	0.10	0.16	7	1.82	
Total								1.14	1.55	79	22.24	

5.2.2. Large Pulley

It is one of the machine element used to transmit motion from the larger pulley to the driver shaft through V-belt. For this pulley manufacturing process is shown on the operation list all necessary information on table sectional view shown as below table 5.2 and fig.5.2.



Table.5.2 .Operation list for larger pulley

Figure.5.2 sectional larger pulley

Operation list													
Part name : large pulley				Quantity:01		Material: aluminum		Blank size: 70x Ø150		Part no:02			Draw. no :02
Revision no:				Date : 12/09/07			Page 2 of 11		Aluminum profile : group				
Op.no.	Description	Machine tool	Tooling	Depth of cut	Speed		Feed	Time			Machine cost	Rem ark	
					V(m/min)	n(rpm)		Setup Time (hrs.)	Machining time (hrs.)	Rate Birr/hr.	Cost Birr.		
001	Cutting off Ø150mm Aluminum ingot to 68mm length	Power saw	HSS	-	-	-	-	0.08	0.16	5	1.20		
002	Mount work piece on chuck and cutters mount	Lathe	Chuck	-	-	-	-	0.10	0	2	0.20		
003	Turn pulley at Ø142mm.	Lathe	Chuck	4	120	850	0.25	0.16	0.35	20	22.12		
004	Face one end to 63mm length	Lathe	HSS	3	80	850	0.5	0.08	0.16	10	2.40		
005	Set drill bit on drill post	Lathe	HSS	-	-	-	-	0.08	0	2	0.16		
006	drill throughout hole using Ø4mm drill bit	Lathe	HSS	3	4.5	350	0.75	0.08	0.16	5	1.20		
007	Boring throughout hole using Ø28mm drill bit	Lathe	HSS	2	25	255	0.25	0.08	0.1	6	1.4		
008	Mount groove of 13mm thickness cutters on tool	Lathe	HSS	-	-	-	-	0.08	0	2	0.16		
009	groove at 13mm thickness & 8mm depth of cut x2	Lathe	HSS	1	10.4	255	0.5	0.08	0.16	8	1.92		
Total								0.82	1.15	60	30.81		

5.2.3 Smaller pulley

It is one of the machine element used to transmit motion from the small pulley to the driver shaft through V-belt. For this pulley manufacturing process is shown on the operation list all necessary information on table 5.3 and fig.5.3 sectional view shown as below.

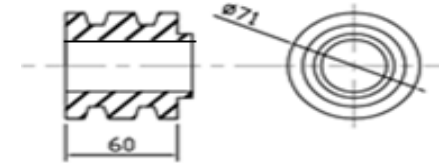


Table .5.3 .Operation list of small pulley

Figure 5.3.Section view smaller Pulley

Operation list												
Part name : motor pulley				Quantity:0 1	Material: aluminum	Blank size: 70x Ø80		Part no:03		Draw. no :03		
Revision no:				Date : 08/09/07			Page 3 of 11		Aluminum profile : group			
Op.no.	Description	Machine tool	Tooling	Depth of cut	Speed		Feed	Time		Machine		Remark
					V(m/min)	n(rpm)		f(mm/mi	Setup Time (hrs.)	Machinin g time	Rate Bir/hr.	
001	Cutting off Ø150mm Aluminum ingot to 68mm length	Power saw	HSS	-	-	-	-	0.08	0.16	5	1.20	
002	Mount work piece on chuck and cutters mount on tool post	Lathe	Chuck	-	-	-	-	0.10	-	2	0.20	
003	Turn pulley at Ø71mm.	Lathe	Chuck	4	120	850	0.25	0.16	0.25	20	8.20	
004	Face one end to 63mm length	Lathe	HSS	3	80	850	0.5	0.08	0.16	10	2.40	
005	Set drill bit on drill post	Lathe	HSS	-	-	-	-	0.08	-	2	0.16	
006	drill throughout hole using Ø4mm drill bit	Lathe	HSS	3	4.5	350	0.75	0.08	0.16	5	1.20	
007	Boring throughout hole using Ø30mm drill bit	Lathe	HSS	2	25	255	0.25	0.08	0.16	6	1.45	
008	Mount groove of 13mm thickness cutters on tool post	Lathe	HSS	-	-	-	-	0.08	-	2	0.16	
009	groove at 13mm thickness & 8mm depth of cut x2	Lathe	carbid	1	10.4	255	0.5	0.08	0.16	8	1.92	
Total								0.82	1.05	60	16.89	

5.2.4. Slider bar

The slider bar is one of the machine element used, manufacturing process would be indicated on the operation list with all information on the table 5.4 below and figure 5.4 of slider bar.

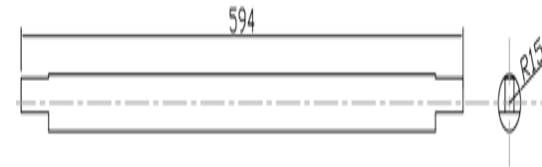


Table 5.4.operation list for Slider bar

Figure.5.4. Slider bar

Operation list												
Part name : Slider bar				Quantity:2	Material:mild steel		Blank size:Ø30x605mm		Part no:04		Draw. no :04	
Revision no:				Date : 08/09/07			Page 4 of 11				Aluminum profile : group	
Op.no	Description	Machine tool	Tooling	Depth of cut	Speed		Feed (m/min	Time		Machining cost		Remark
					v(m/min	n(rpm		Setup time(min	Machining time (min)	Rate Birr/hr.	Cost birr	
001	Measuring mild steel bar of Ø30mm at length 605mm	-	Tape rule	-	-		-	0.08	-	3	0.5	
002	CuttingoffØ30mm bar stock to 605mm length	Power hacksaw	HSS	30	-	-	0.2	0.16	0.35	9	10	
003	Mount work piece on the chuck and cutters mount on tool post	Lathe	chuck	-	-		-	0.08	0.16	5	1.20	
004	Face one end to 602mmlength	Lathe	HSS	4	61	625	0.5	0.16	0.42	8	6.80	
005	Face another end to 600mm length	Lathe	HSS	4	61	625	0.5	0.16	0.42	8	6.80	
006	End mill at both end to length of 40x4mm	milling	HSS	3	9.45	265	0.25	0.16	0.7	10	17.20	
Total								0.8	2.05	43	42.5	

5.2.5 Bearing support plate

It is one of the elements of machine; it is used to support bearing house with the station, to manufacture process could be indicated on the operation list with all information on the below table 5.5 and figure 5.5 of support plate.

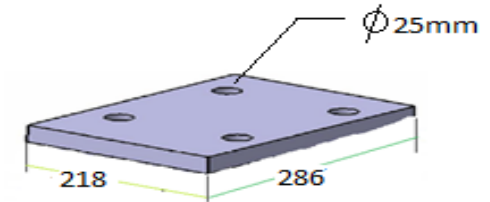


Table 5.5.operation list for bearing support plate

Figure 5.5. Bearing support plate

Operation list													
Part name : Bearing support plate		Quantity:1	Material:mild steel		Blank size: 300x220mm			Part no:05		Draw. no :05			
Revision no:		Date : 08/09/07			Page 5 of 11			Aluminum profile : group					
Op.no.	Description	Machine tool	Tooling	Depth of cut	Speed		Feed		Time		Machining cost		Remark
					v(m/min)	n(rpm)	f(mm/min)	Set-up time (min)	Machining time (min)	rate birr/hr.	cost birr		
001	Measuring ,laying out scribing	-	Scriber, tape	-	-		-	0.08	0.16	4	1		
002	Cutting off plate stock to 286x218x5mm	grinder	carbide	-	-		-	0.16	0.7	15	13		
003	Smooth edge	Grinder.	Grinder disk	-	-		-	0.16	0.35	6	3.15		
004	Scribing for make hole	-	Scriber,		-		-	0.08	0	6	0.50		
005	Mount plate on portable grinder machine	portable grinder	Drill bit		-		-	0.08	0	8	0.65		
006	Drill four hole atØ25mm	Drill	Drill bit	5	19.65	250	0.5	0.08	0.35	5	8.60		
Total								0.64	1.56	30.65	26.9		

5.2.6. Belt tension plate

It is one of the elements of machine; it is used to tighten and loose the belt with the station, to manufacture process could be indicated on the operation list with all information on the below table 5.6 and figure 5.6 of belt tension plate

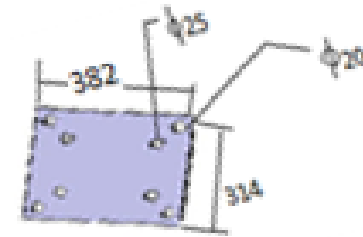


Table 5.6.operation list for Belt tension plate

Figure 5.6. Belt tension

Operation list												
Part name: Belt tension plate		Quantity:1	Material:mild steel		Blank size: 400x320mm			Part no:06			Draw. no :06	
Revision no:		Date : 08/09/07			Page 6 of 11			Aluminum profile : group				
Op.no.	Description	Machine tool	Tooling	Depth of cut	Speed		Feed	Time		Machining cost		Remark
					v(m/min)	n(rpm)		f(mm/min)	Set-up time (min)	Machining time (min)	rate birr/hr.	
001	Measuring ,laying out scribing	-	Scriber, tape	-	-		-	0.08	0	4	0.32	
002	Cutting off plate stock to 382x314x5m	grinder	carbide	-	-		-	0.08	0.7	8	6.24	
003	Smooth edge	Grinder.	Grinder disk	-	-		-	0.16	0.08	6	1.44	
004	Scribing for make hole	-	Scriber,		-		-	0.15	0.10	6	1.50	
005	Mount plate on portable grinder	Grinder	Drill bit		-		-	0.16	0	8	1.28	
006	Drill four hole atØ25mm	Drill	Drill bit	5	19.65	250	0.5	0.16	0.10	5	1.30	
007	Drill four hole atØ20mm	Drill	Drill bit	5	15.7	250	0.5	0.15	0.08	5	11.60	
Total								0.94	1.06	27.5	23.68	

5.2.7. Motor support plate

It is one of the elements of machine; it is used to support the motor station, to manufacture process could be indicated on the operation list with all information on the below table 5.7 and figure 5.7 of motor support plate.

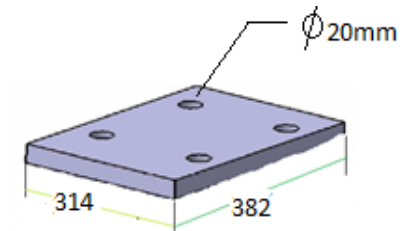


Table 5.7.operation list for motor support plate

Figure 5.7. Motor support plate

Operation list												
Part name: motor support plate			Quantity:1	Material:mild steel	Blank size: 400x320mm			Part no:07		Draw. no :07		
Revision no:			Date : 08/09/07			Page 7of 11			Aluminum profile : group			
Op.no.	Description	Machine tool	Tooling	Depth of cut	Speed		Feed	Time		Machining cost		Remar k
					v(m/min)	n(rpm)	f(mm/min)	Set– uptime (min)	Machinin g time (min)	rate birr/hr.	cost birr	
001	Measuring ,laying out scribing	-	Scriber, tape rule,	-	-		-	0.15	0.10	4	1	
002	Cutting off plate stock to 382x314x5mm	grinder	carbide	-	-		-	0.2	0.16	15	5.40	
003	Smooth edge	Grinder.	Grinder disk	-	-		-	0.16	0.08	6	1.44	
004	Scribing for make hole	-	Scriber,		-		-	0.08	0	6	0.48	
005	Mount plateon vice	drilling m/c	Drill bit		-		-	0.16	0	8	1.28	
006	Drill four hole atØ20mm	Drill m/c	Drill bit	5	15.7	250	0.5	0.16	0.14	5	1.50	
Total								0.91	0.48	21.32	11.1	

5.2.8. U-Channel

One of the machine element used, manufacturing process indicated on the operation list could be with available information shown below on table 5.8 and figure 5.8 of U- channel.

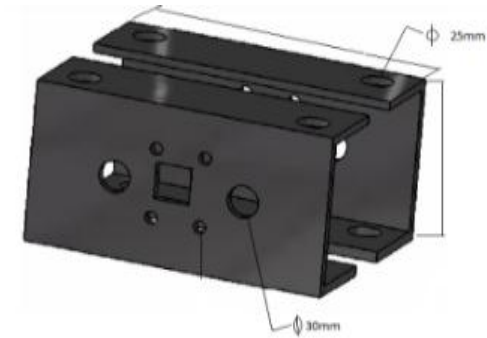


Table 5.8 Operation list of u-channel

Figure 5.7 Motor support plate

Operation list												
Part name : u- channel					Quantity:2	Material:mild steel		Blank size:286x60x6mm			Part no:08	Draw. no :08
Revision no:					Date : 08/09/07			Page 8 of 11		Aluminum profile : group		
Op.no.	Description	Machine tool	Tooling	Depth of cut	Speed		Feed	Time		Machining cost		Remark
					v(m/min	n(rpm		Setup time (min	Machining time (min	rate (birr/hr.	cost (Birr.)	
001	Measuring laying out and scribe	-	Scriber, tape	-	-		-	0.09	0	3	0.54	
002	Cutting off plate to 286x60x6mm	Power hacksaw	Cutting blade	6	-	-	-	0.12	0.2	8	10.24	
003	Drilling four holes at Ø25mm	Drilling machine	Drill bit	6	19.65	250	0.2	0.16	0.10	5	10.40	
004	Drilling four holes at Ø30mm	Drilling machine	Drill bit	6	23.55	250	0.2	0.16	0.10	5	10.40	
Total								0.53	0.4	21	31.58	

5.2.9. Stud

The stud is one of the machine element used, manufacturing process would be indicated on the operation list with all information on the table 5.9 below and figure 5.9 of stud.

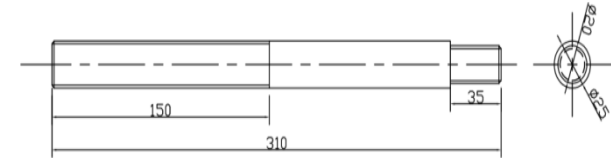


Table 5.9.operation list for stud

Figure.5.9.stud

Operation list for stud												
Part name : stud			Quantity:8	Material:mild steel	Blank size: Ø25x312mm				Part no:09		Draw. no :09	
Revision no:			Date : 08/09/07		Page 9 of 11			Aluminum profile : group				
Op.no.	Description	Machine tool	Tooling	Depth of cut	Speed		Feed	Time		Machining cost		Remark
					v(m/m in)	n(rpm)		f(mm /min)	Setup time (min)	Machining time	rate birr/hr	
001	Measuring ,laying out And scribing	-	Scriber, stool rule, tape rule, center punch		-	-		0.16	0	3	3.80	
002	Cutting off plate stock to Ø25x312mm	Hand hacksaw	carbide		-	-		0.16	0	2	2.56	
003	Turn one end at 35mm Length & Ø20mm	Lathe	HSS	1.5	34.54	550	0.5	0.08	0.10	5	7.2	
004	Surface finish another end at 150mm & Ø24	Lathe	HSS	0.5	34.54	550	0.5	0.12	0.1	7	13.22	
005	face booth ends	Lathe	HSS	0.5	34.54	550	0.5	0.16	0.08	4	7.68	
006	make thread	Die	HSS M20,1.5	1.5	-	-	-	0.08	0.1	8	11.52	
007	make thread	Die	HSS M24,1.5	1.5	-	-	-	0.08	0.3	10	30.40	
Total								0.84	0.68	39	76.38	

5.2.10. Frame

Frame is one part of machine element; it is used to support the whole machine element. Manufacturing process indicated on the operation list with available information shown below table 5.10 and figure 5.10 of frame.

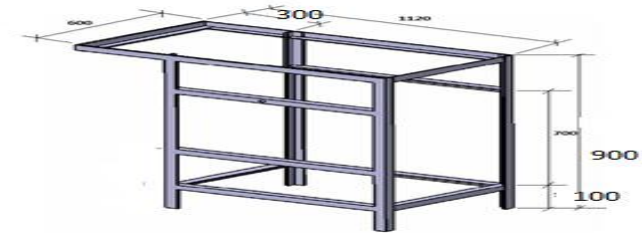


Table 5.10. Operation list for frame

Figure 5.10.frame

Operation list												
Part name : frame		Quatity:1			Material :Mild steel	Overall dimension:1120x600x900mm			Part no:10		Draw. no :10	
Revision no:		Date : 08/09/07					Page 10 of 11		Aluminum profile : group			
Op.no.	Description	Machine tool	Tooling	Depth of cut	Speed		Feed	Time		cost		Re.
					V(m/min)	n(rpm)		f(mm/min)	Set-up time (hrs.)	Machining. Time (hrs.)	Rate Birr/hr	
001	Measure,laiying out according to drawing	-	Tape rule, steel rule scriber	-	-	-	-	0.09	-	4	2.88	
002	Cutting off 6000mm length Angle Iron to 900mm length x(4)	Power hacksaw	HSS	40	-	-	-	0.16	0.35	3	6.12	
003	Cutting off 6000mm length Angle Iron to 600mm length x(7)	Power hacksaw	HSS	40	-	-	2	0.16	0.35	3	10.71	
004	Drill one Angle iron of 900mm length at center $\phi 8\text{mm}$	Drill machine	HSS	3	6.28	250	0.2	0.12	0.25	4	5.92	
005	join the front side frame	Arc welding	Electrode $\phi 2.5\text{mm}$	-	-	-	-	0.08	0.8	4	14.08	
006	join the back side frame	Arc welding	Electrode $\phi 2.5\text{mm}$	-	-	-	-	0.08	0.8	4	14.08	
007	Assemble the frame	Arc welding	Electrode $\phi 2.5\text{mm}$	-	-	-	-	0.16	0.9	6	6.36	
TOTAL								0.85	3.45	28	60.15	

5.2.11. Table top board

It is one of the part of machine; it is used to support holding work piece with the station, to manufacture process could be indicated on the operation list with all information on the below table and figure 5.11 of table 5.11 top board.

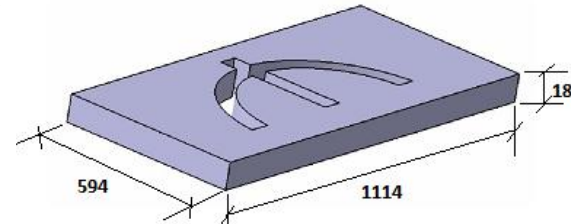


Figure 5.11. Table top board

Table 5.11.operation list for Table top board

Operation list												
Part name : Table top board			Quantity:1	Material:siferial		Blank siz:600x1120x4mm		Part no:10		Draw. no :10		
Revision no:			Date : 08/09/07			Page 10 of 10		Aluminum profile : group				
Op.no.	Description	Machine tool	Tooling	Depth of cut	Speed		Feed	Time		Machining cost		Re m ar k
					v(m/mi	n(rpm	(mm/mi n	Setup time (min)	Mach ing time (min)	rate birr/hr.	cost Birr.	
001	Measuring ,laying out and scribing	-	Scriber, , tape rule,	-	-		-	0.16	0	2	0.32	
002	Cutting off wood to 1120x600x6mm	Wood saw	Circular saw	6	45	2000	0.4	0.08	0.16	10	2.40	
003	Smooth surface finish	-	Sand paper	-	-		-	0.07	0.10	3	0.51	
004	Scribing for make Saw cutting hole	Scribing table	Scriber, steel rule, center punch		-		-	0.08	0.06	6	0.84	
005	Make graduation arc at top	-	Table support	-	-	-	-	0.4	-	20	8	
006	surface finish	-	Sandpaper		-			0.10	0.05	4	0.60	
007	Inspection	-	-		-			0.10	0.08	5	0.90	
Total								0.99	0.13	50	13.57	

5.3. Fit and Tolerance for Hole and Shaft

Fit is a contact between two mating cylindrical parts (a hole and a shaft) which can govern the performance of a large number of machines.

Tolerance is the total amount a dimension may vary and is the difference between the

Upper (maximum) and lower (minimum) limits because it is impossible to make everything to an exact size, tolerance are used on production drawing to control the parts. There are three types of fits are occurred [21].

✓ Interference fit

It also known as a press fit or friction fit, is a fastening between two parts which is achieved by friction after the parts are pushed together, rather than by any other means of fastening. for metal part in particular, the friction that holds the parts together is often greatly increased by compression of one part against the other, which realize on the tensile and compressive strength of the material the parts are made from. Typical example of interference fits are the press fitting of shafts in to bearings or bearing in to their housings.

✓ Clearance fit

A clearance fit results in limits of size that assure clearance between assembled mating parts.

✓ Transition fit

It might be either a clearance or interference fit .that is, a shaft may be either larger or smaller than the hole in the mating parts.

The standard uses tolerance position letters, with capital letters for internal dimensions (holes) and lower case letters for external dimension (shaft). The fundamental deviation locates the tolerance zone relative to the basic size for letter codes c, d, f, g, and h,

Upper deviation = fundamental deviations

Lower deviation = upper deviation –tolerance grade.

5.3.1 Tolerance and fit on pulley

The shaft has mounted in the pulley. The tolerance of shaft, pulleys and fits has clarified in appendix 10.

The basic size of shaft and pulley hole is 30mm. The ISO symbol of clearance fit 30H11/C11 and the tolerance grade IT11= 0.130mm (for nominal size 18-30).

The symbol H11/C11 therefore says that change in diameter, $\Delta D = \Delta d = 0.130\text{mm}$

Where H11/C11 is ISO symbol of clearance fit for a hole.

Maximum diameter, $D_{\max} = D + \Delta D = 30 + 0.130\text{mm} = 30.130\text{mm}$

The shaft is designed as a 30 c11 shaft. The fundamental deviation is, (for nominal size 24-30), Fundamental deviation, $\sigma_f = -0.110\text{mm}$, using the equation we get the shaft dimension.

From appendix 11.

$$d_{\max} = d + \sigma_f = 30 + (-0.11) = \underline{29.98\text{mm}}$$

$$\text{Minimum diameter, } d_{\min} = d + \sigma_f - \Delta d = 30 + (-0.110) - 0.130 = 29.76$$

Where, d =basic size of shaft, D =basic size of hole and, σ_f =fundamental deviation,

ΔD =tolerance grade for hole, Δd = tolerance grade for shaft.

5.3.2 Tolerance and fit on main shaft and its bearings

Basic size of shaft and bearing are 45mm. The standard symbol for light force fit 45H7/p6, the tolerance grade is IT11= 0.016mm. $\Delta D = \Delta d = 0.016\text{mm}$.

$$D_{\max} = 45 + 0.016 = 45.016\text{mm}.$$

$$D_{\min} = D = 45\text{mm}$$

$$\sigma_f = +0.043\text{mm}$$

$$d_{\max} = d + \sigma_f = 45 + 0.043 = 45.043\text{mm}$$

$$d_{\min} = d + \sigma_f - \Delta d = 45 + 0.043 - 0.011 = 45.032\text{mm}.$$

5.3.3 Tolerance and fit on stud and its plate

Basic size of stud and plate are 25mm. The standard symbol for normal running 25H11/c11, the tolerance grade is IT11= 0.013mm. $\Delta D = \Delta d = 0.013\text{mm}$.

$$D_{\max} = 25 + 0.013 = 25.013\text{mm}.$$

$$D_{\min} = D = 25\text{mm}$$

$$\sigma_f = +0.043\text{mm}$$

$$d_{\max} = d + \sigma_f = 25 + 0.043 = 25.043\text{mm}$$

$$d_{\min} = d + \sigma_f - \Delta d = 25 + 0.043 - 0.011 = 25.032\text{mm}.$$

5.4. Steps to assembling components are:-

Now all the parts needed for making the project are manufactured and prepared as necessary. Then the next step is assembling of manufactured components in their correct place for making the project functional

Therefore assembling of components with their step is as follows:-

Step 1. Assembly of frame by welding.

Frame has fabricated with the length, width and height by using angle iron with the respectively 1120mm x 600mm x 900mm with permanent fastening system and mechanical fastening (bolt & Nut) shown the below figure.

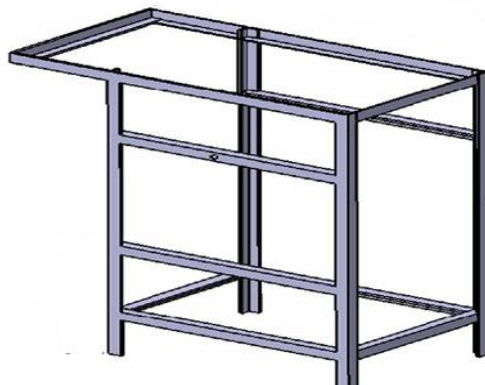


Figure 5.12 Frame assembly

Step 2. Assembly of ball bearing with bearing house by light fit.

On the step to shows the assembled of bearing as bearing house on the figure below.

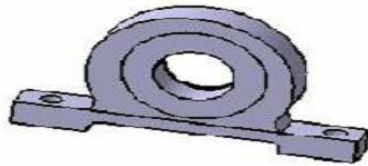


Figure 5.13 Bearing house assemblies

Step 3. Assemble of main shaft with bearing and bearing house.

A figure blow shows the assembled part of main shaft with bearing and bearing house.

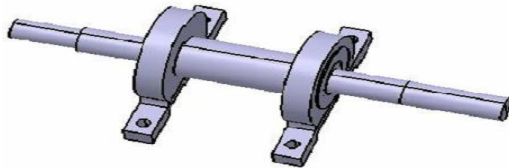


Figure 5.14 shafts and bearing house assembly

Step 4. Assemble of step 2 with the small pulley

Assembled part of main shaft, bearing, bearing house as small pulley could be shown on the below figure.

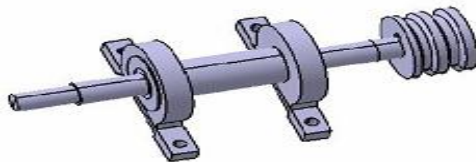


Figure 5.15 Shaft and small pulley assembly

Step 5. Assemble of step 3 with the cutter and cutter holder (on separate place)

On the blow figure show the assembled part of main shaft, bearing, bearing house, small pulley and cutter (blade) with cutter holder.

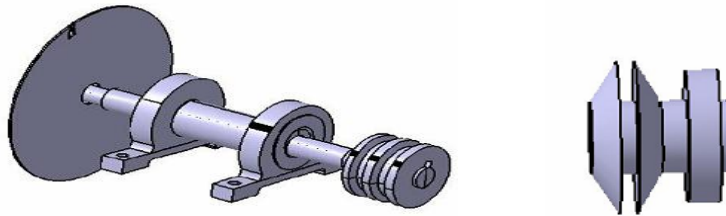


Figure 5.16 Shaft and Blade Assembly

Step 6. Assembly of U-channel with plate of bearing house support, slider bar, bolt and nut.

The assembled part of step 6 consist of U-channel, bearing house, support, slider bar, stud bar, bolt and nut would be shown on the blow figure.

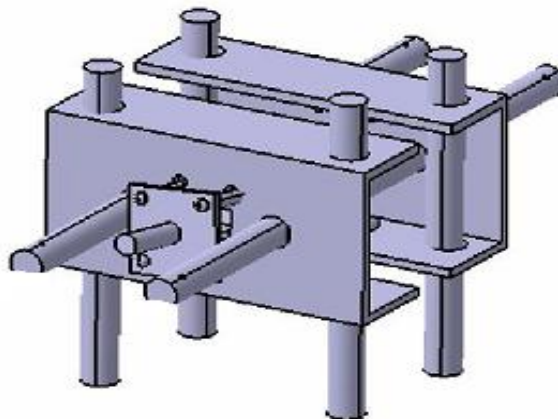


Figure 5.17 U-Channel Assembly

Step7. Assembly of the step 5 connects with motor support plate, belt tensioning plate, stud and nut.

It shows the assembled part of motor support plate, belt tensioning plate as stud and nut on the figure.

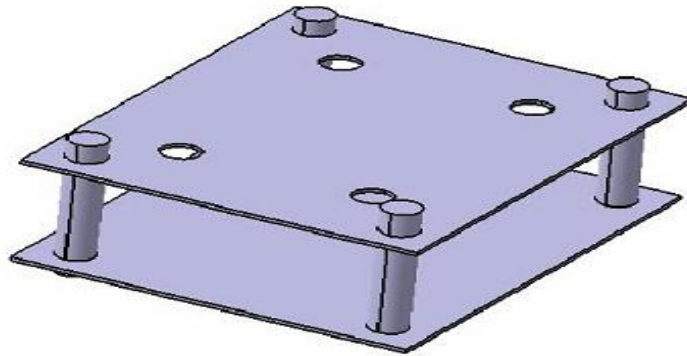


Figure 5.18 Belt tension and motor support plate assembly

Step8. Assembly of sub -assemblies step 4, 5 and 6.

The blow figure shows assembled part of main shaft bearing, bearing house small pulley, U-channel, bearing support plate, slider bar, stud bar, bolt and nut.

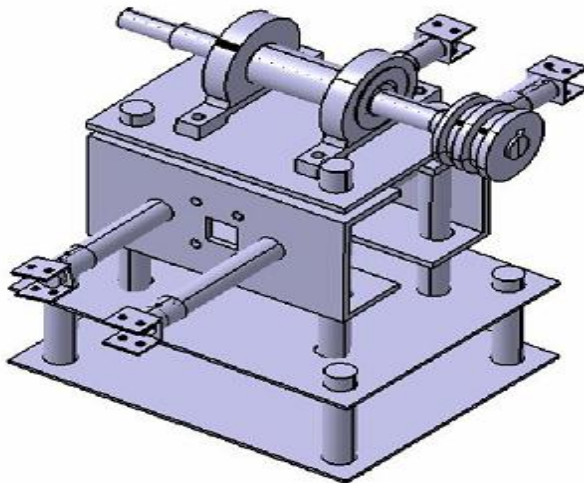


Figure 5.19 U-channel sub-assemblies

Step 9. Assembly of step 7 with motor and large pulley.

The blow figure shows assembled part of main shaft bearing, bearing house small pulley, U-channel, bearing support plate, slider bar, stud bar, bolt and nut, motor and large pulley.

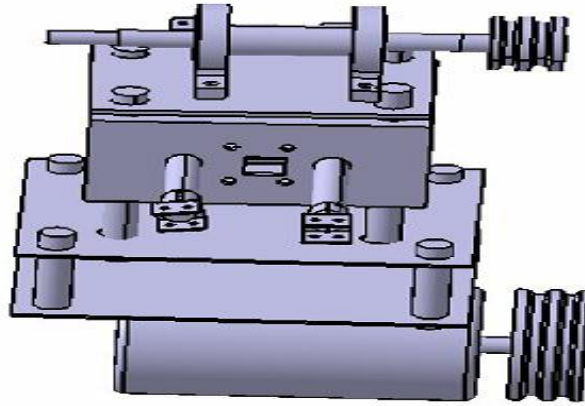


Figure 5.20 motor assembly

Step10. Motor shaft with large pulley with belt.

The assembled part of main shaft, bearing, bearing house, small pulley, cutter (blade), large pulley, motor and belt indicated the center distance of two shaft shown on the blow figure.

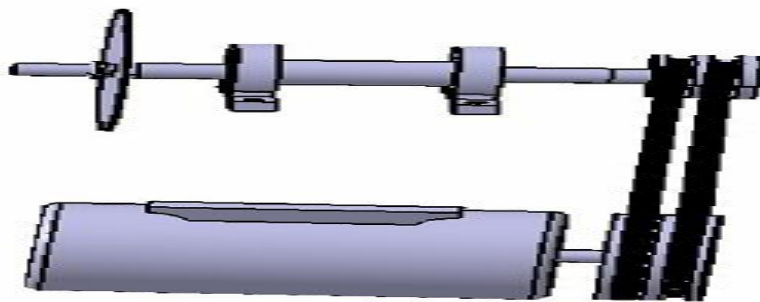


Figure 5.21 Belt assembly

Step11. Final assembly of the machine

Figure blow show the overall assembled aluminum profile cutting machine.

This machine assembled from:

- Frame
- Internal Component (sub assembled like slider bar, Belt, pulley, U-channel, Shaft bearing, tension screw.
- Push or pull (handle)
- Top plate
- Circuit breaker, 32A
- Body (sheet metal)
- Safety guard
- Motor
- Work piece holder
- graduated angle plate from 0-180⁰
- Single phase cable

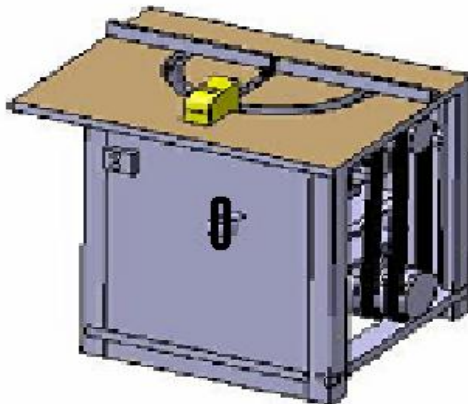


Figure 5.22 Aluminum profiles cutting machine

In general, the final assembled machine considered the designed principle, material selection criteria, the assembled easily and maintained, aesthetics, move from one place to other site easily, ergonomically , safety guard and the capacity higher than those imported.

5.5. Maintenance and Its Uses

Before apply a maintenance program for the machine, first realize the following questions.

- What is maintenance and why is it performed?
- What type of maintenance needed to prolong the life of the machines?
- What time interval to maintain the machine?

- Frequently which parts of the machine will be damaged? So what type of maintenance will be choose or preferable.
- What are the common tasks of Preventive maintenance for the machines?

5.5.1 The need for maintenance

Maintenance is “the work of keeping something in proper condition; upkeep.” This would imply that maintenance should be actions taken to prevent a device or component from failing or to repair normal equipment degradation experienced with the operation of the device to keep it in proper working order [25].

The need for maintenance is predicated on actual or impending failure – ideally, maintenance is performed to keep equipment and systems running efficiently for at least design life of the component(s). As such, the practical operation of a component is time-based function.

5.5.2 Types of maintenance

There are four main types to maintain for this machine.

1. **Reactive Maintenance:** - This is also referred as breakdown or run-to-failure maintenance. It is basically the “run it till it breaks” maintenance mode. No actions or efforts are taken to maintain the equipment as the designer originally intended to ensure design life is reached.
2. **Preventive Maintenance (Time-Based Maintenance):-** can be defined as actions performed on a time- or machine-run-based schedule that detect, prevent, or alleviate degradation of a component or system with the aim of sustaining or extending its useful life through controlling degradation to an acceptable level.
3. **Predictive Maintenance (Condition-Based Maintenance):-**

Can be defined as measurements that detect the onset of system degradation (lower functional state), thereby allowing causal stressors to be eliminated or controlled prior to any significant deterioration in the component physical state.

Basically, predictive maintenance differs from preventive maintenance by basing maintenance need on the actual condition of the machine rather than on some preset schedule. “Scientific application of proven predictive techniques increases equipment reliability and decreases the costs of unexpected failures.” You will recall that preventive maintenance is time-based. Activities such as changing lubricant are based on time, like calendar time or equipment run time.

4. The proactive maintenance:-

Monitoring and correcting of failing root cause. This department does not wait for the breakdown, but goes out onto the plant floor looking for future problems. Understood in proactive approach is the will to take equipment out of service for repair before the breakdown. The reactive approach says, “don’t fix it *if* it isn’t broke.” The proactive approach says, “don’t let it break down-period!”

Examples of proactively include inspection, cleaning, tightening, lubrication (all PM activity), complete testing of new equipment, operator certification programs, continuous training programs, reviewing designs before construction for maintainability, etc.

5.5.3 Maintenance and their functions

Some of the important functions of the maintenance programs are as follows:-

1. Inspection or checkups.
2. Lubrication.
3. Planning and Scheduling.
4. Records and analysis.
5. Storage of Spare Parts

➤ Inspection or Check-ups.

Inspection is an essential function of the maintenance program. There are external and internal inspections. External inspection means to watch for, and detect defects form abnormal sound, Vibration, heat, smoke etc. When machine is in operation; internal inspection means inspection of internal parts, such as bearings, bearing house, pulley, tolerances in the parts etc.,

Frequency of inspection should be decided very carefully, as too less inspection may cause break down, as defects could not be traced out and rectified immediately; while too much inspection, wastage of machine time and labor productivity. Hence frequency inspection should be decided on the basis of past experiences and scheduled program for inspection.

➤ Lubrication

We use systematic way of lubrication which is applying the right type of lubricant at the right time, at right place and in right quantity. For lubrication, we should be prepared and that should be followed a lubrication schedule strictly.

➤ Planning and Scheduling.

Every preventive maintenance work should be pre-planned in detail on the basis of the analysis done on the past records. Thus programmed should be in detail specifying the point requiring daily, weekly, monthly, and half yearly or yearly attention.

➤ Records and Analysis.

Good record keeping is essential for good maintenance. With the help of records possible cause for major repetitive failures can be examined and rectified so as not to repeat so early.

➤ Storage of Spare Parts

Sometimes machine remains idle for want of spare parts for considerable time and thus it, affects considerable loss of production. Hence it is essential to keep the spare parts so as to avoid loss of production.

5.5.4 The expecting problems in Aluminum profiles cutting machine

The main expected problems in the operations of the Aluminum profiles cutting machine and the elements that will require maintenance activities are:-

- ✓ Bolt and nuts are loosen or easily damaged or broken.
- ✓ Bearing parts can be easily worn-out.
- ✓ The sliding U-channel may not be operating correctly.
- ✓ During the operation, vibration might be observed.
- ✓ The belt parts might be tensioned and it will produce slippage.
- ✓ Most parts of the machine might be corroded easily.
- ✓ Some machines haven't any safety guards so it leads for accident.
- ✓ Improper alignment of pulley
- ✓ Knives are blunt.
- ✓ Too thick chip is adjusted and the operator has to adjust it according to the width and hardness of the Aluminum profiles.
- ✓ The electric motor has no sufficient output, it is necessary to call qualified electrician.
- ✓ Knives have no the same width.
- ✓ The machine was installed on uneven surface.
- ✓ Incorrect pushing or leading of the working piece while cutting.

Due to the above problems operator must not work on an Aluminum profiles cutting machines without first receiving sufficient training and without being informed of the risks, the precautions required and operating instructions for the guards and compulsory safety devices.

5.5.5 Maintenance and repairs for Aluminum profiles cutting machines

1. Lubrication

- ✓ The machine should be cleaned twice a week or after intensive use.
- ✓ Always examine bearings for proper alignment and lubrication.

2. Belt and pulley

- ✓ Check belt tension, and, if necessary, re-tension the belt. If too little tension is applied, V-belts may slip.
- ✓ Check the belt for excessive heat. Belts do warm up while operating, but temperatures must not exceed certain limits. Our hand can tolerate up to about 60°C (140°F); if belts are too hot to touch, troubleshooting may be needed.
- ✓ Check the pulley diameters over the width of the pulley to ensure they are consistent and meet our tolerances. Always check pulleys for proper alignment and mounting. Improperly aligned pulleys result in reduced service life.

Other activities

- ✓ Defect would minimize if correct operation sequence of the machine is followed and making the suitable maintenance regularly. In case that the saw chip sticks on the cutter block, switch off the electric motor before you start any repairs.
- ✓ Exchange them immediately in such a case. If the machine embodies increase vibrations, check its placing, fixing or balance of tools.

5.5.6 When to perform periodical or routine maintenance?

Due to the continuous period of operation, it is necessary to clean and lubricate the equipment daily after the work finish. Routine maintenance, like cleaning or lubrication, is required to ensure the saw, the drilling and its safe guards operate properly.

The first maintenance activities for every workshop are cleaning. Cleaning is a prime important activity in maintenance because cleaning removes the source of contaminations; dust, chips and dirty mixed with oil and grease forming abrasive materials. They can clog into machine parts and this accelerates wear and tear on the machine components and cause breakdowns, precision from close tolerance is compromised.

And also cleaning remove unnecessary things which conceal machine problems or abnormalities. It is difficult to detect missing cracks or troubles when the machine components aren't cleaned

properly. So we recommend that for some of the daily, weekly, monthly, quarterly and yearly schedules in preventive maintenance.

- Daily:-
 - ✓ Cleaning dusts chips and dirt from the machine.
 - ✓ Clean off any grease or oil that may have been spilled onto the guard.
- Weekly:-
 - ✓ Check the functionality of the whole equipment once at the time.
 - ✓ Make sure the belt tension is correct.
 - ✓ Check the condition of the switch
 - ✓ Checking for cracks, frayed spots, cuts or unusual wear patterns.
- Twice per year:-
 - ✓ Clean the equipment from oil and dirt especially inside parts like bearing and bearing houses.
 - ✓ Check that the adjusting all the equipment's are working properly.
 - ✓ Perform a full check of all function such the sharpness of the knives, the condition of the jointer blades and also circular saw blade.
- Yearly:-
 - ✓ At least once per year maintain all the tool, equipment's and inventory control for each material and equipment or spare parts.

What are the common tasks associated with preventive maintenance of Aluminum profiles cutting machine?

In the series of tasks that either extend the life of a machine components or detect that an asset has had critical problems and is going to fail or break down the parts: - we simply check and maintain the common tasks associated with Preventive Maintenance.

Types of Task	Examples
✓ Inspection.....	Detect defects form abnormal sound, Vibration, heat, smoke
✓ Cleaning.....	Cleaning chips, dusts from the work tables.
✓ Tightening.....	Check bolts nuts firmly tightening
✓ Lubrication.....	Proper lubricant needed for bearing, bearing houses....
✓ Adjustment.....	Adjust tension on drive belt
✓ Interview operators	Ask operator how the machine is operating.

Tasks of maintenance	Examples
Key	Wear
Pulley.....	Wear, key way, under groove
Blade.....	Burn, dull, wear
Belt.....	Wear, burn, elongate
Slider bar.....	Wear out, under size.
Tension screw.....	Lubrication
Bearing.....	Lubrication

5.6. Machine testing

This Aluminum profile cutting machine has tested by cutting cross (straight line) and angular in a different Aluminum profile height and width on this cross or straight line cutting different Aluminum profile used on doors, windows, staircases, partition, railing ,furniture and structure work on building construction work.

Generally, the machine cutting recommended width and height respectively 100mm x77mm.The machine easily cut because of the motor capacity as well as cutter used would be better. The machine comfortable for the sight work as well as and the mini work shop.

- It doesn't have a disturbing sound
- The machine easily transported from one work site to other site(it doesn't have much weight)
- It advisable to use this technology for SME's and private sector.



Fig 5.23 Final Aluminum profile cutting machine

CHAPTER SIX: COST ANALYSIS

6.1. Introduction

Cost Analysis is detailed analysis of the actual cost of manufacturing parts, equipment and machineries to determine the optimum cost of the product. Cost consideration is a basic issue in manufacturing sector in order to make the enterprises competent in local and global market in terms of providing goods with low cost and good quality [16].

Design and manufacture a product according to a certain specification by minimizing total cost and maximizing efficiency of the product or machine to meet service requirements is only one aspect of production. Based on these the design and manufacture of certain Aluminum profiles cutting machine analysis should be done in order to be competitive.

This analysis computes the overall cost by adding costs of:-

- raw materials and standard items,
- manufacturing cost
- labor cost

In the cost consideration in manufacturing has the following point:-

- labor per day(time)
- cost of amount of stoke material
- Renewable (consumable) material cost
- Machine depreciation cost

6.1.1 Row material cost

Material is the substance from which the product is made. It may be in a raw or manufactured state. Material is classified into two categories like as, direct material and indirect material. Direct Material is that material which can be easily identified and related with specific product, job, and process. In our case steels which are purchased in the form of sheet, plate, rod and angle Iron are raw materials for making the project.

All available raw material costs indicated on the table blow with the item, specification and total cost

Table 6.1 the costs of raw materials

No	Item	Specification	Amount		Unit price		Total cost	
			Unit	Quantity	Birr	cent	(birr)	Cent
1	Sheet metal	1000mmx2000mmX0.5mm	Pcs	1	390	15	390	15
2	Steel plate	1000mmx2000mmX5mm	Pcs	0.25	1155	0	288	75
3	U- channel	326mmx150x 8mm	Pcs	2	150	0	300	0
4	Angle Iron	40mmx40mmx3mm	Pcs	2	485	0	970	0
5	Mild steel Round bar	Φ50x600mm	Meter	0.25	400	0	40	0
6	Mild steel Round bar	Φ30x600mm	Meter	0.25	600	0	150	0
7	Mild steel Round bar	Φ25mmx1000mm	Meter	0.5	600	0	300	0
8	Mild steel Round bar	Φ10x1000mm	Meter	0.25	250	0	25	0
9	Aluminum Ingot	Φ80mm	Kg	4	300	0	300	0
10	Aluminum Ingot	Φ150mm	Kg	2	150	0	150	0
11	Siferial	100x2000x16mm	Pcs	1	453	0	452	0
12	Hexagonal bolt with nut	M10x45	Pcs	18	7	0	126	0
13	Hexagonal bolt with nut	M8x40	Pcs	10	6	0	60	0
14	Plain washer	M8	Pcs	10	2	0	20	0
15	Plain washer	M10	Pcs	18	2	0	36	0
16	V-belt	zx53 0.25	Pcs	2	90	0	180	0
17	Push button switch	3-phase	Pcs	1	150	0	150	0
18	Cable wire	Ø 2.5x40	Meter	4	60	0	240	0
19	Ball bearing with house	UCP 209	Pcs	2	450	0	900	0
20	Pin	Ø4	Pcs	4	12	0	48	0
21	plain milling cutter	Ø 60	Pcs	1	277	0	277	0
22	Motor	4KW	Pcs	1	4500	0	4500	0
23	End mill cutter	Ø 8	Pcs	2	173	0	346	0
24	Carbide cutter	20x20x150	Pcs	2	255	0	510	0
Total								90

The above mentioned materials are selected and purchased based on their availability, cost, manufacturability and desired mechanical property from local market in Adama city.

6.1.2 Manufacturing cost

The manufacturing cost consists of power consumption, labor cost, operation process, depreciation cost, and consumable material.

To get the total manufacturing (production) cost of the material, some cost like power consumption, labor cost, machine depreciation cost and the operation process cost must be announced.

6.1.2.1 Power consumption

As the cost of Ethiopian Electric consumption is from 1kw-50kw for the industries is 17birr. The project is estimated to take about 50kw power

$$=50\text{kw} \times 17\text{birr} = 850\text{birr}$$

6.1.2.2 Labor cost

Now a days a labor of manufacturing costs 25 birr per hour and project is estimated to take 72hrs (operation process cost) on the maximum level the labor cost $25\text{birr/hr} \times 72\text{hrs} = 1800\text{birr}$

6.1.2.3 The operation processing cost

This cost includes the total loading and unloading material handling of time cost of labor.

- Starting and stopping time =120min
- Load and unload time =70 min
- Over time (off time)=(120+70+40)=220min

The cost of labor per hours is 25hrs

The operation processing time 72hrs

So total operation cost = $25\text{birr} \times 72\text{hrs} = 1800\text{birr}$

process cost=356birr

Total operation cost=operation cost + labor process cost

$$=356+1800=2156\text{birr}$$

6.1.2.4 Machine Depreciation Cost

Depreciation is defined as the reduction in value of the machine over time as it is working at a specific task (Sessions, 1992). Depreciation occurs due to wear that gradually declines the capacity of the piece of equipment to perform its function. The objective of the depreciation schedule is to recover the initial investment cost of equipment each year over its economic life (Miyata, 1980). Straight-line method assumes that the value of the equipment reduces at a constant rate for each year over its economic life. The straight-line method is the simplest way for estimating depreciation costs and may be most preferable method to calculate equipment cost per unit of time (Miyata, 1980). The mathematical formula for the yearly depreciation charge using the straight-line method is:-

$$D = (P - S) / N \dots \dots \dots \text{equation 5.1}$$

Where, D = Depreciation charge

P = Initial purchase price (actual price)

S = Salvage value (take average 30% initial price P)

N = Economic life (in year or scheduled machine hours)

Example: For our project the depreciation cost of power hacksaw is calculated as follows and the same is done for other machines.

$$D = (P - S) / N$$

$$P = 40,000 \text{ Birr}$$

$$S = 30\% \text{ of } 40,000 = 12,000 \text{ Birr}$$

$$N = 10 \text{ yrs}$$

$$D = (40000 - 12000) / 10 = \underline{2800 \text{ birr/year}}$$

In one year we have 12 months, and the depreciation cost for a month, $2800 / 12 = 233.33 \text{ Birr/month}$ since there are 4 weeks in a month, the depreciation cost for a week $= 233.33 / 4 = 58.33 \text{ Birr /week}$. In a week we have 5 working days the depreciation cost per day $= 58.33 / 5 = 11.67 \text{ Birr/day}$. Further we have 8 working hours in a day so the depreciation cost per hour $= 11.67 / 8 = 1.46 \text{ Birr/hr}$. Therefore the time period over which hourly depreciation of the machine that we have used to manufacture our product is already calculated. Therefore, we can take the depreciation of those machines from the university scheduled data.

Therefore by summing up all the time for machining from the operation sheet we can calculate

the total depreciation of these machines by multiplying the time we operated the m and the hourly depreciation.

On the cost estimation of different machines used for manufacturing processed has been calculated according to the life span of machine so that the depreciation cost of different machines shown on the table blow.

Table 6.2 Depreciation cost of different machines

No	machine part	Life span(years)	usage time	Machine price		Depreciation values/hr		Total depreciation value	
				birr	Cents	Birr	cents	birr	cents
1	Power hacksaw	10	3:10	40,000	0	1	46	8	40
2	Lathe machine	10	7:55	150,000	0	5	46	43	22
3	Milling machine	12	5:35	200,000	0	6	70	37	40
4	Arc welding machine	5	6:00	30,000	0	2	18	13	8
5	Drilling machine	10	3:00	100,000	0	3	64	10	92
6	Portable hand grinder	3	2:30	3500	0	0	42	1	5
7	Jig saw	5	2:00	4500	0	0	32	0	64
TOTAL			29.1	528,000	0	17		115	88

For manufacturing of these parts it has used consumable material cost indicated with item specification and process of each item and total cost shown on the table.

6.1.2.5 Consumable material cost

Table 6.3 consumable material cost

No	Item	Specification	Amount		Unit price		Total cost	
			Unit	Quantity	birr	Cent	(birr)	cent
1	Hack saw blade	18T/inch	pcs	5	30	0	150	0
2	Anti-rust	Gallon	pcs	1	65	0	65	0
3	Paint green	Green	liter	1	70	0	70	0
4	Paint blue	Blue	liter	1	70	0	70	0
5	Grinding disk	Ø180mmx22mmx6mm	pcs	3	35	0	105	0
6	Cutting disk	Ø180mmx22mmx3mm	psc	4	35	0	140	0
7	Electrode	Ø 2.5	packet	0.25	150	0	37	50
8	Drill bit	Ø 10	pcs	3	12	0	36	0
9	Drill bit	Ø 20	pcs	1	20	0	20	0
10	Drill bit	Ø 30	pcs	1	100	0	100	0
11	Brush	2.5"	pcs	2	15	0	30	0
12	Thinner	Gallon	liter	3	65	0	130	0
Total							953	50

6.1.3 Total cost of Aluminum profile cutting Machine

➤ Manufacturing cost

- Material cost ----- = 10758.90 Birr
- Labor cost ----- = 1800Birr
- Electric power consumption cost = 850 Birr
- Machine depreciation cost ----- = 115.88Birr
- Operational process cost -----=2156birr
- Consumable cost-----=953.50birr

Manufacturing cost = 16518.40 Birr

✓ Contingencies: - it is compensation due to some errors and unexpected failure of time in our project it is usually taken as 10% of the manufacturing cost.

$$\begin{aligned}\text{Contingency} &= 10\% \times 16518.40 \text{ Birr} \\ &= 1651.84 \text{ birr}\end{aligned}$$

$$\text{Contingency} = 1651.84 \text{ birr}$$

$$\begin{aligned}\text{✓ Total manufacturing cost} &= \text{Manufacturing cost} + \text{Contingency} \\ &= 16518.40 \text{ Birr} + 1651.84 \text{ birr} \\ &= 18170.24 \text{ birr}\end{aligned}$$

✓ Profit: - it is usually taken as 20% of the total cost.

$$\begin{aligned}\text{Profit} &= 20\% \times 18170.24 \text{ birr} \\ &= 3634.05 \text{ birr}\end{aligned}$$

$$\text{Profit} = 3634.05 \text{ birr}$$

$$\begin{aligned}\text{✓ Selling price} &= \text{Profit} + \text{Total manufacturing cost} \\ &= 3634.05 \text{ birr} + 18170.24 \text{ birr} \\ &= \mathbf{21,804.29 \text{ birr}}\end{aligned}$$

6.1.4 Payback period

If aluminum profiles cutting machine purchase by 21,804.29 birr by borrowing from the Awash International bank of Adama branch with an interest of 15% for 3 years with repayment (payback) of 755.85 birr which is obtained using Loan Amortization Formula software per monthly will be profitable.

Assume Gada SME Aluminum profile installation & Fabrication loan money from Awash international bank.

$$\text{Initial investment} = 21,804.29$$

$$\text{Interest} = 20\%$$

$$\text{Year} = 3$$

By using Amortization Formula software to calculate the payback as economic consideration the interests of the bank 5406.41 birr in three years.

- Monthly interest payback
= 5406.41 birr / 36 month

=150.18birr per month payback to the bank.

- Assume the SMEs owners get monthly 15,000birr income generate.
- Then total SMEs investment per month are:
 - Maintenance cost =600birr
 - Deprivation cost=317.98birr
 - Labor cost=3000birr
 - Overhead and electrical power=1000birr
 - Monthly interest payback=150.18birr

Total cost=5068.16 birr per month

- The growth income generation in three years are :
 $15000 \text{ birr} \times 36 \text{ month} = 540,000 \text{ birr}$ in three year from this machine.
- Total investment in three years are :
 $5068.16 \text{ birr} \times 36 \text{ month} = 182472.48 \text{ birr}$ in three year for this machine.
- Therefore, the net income generate of Gada SMEs in three years are:
Net income =growth revenue-total investment cost-loan birr from bank
 $= 540,000 \text{ birr} - 182472.48 \text{ birr} - 21804.29 \text{ birr}$
 $= \underline{\underline{335,723.23 \text{ birr}}}$

Generally, when we compare the cost of our prototype machine with the existing; the fabricated machine is cheaper than the imported Bosch portable Aluminum cutting machine; as our costs 21804.29 Eth. Birr and the imported is 25,000 and 42,000 Eth. Birr respectively. Besides, we expect the cost will minimize even more than that when it is produced.

CHAPTER SEVEN: RESULT AND DISCUSSION

7.1 Result and Discussion

- The result from the study at work site of Aluminum profile cutting and assembly processes indicates that: -
- Among the distributed questionnaires the respondents were 12 males and 3 females, total 15, age of 20-50 and working experience as qualification.
- From quantitative data analysis field by respondent as result, from respondent 15;
 - At this time, is there a need Aluminum profiles cutting machine on the market? They are respond on Yes 86.66% and No 13.33%
 - The hand tools or machine you are using in your shop, are not they suitable for all workers? They are respond on Yes 73.33% and No 26.66%
 - To solve the above problem raised (2 question) on aluminum cutting area, what was the way to improve the fabrication system? They are respond on Yes 66.66% and No 33.33%
 - What is your opinion about Aluminum profiles cutting machine will be design and manufacture at Adama Science and Technology University with affordable price? Yes 100%
 - Are you using hand tools for cutting process of Aluminum profile products? This is due to either machines are not available with fair price or hand tools better than those machines? They are responding on Yes 60% and No 40%
 - Have you feeling in order to substitute the product in to local area manufacturing of aluminum building construction work? They are respond on Yes 86.66% and No 13.33%
 - Have you ever bought and used Aluminum profiles cutting machines? They are respond on Yes 73.36% and No 26.66%
 - In working Aluminum doors, Window, stair case, structures and partitions perfect cutting system increase quality? They are responding on Yes 100%

So, that the findings indicate that, there is lack of Aluminum profile cutting machine and currently this machine is highly wanted by the Aluminum profile workers at Adama city.

- From qualitative data analysis the respondents as they replied according to their experience, there were comfortable used rather than tradition one. They used:
 - Without Clamp
 - Work Piece Supporter
 - No Safety Guard Of Chip
 - Limited To 0-90⁰ Angle And
 - Unexpected Angle Is Formed when cut

So, that those cause lead to:-

- burn
 - injuries
 - unsatisfied of operator on work due to lack of safety guard
 - lose concentration
 - is not accurate joint
- According to them, they have no opportunity to select extra machine on the market.so,that the researcher arrived on conclusion to design and manufacturing Aluminum profile cutting machine with having 0-180⁰ adjustable angle.
 - The manufacturing technology processes to fabricated by using the format production operation list consisting of part name, quantity, material, blank size, part number, drawing number, revision number, machine tool, tooling, other parameters, cost of each machining steps and so on...
 - The operation types with technology processes
 - Shaft,pulley,slider bar-----by machining process
 - Frame -----by welding process
 - Body cover -----by mechanical fastener
 - All plate -----by cutting processes, drilling
 - Final assembled machine from Frame, internal component like slider bar, belt,pulley,U-chennel, shaft, bearing, tensioning screw, push pull Handel, top palte, circuit breaker 32A,body cover(sheet metal),safety guard, motor, workpiece clamp ,single cable and graduated angle from 0-180⁰

- Generally, the machine cutting recommended width and height respectively 100mm x77mm. The machine easily cut because of the motor capacity as well as cutter used would be better. The machine comfortable for the sight work as well as and the mini work shop.
 - It doesn't have a disturbing sound
 - The machine easily transported from one work site to other site(it doesn't have much weight)
 - It advisable to use this technology for SME's and private sector.
- So, that the final assembled machine considered the designed principle, material selection criteria, the assembled easily and maintained, aesthetics, move from one place to other site easily, ergonomically , safety guard and the capacity higher than those imported.
- When we compare the cost of the prototype machine with the existing; the fabricated machine is cheaper than the imported Bosch portable Aluminum cutting machine; as our costs 21804.29 Eth. Birr and the imported is 25,000 and 42,000 Eth. Birr respectively. Besides, we expect the cost will minimize even more than that when it is produced.
- Aluminum profile cutting machine used for cutting processes operated electrical system by sliding the cutter blade, the work piece, clamped with the guide at the required cutting angle or straight (to the size), the angle graduation from 0-180⁰ and it has safety guard. The machine easily move from one place to other work site.

CHAPTER EIGHT: SUMMARY, CONCLUSION AND RECOMMENDATION

8.1. Summary

An Aluminum profiles joining system consists of many individual sub-assemblies and frame structure parts mechanically fastened together. Designing a fixture for larger frame structure such as modern building like door, window, stair case, partitions etc and home and office equipment like furniture, shelf etc structure assemblies is a challenging effort. Adama city SME and private Aluminum profile working industries assemble different building, furnitures etc by importing semi-finished profile parts. Among the fabrication performed in construction SME assembling cutting of Adama city Aluminum profile is the one that has attention in the building site work area. Aluminum profile is assembled & cut at Adama city construction industry & SME by importing all semi-manufactured profile of the door, window, stair case, partition & furniture.

- ❖ In line with the objective of the study to design and develop the technological process for design and manufacturing Aluminum profile cutting machine for door, window, stair case and furniture fabrication and assembly fixture frame structure the following conclusion are made.
- ❖ The design of machine has been made based for the particular Aluminum material profile shape & size of the door, window stair case partition and furniture frame structure. Material for Aluminum profile cutting machine are selected using ranking order after analyzing the performance index of the material in addition to availability, manufacturability and costs factors. According to the ranking order mild steel AISI No 1020 for shaft, Aluminum alloy AA2014 T6 (UNSA92014) for large & small pulley, Carbon steel AISI 1080 for key, Carbon steel SAE 1045 for bolt and Nut, frame plate and U-channel are selected which are economical and sufficient in strength to hold all load acting on the machine.
- ❖ Locating and clamping of the cutting work piece parts of the Aluminum profile has been designed complete orientation and location is granted to the restricted the degree of freedom of cutting frame structure. For better operator convenience the top table board are graduated to cutting 0-180° angles for the effective and efficient cutting and assembling the aluminum profile with minimum time, cost and use the scientific work procedure by

eliminating trial and error on the Aluminum profile work in the construction industry with minimum material wastage and labor cost.

- ❖ The catia, loan Amortization formula software & Auto CAD software packages are used for the geometrical design of the machine elements. The mathematical calculations of machine elements are made which includes analysis of the frame structure, longitudinal and transverse support and also shaft, key, bolts and nut and clamp.
- ❖ Main (critical) machine elements top table board, frame, U channel and plates, Shafts, pulley, clamps, handle and bar can be manufactured in the Adama Science & Technology mechanical, department work shop while standard parts includes bolts and nuts, bearing& bearing house, cutting tool, belts, Motor are purchased.
- ❖ Detail technological process for manufacturing of each machine elements has been developed by considering the available resource in the Adama city market which profitable the fabrication of the critical (main) machine parts in Adama Science & Technology mechanical, department work.

8.2 Conclusions

Based on finding of the research, the following conclusions are made:-

This research consisted of subjective and objective method.

Subjective method had been carried out in the form of structured questionnaire and interview, at nowadays used machine and the quality, minimum cost and efficiency of the machine.

Objective method researcher discussion and which required the results (output) in the form at designing and manufacturing of Aluminum profile cutting machine.

- Through subjective assessment the capacity, quality, availability on market locally manufacturing had been evaluated Table 3.2, and although the respondents were satisfied with some of the capacity, availability on market technology, substituted by locally manufactured and existing machine, they still complained about certain at the machine, such as used for mine work (not for site work), when cutted by itself un wanted angle formed, cutter easily become hot, capacity to cut thick Aluminum profile (on winding problem). This study is an indication that the machine availability on the market.
- As it has been discussed in the literature review metal cutting design heavily relies on the data to meet an ergonomic machine design. Therefore the study provides the machine

design capacity and substituting by locally (fabrication) manufactured part to increase the quality of Aluminum works product.

- Therefore the objectives of this study have been achieved and would definitely assist in an ergonomic aluminum cutting machine design.
- When we compare the cost of this prototype machine with the existing; the fabricated machine is cheaper than the imported Bosch portable Aluminum cutting machine and KT-323E Aluminum profiles cutting table saw machine; as our costs 21804.29 Eth. birr and the imported is 25,000 and 42,000 Eth. Birr respectively. Besides, we expect the cost will minimize even more than that when it is produced. When we compare to with performance the fabricated machine can cut Aluminum profiles more than 100x77mm cross section and have a work piece holding table on the aluminum cutting machine table that enable to cut the aluminum profiles cross section more than 220x 77mm easily with high comfortable and safe work for the operator at ergonomically consideration in the standing working posture without muscular disorder cause on the worker with minimum load of work.

8.3. Recommendation

As per the result of the study, it is possible to make certain recommendations in order to improve the Aluminum profile cutting machine design and manufacturing.

The overall idea of this study is not to give a detail design at machine parts. However the suggestion that are forwarded here are aimed at giving more general guidelines to better suit this cutting machine design in its role toward improving the performance of the machine ,manufacturing and reducing the level of discomfort current observed.

The following suggestions are forwarded as result of the present study.

- In order to allow the cutting machine design a sense of comfort, capacity to cutting machine should be ergonomically designed.
- It is recommended that while designing cutting machine, the workers should use guidelines for fabrication of part according to accuracy and precision manufacturing technology process.
- The import substitution by locally manufactured cutting machine usually design or redesign the machine to suit the expectation of their customer without due consideration

for comfort as safety of the machine. Therefore, it is advisable if the SME and private used by this machine.

- As this research was find more on the Aluminum profile cutting work area, there was not much focusing on other factors for seal fit.
- The machine cutting system are limited to the straight and angle cutting system so, the circle and arc cutting process system put on for the system may subjected to suggested for future research.
- Finally the Adama city aluminum industries, construction industries and SME needs to use as a basement the output of this and similar other studies to materialized the designing and manufacturing Aluminum profiles machine locally in line with the import substitution industrial development direction of the Ethiopia.

8.4 Future works

The project is feasible and functional as per the design. It should be distributed to all the country especially where Aluminum profile work. Resources are available in order to initiate in the areas of Aluminum profile products and building construction work so as to create job for the people and to get government income tax. Thus, all concerned body should work on Aluminum profile products to get advantages from the resources. Since the design is concerned only on Aluminum profile cutting machine, it doesn't cut circular, arc shape and automatic. So for the future the design can be modified by including circular, arc shape and automatic making operations with straight and angle cutting unit that can perform electrically.

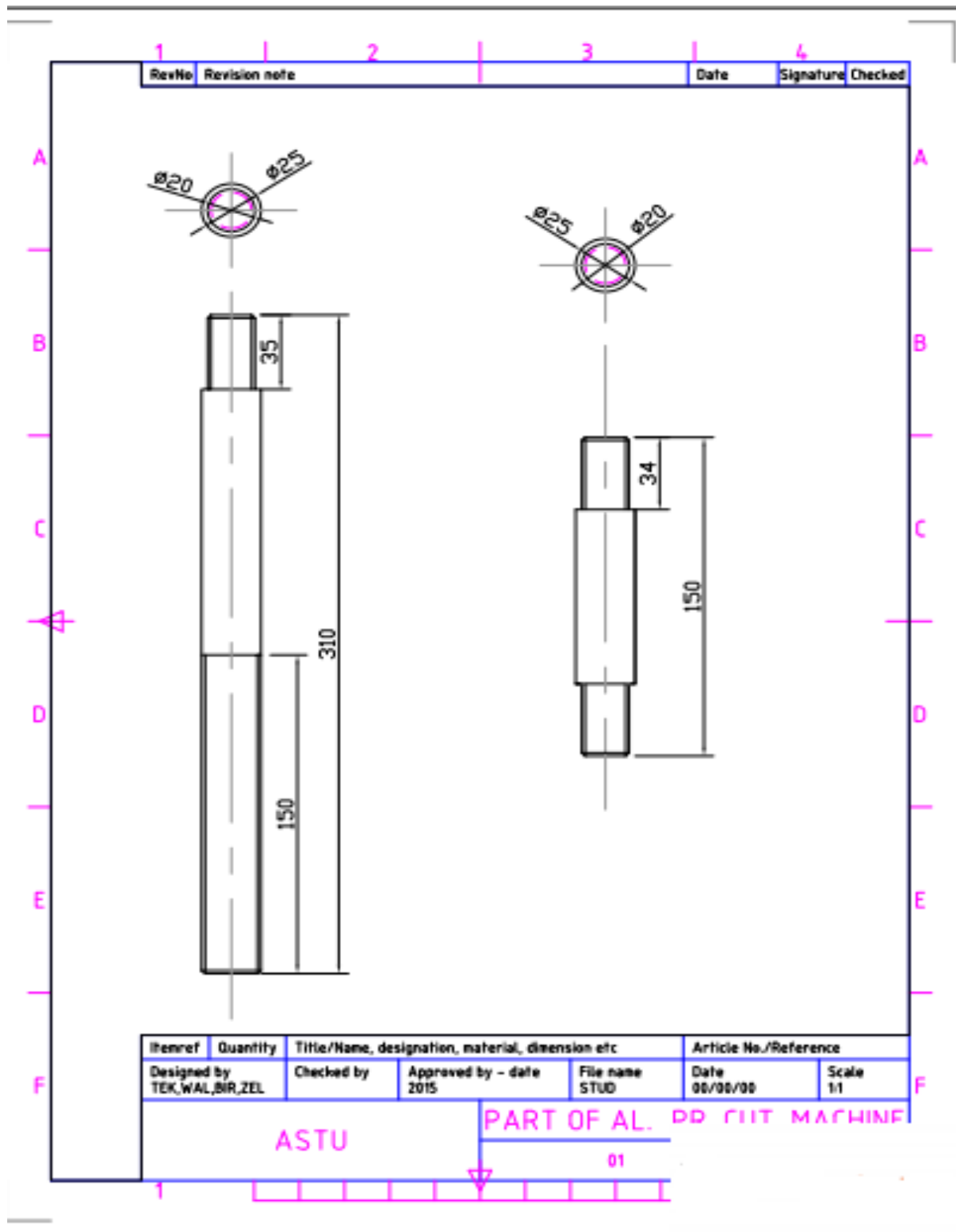
In order to get the required cutting thickness, the winding capacity on motor needs modification on wire or coil.

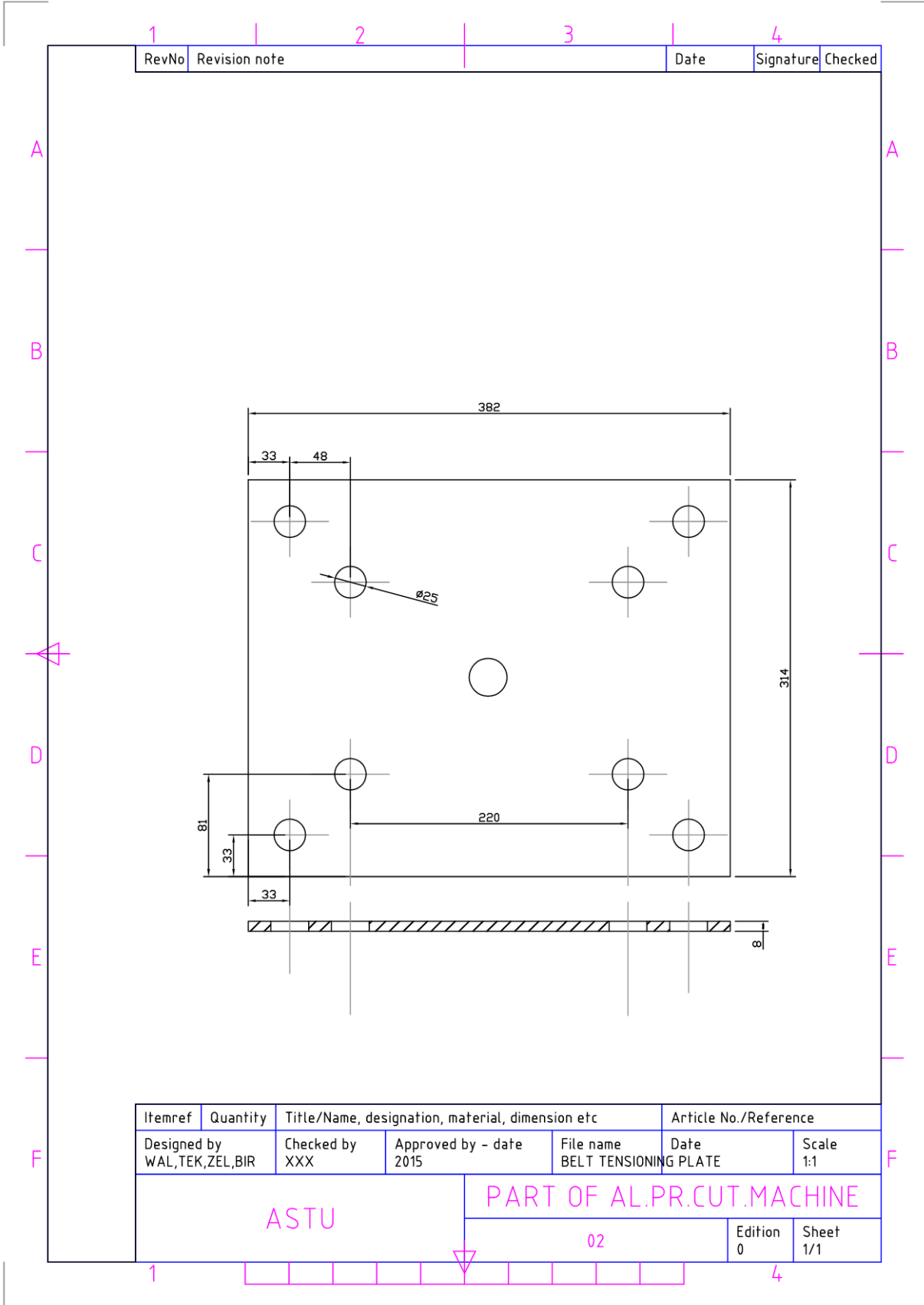
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29. www.made in china.com

APPENDIX 1: Drawing





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B
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594

37

slider shaft
x2

Itemref	Quantity	Title/Name, designation, material, dimension etc	Article No./Reference		
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218

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Quantity

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File name
TOP PLATE

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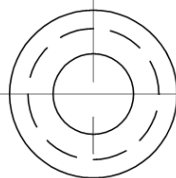
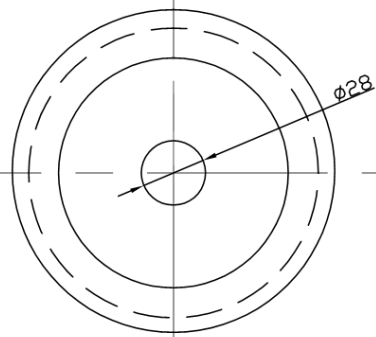
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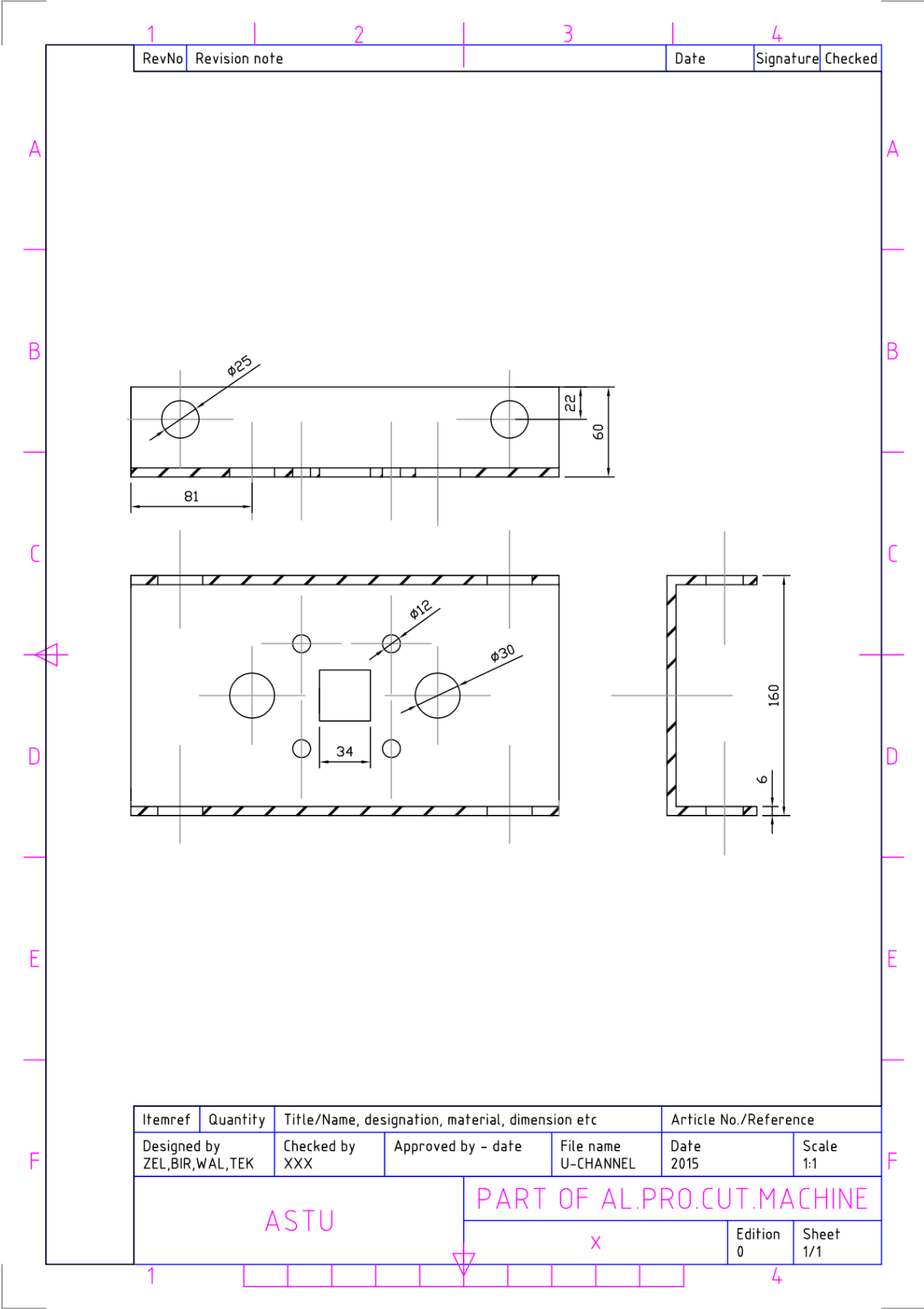
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F

Technical drawing of a mechanical part. The top view shows a rectangular piece with a central slot. The slot is 100 units wide and 100 units long. The left end has a circular feature with a radius of R6. The side view shows a rectangular piece with a height of 37 units and a length of 300 units. A detail view shows a corner with a radius of 40 units.

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1120

900

600

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40

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12

4

Itemref	Quantity	Title/Name, designation, material, dimension etc	Article No./Reference
Designed by TEK,BIR,ZEL,WAL	Checked by XXX	Approved by - date 2015	File name LEG, FRAME, SUPPORTER
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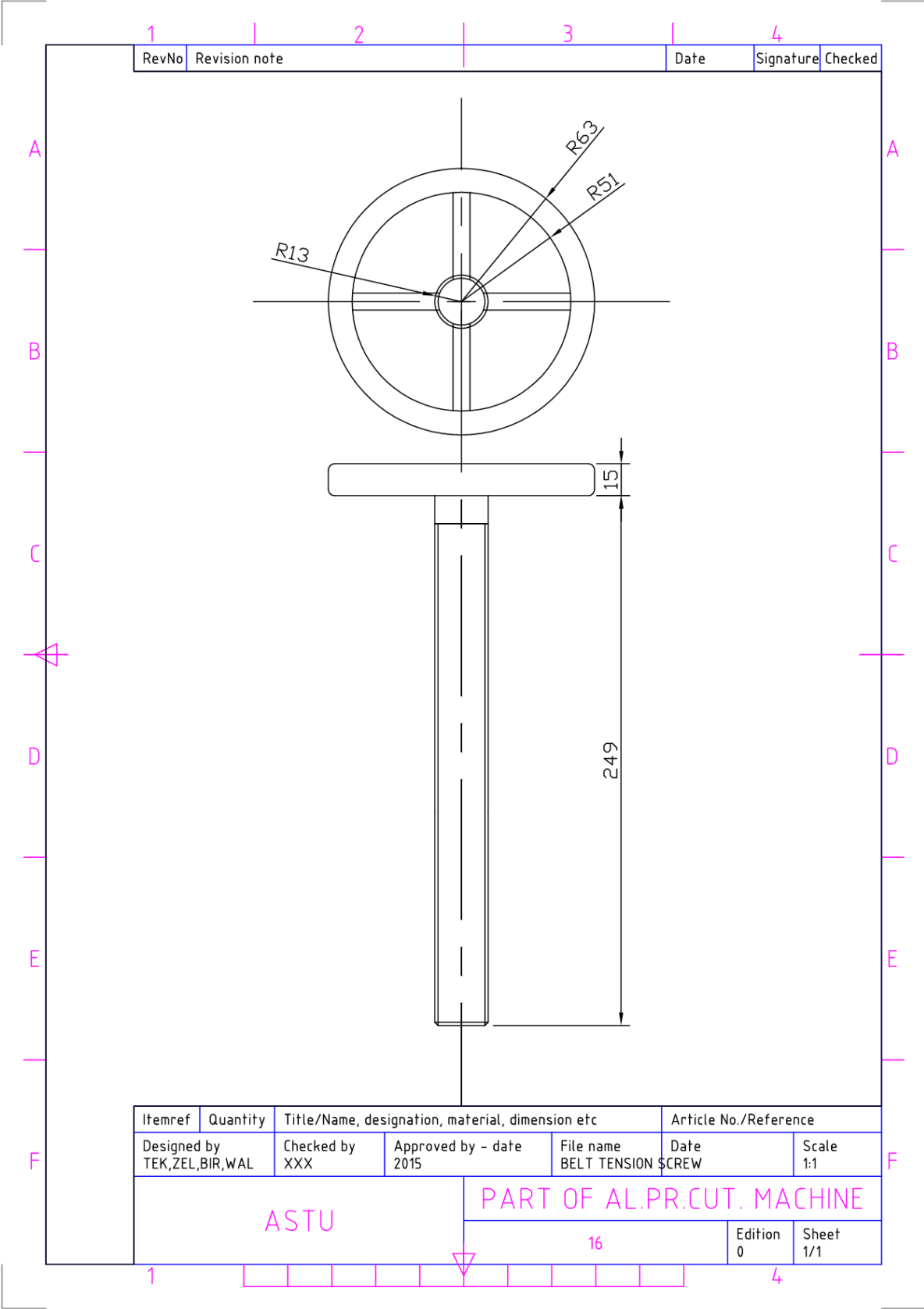
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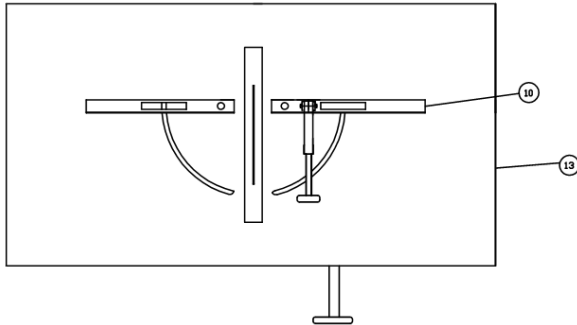
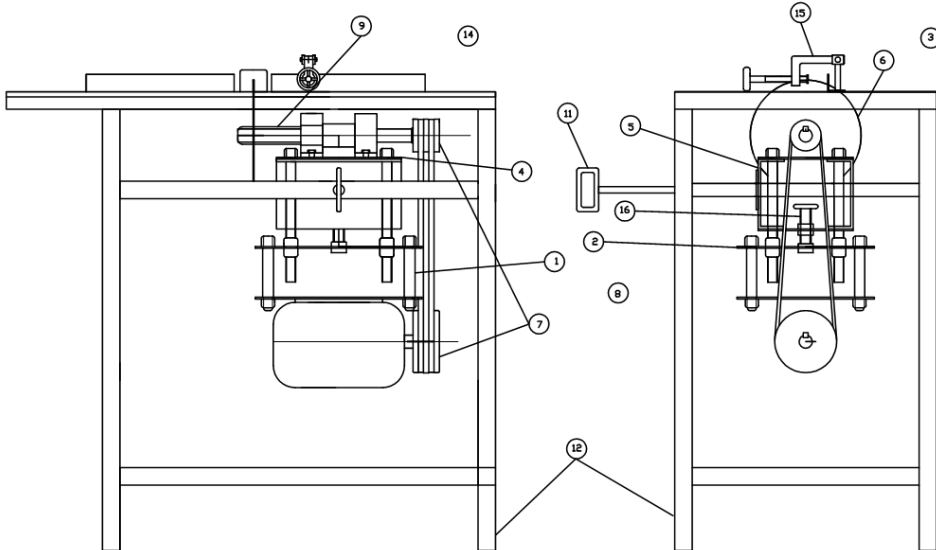
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APPENDIX: 2 Questionnaire

ADAMA SCIENCE AND TECHNOLOGY UNIVERSITY

School Of Mechanical, Chemical and Material Engineering

Department Of Mechanical and Vehicle Engineering

Questionnaire for Design and Manufacturing of Aluminum Profile Cutting Machine in Adama,
Ethiopia

Questionnaire for data collection

Site of data collection: Adama Science and Technology University

Dear participant:

The purpose of this questionnaire is to collect data about need assessment of Aluminum Profiles cutting machine for the project of master graduate project that to design and manufacture this machine at Adama Science and Technology University. For the ideas that you will give us genuine information about the demand and importance of this machine we would like to thank you in advance.

Direction Tick (✓ or x) in the given box.

I. Personal characteristics (Demography)

1. Sex: Male ☐ Female ☐

2. Age: 15 -20 ☐ 21 – 30 ☐ 31 – 40 ☐ Above 40 ☐

3. Educational qualification level:

Under graduate (Degree) ☐ Diploma ☐

Postgraduate (Master) ☐ Certificate ☐ By experience ☐

Questioner type (open and closed)

Part-1 Questionnaires

I. For the questions in the table below, read and if you agree with the statement tick (✓ or x) this sign under Yes and if you do not agree with it tick under No.

no	Questionnaire	No.of respondent/sampl e size	Yes	No
1	At this time, is there a need Aluminum profiles cutting machine on the market?			
2	The hand tools machine that you are using in your shop, are they suitable for all workers?			
3	To solve the above problem raised on aluminum cutting area what shall to improve the fabrication system?			
4	What is your opinion about Aluminum profiles cutting machine is going to design and manufacture at Adama Science and Technology University with affordable price?			
5	You are using hand tools to process Aluminum profile products. This is due to either machines are not available with fair price or hand tools are better than those machines?			
6	Have you feeling in order to substitute the product in to local area manufacturing of aluminum building construction work?			
7	Have you ever bought and used Aluminum profiles cutting machines?			

Part II

1. For How many years have you been worked on Aluminum work area?

2-3 ☐

4-5 ☐

more than 6 ☐

2. What type of cutting system used in Aluminum profile cutting?

Grinding Cutting ☐

Power hacksaw ☐

Hack saw ☐

3. At this time, is there a need Aluminum profiles cutting machine on the market?

4. The hand tools machine that you are using in your shop, are they suitable for all workers?

5. In working Aluminum doors, Window, stair case, structures and partitions perfect cutting system increase quality?

Yes ☐

No ☐

- A. If say yes, what is the reason

- B. If say No, write the reason

6. Which is the major problem of that affect the fabrication part?

Cutter ☐

Quality ☐

Power ☐

Silant ☐

7. To solve the above problem raised on aluminum cutting area what shall to improve the fabrication system?

8. Is there side effect when you are using existing machines & hand tools on Aluminum profile cutting works? Yes ☐ No ☐

If your answer is yes, please mention the pains that you feel when you use these tools.

9. What is your opinion about Aluminum profiles cutting machine is going to design and manufacture at Adama Science and Technology University with affordable price?

10. You are using hand tools for cutting process of Aluminum profile products. This is due to either machines are not available with fair price or hand tools real better than those machines?

11. Have you feeling in order to substitute the product in to local area manufacturing of aluminum building construction work?

Yes ☐

No ☐

A. If say yes, how can substitute it?

B. If says No, What is the reason of no substitution?

12. Are you believe to increase quality of Aluminum building construction work by

Existing cutting machine ☐

recent cutting machine ☐

Additional comments

Please use this space if you have any other comments you would like to make regarding your experience of aluminum work like doors, windows, stair cases, structures and partition on profile cutting area.

APPENDIX: 3: Dimensions of normal-profile belts

Classical belt	ISO marking	Z	A	B	-	C	-	D	E
	DIN marking	10	13	17	20	22	25	32	40
approximate upper width l_o		10	13	17	20	22	25	32	40
pitch width l_p		8,5	11	14	17	19	21	27	32
belt height h_o		6	8	11	12,5	14	16	20	23
height under pitch line b_p		2,5	3,3	4,2	4,8	5,7	6,3	8,1	9,6
minimal pulley pitch diameter $d_{p \min.}$		50	71	112	160	180	250	355	500
1 m belt mass [kg] $\approx$		0,07	0,12	0,20	0,27	0,37	0,44	0,69	1,03

APPENDIX: 4: Recommended length of normal-profile length of v-belt design hand book

Code	Internal length L_i (mm)	Code	Internal length L_i (mm)	Code	Internal length L_i (mm)	Code	Internal length L_i (mm)	Code	Internal length L_i (mm)	Code	Internal length L_i (mm)	Code	Internal length L_i (mm)	Code	Internal length L_i (mm)
A 15	382	A 28	710	A 36 1/2	925	A 43 3/4	1111	A 53 1/4	1355	A 70	1775	A 86	2187	A 107	2725
A 18	457	A 28 1/2	724	A 37	942	A 44	1120	A 54	1372	A 71	1800	A 87	2212	A 108	2743
A 19	480	A 29	737	A 37 1/4	946	A 44 1/2	1132	A 55	1400	A 72	1825	A 88	2240	A 110	2800
A 20	508	A 29 1/2	750	A 37 1/2	950	A 45	1143	A 56	1422	A 73	1854	A 89	2267	A 112	2845
A 21	535	A 30	767	A 38	965	A 45 1/2	1150	A 57	1450	A 74	1880	A 90	2286	A 113	2870
A 22	560	A 30 1/2	775	A 38 1/2	975	A 46	1168	A 58	1475	A 75	1900	A 91	2311	A 114	2896
A 23	587	A 31	787	A 39	992	A 46 1/2	1180	A 59	1500	A 76	1930	A 92	2337	A 116	2946
A 23 1/2	600	A 31 1/2	800	A 39 1/2	1000	A 47	1200	A 60	1525	A 77	1956	A 93	2360	A 118	3000
A 24	610	A 32	813	A 40	1016	A 48	1220	A 61	1550	A 78	1980	A 94	2388	A 120	3048
A 24 1/2	620	A 32 1/2	825	A 40 1/2	1030	A 48 1/4	1225	A 62	1575	A 79	2000	A 95	2413	A 124	3150
A 24 3/4	630	A 33	838	A 41	1041	A 49	1250	A 63	1600	A 80	2032	A 96	2438	A 128	3250
A 25	637	A 33 1/4	847	A 41 1/2	1050	A 50	1270	A 64	1625	A 81	2060	A 97	2464	A 130	3302
A 25 1/2	647	A 33 1/2	850	A 41 3/4	1060	A 51	1300	A 65	1650	A 82	2083	A 98	2500	A 132	3350
A 26	660	A 34	867	A 42	1067	A 51 1/2	1307	A 66	1676	A 83	2100	A 100	2540	A 134	3404
A 26 1/2	670	A 34 1/2	875	A 42 1/2	1075	A 52	1320	A 67	1700	A 83 1/2	2120	A 102	2591	A 136	3454
A 27	686	A 35	900	A 43	1100	A 52 1/2	1337	A 68	1725	A 84	2134	A 104	2650	A 140	3550
A 27 1/2	700	A 36	914	A 43 1/2	1105	A 53	1346	A 69	1750	A 85	2160	A 105	2667	A 144	3658

APPENDIX: 5 Value of k_l coefficient factor of-profile of belts. (Accordance to the driven machine)

Examples of driven machines	Examples of driving machines					
	AC motors and 3-phases induction motors of normal torque (of value maximum 2x of nominal torque) for example synchronous motors and 1-phase with auxiliary booting phase, 3-phase induction motors operated by star/delta switch or slip ring starter, shunt dc motor, internal combustion engines and turbines of above 600 revolutions/minute			AC motors and induction motors of high torque (of value maximum 2x of nominal torque) for example 1-phase motors of high torque, serial and serial-shunt DC motors, combustion engines and turbines of above 600 revolutions/minute		
	Values of work coefficient k_T					
	For day time of work [h]			For day time of work [h]		
	to 10	from 10 to 16	powyżej 16	to 10	from 10 to 16	above16
Low-power drives: blowers and extractors, fluid mixers, pumps and centrifugal turbines, belt conveyors for light materials, fans of power not bigger then 7,5 kW;	1,0	1,1	1,2	1,1	1,2	1,3
Middle-power drives: printing machines, agitators for cakes, metal processing machines (lathes, grinders), transmissions, three-cylinder (or more) pumps and compressors, washing machines, presses, stamping plants, shears, generators, chain and belt conveyors for heavy materials, revolving and vibration screens, fans and pumps of power above 7,5 kW;	1,1	1,2	1,3	1,2	1,3	1,4
High-power drives: displacement blowers, machines: brick, paper and fabric, hammer mills, log saws, 1-cylinder and 2-cylinder pumps and compressors, briquette presses, conveyors: bucket, scrapper and worm, atomizers, exciters;	1,2	1,3	1,4	1,4	1,5	1,6
Very high-power drives: cranes and lifters, calenders for rubber, stone splitters, mills: ball, rod and pipe.	1,3	1,4	1,5	1,5	1,6	1,8

APPENDIX: 6 Belt contact factor diagram

$\frac{D_p - d_p}{A}$	Wrap angle $\phi \approx$	k_ϕ angle coefficient
0,00	180°	1,00
0,05	177°	0,99
0,10	174°	0,99
0,15	171°	0,98
0,20	169°	0,97
0,25	166°	0,97
0,30	163°	0,96
0,35	160°	0,95
0,40	157°	0,94
0,45	154°	0,93
0,50	151°	0,93
0,55	148°	0,92
0,60	145°	0,91
0,65	142°	0,90
0,70	139°	0,89
0,75	136°	0,88
0,80	133°	0,87
0,85	130°	0,86
0,90	127°	0,85
0,95	123°	0,83
1,00	120°	0,82
1,05	117°	0,81
1,10	113°	0,80
1,15	110°	0,78
1,20	106°	0,77
1,25	103°	0,75
1,30	99°	0,73
1,35	95°	0,72
1,40	91°	0,70
1,45	87°	0,68
1,50	83°	0,65

APPENDIX: 7 Rated power p_0 transferred by one belt of a (13x8)

d _p [mm]	i or 1/i	Smaller pulley speed <i>n_d</i> [r.p.m.]																							
		200	400	700	800	950	1 200	1 450	1 600	2 000	2 400	2 800	3 200	3 600	4 000	4 500	5 000	5 500	6 000						
		Nominal power value <i>N_r</i> [kW]																							
71	1	0,14	0,23	0,35	0,39	0,44	0,51	0,58	0,61	0,70	0,77	0,82	0,80	0,87	0,87	0,85	0,78	0,69	0,58						
	1,05	0,14	0,24	0,36	0,40	0,45	0,53	0,60	0,64	0,72	0,80	0,85	0,89	0,90	0,90	0,87	0,81	0,71	0,58						
	1,2	0,15	0,25	0,38	0,41	0,47	0,55	0,62	0,66	0,75	0,82	0,88	0,92	0,94	0,93	0,90	0,84	0,74	0,60						
	1,5	0,15	0,26	0,39	0,43	0,48	0,56	0,64	0,68	0,77	0,85	0,91	0,95	0,97	0,97	0,93	0,87	0,76	0,62						
	>3	0,16	0,27	0,40	0,44	0,50	0,58	0,68	0,70	0,80	0,88	0,94	0,98	1,00	1,00	0,96	0,89	0,79	0,63						
80	1	0,18	0,31	0,47	0,52	0,60	0,71	0,81	0,87	1,01	1,12	1,22	1,29	1,34	1,37	1,36	1,31	1,21	1,06						
	1,05	0,18	0,32	0,49	0,54	0,62	0,73	0,84	0,90	1,04	1,16	1,26	1,34	1,39	1,41	1,41	1,35	1,25	1,10						
	1,2	0,19	0,33	0,51	0,56	0,64	0,76	0,87	0,93	1,08	1,20	1,30	1,38	1,43	1,46	1,45	1,40	1,29	1,13						
	1,5	0,20	0,34	0,52	0,58	0,66	0,78	0,90	0,96	1,11	1,24	1,35	1,43	1,48	1,51	1,50	1,45	1,34	1,17						
	>3	0,20	0,35	0,54	0,60	0,68	0,81	0,92	0,99	1,15	1,28	1,39	1,47	1,53	1,56	1,55	1,49	1,38	1,21						
90	1	0,22	0,39	0,61	0,68	0,77	0,93	1,07	1,15	1,34	1,50	1,64	1,75	1,83	1,87	1,88	1,82	1,70	1,50						
	1,05	0,23	0,40	0,63	0,70	0,80	0,96	1,10	1,19	1,38	1,56	1,70	1,81	1,89	1,94	1,94	1,88	1,76	1,55						
	1,2	0,24	0,41	0,65	0,72	0,83	0,99	1,14	1,23	1,43	1,61	1,76	1,87	1,96	2,00	2,01	1,95	1,81	1,60						
	1,5	0,24	0,43	0,67	0,75	0,85	1,02	1,18	1,27	1,48	1,66	1,82	1,94	2,02	2,07	2,07	2,01	1,87	1,66						
	>3	0,25	0,44	0,69	0,77	0,88	1,05	1,21	1,31	1,53	1,71	1,87	2,00	2,09	2,14	2,14	2,07	1,93	1,71						
100	1	0,26	0,47	0,74	0,83	0,95	1,14	1,32	1,42	1,66	1,87	2,05	2,19	2,28	2,34	2,33	2,25	2,07	1,80						
	1,05	0,27	0,48	0,77	0,85	0,98	1,18	1,36	1,47	1,72	1,94	2,12	2,26	2,36	2,42	2,42	2,33	2,15	1,87						
	1,2	0,28	0,50	0,79	0,88	1,01	1,22	1,41	1,52	1,78	2,01	2,19	2,34	2,44	2,50	2,50	2,41	2,22	1,93						
	1,5	0,29	0,52	0,82	0,91	1,05	1,26	1,45	1,57	1,84	2,07	2,27	2,42	2,52	2,58	2,58	2,48	2,29	1,99						
	>3	0,30	0,53	0,84	0,94	1,08	1,30	1,50	1,62	1,89	2,14	2,34	2,49	2,60	2,66	2,66	2,56	2,36	2,05						
112	1	0,31	0,56	0,90	1,00	1,15	1,39	1,61	1,74	2,04	2,30	2,51	2,68	2,78	2,83	2,79	2,64	2,37	1,96						
	1,05	0,32	0,58	0,93	1,04	1,19	1,44	1,67	1,80	2,11	2,38	2,60	2,77	2,88	2,93	2,89	2,74	2,45	2,03						
	1,2	0,34	0,60	0,96	1,07	1,23	1,49	1,72	1,86	2,18	2,46	2,69	2,86	2,98	3,03	2,99	2,83	2,54	2,10						
	1,5	0,35	0,62	0,99	1,11	1,27	1,54	1,78	1,92	2,25	2,54	2,78	2,96	3,08	3,13	3,09	2,92	2,62	2,17						
	>3	0,36	0,64	1,02	1,14	1,31	1,59	1,84	1,98	2,33	2,62	2,87	3,05	3,17	3,22	3,18	3,01	2,70	2,24						
125	1	0,37	0,67	1,07	1,19	1,37	1,66	1,92	2,07	2,44	2,74	2,98	3,16	3,26	3,28	3,17	2,91	2,48	1,87						
	1,05	0,38	0,69	1,10	1,23	1,42	1,72	1,99	2,15	2,52	2,84	3,09	3,27	3,37	3,39	3,28	3,01	2,57	1,93						
	1,2	0,39	0,71	1,14	1,28	1,47	1,77	2,06	2,22	2,61	2,93	3,19	3,38	3,49	3,51	3,39	3,12	2,66	2,00						
	1,5	0,41	0,74	1,18	1,32	1,52	1,83	2,13	2,29	2,69	3,03	3,30	3,49	3,60	3,62	3,50	3,22	2,74	2,06						
	>3	0,42	0,76	1,22	1,36	1,57	1,89	2,19	2,36	2,78	3,12	3,40	3,60	3,72	3,74	3,62	3,32	2,83	2,13						
140	1	0,43	0,78	1,26	1,41	1,62	1,96	2,28	2,45	2,87	3,22	3,48	3,65	3,72	3,67	3,44	2,99	2,31	1,37						
	1,05	0,45	0,81	1,30	1,46	1,68	2,03	2,36	2,54	2,97	3,33	3,60	3,78	3,85	3,80	3,56	3,10	2,39	1,42						
	1,2	0,46	0,84	1,35	1,51	1,74	2,10	2,43	2,62	3,07	3,44	3,72	3,91	3,98	3,93	3,68	3,20	2,47	1,46						
	1,5	0,48	0,86	1,39	1,56	1,79	2,17	2,51	2,71	3,17	3,56	3,85	4,03	4,11	4,06	3,80	3,31	2,55	1,51						
	>3	0,49	0,89	1,43	1,60	1,85	2,24	2,59	2,79	3,27	3,67	3,97	4,16	4,24	4,19	3,92	3,41	2,63	1,56						
160	1	0,51	0,94	1,51	1,69	1,95	2,36	2,73	2,94	3,42	3,80	4,06	4,19	4,17	3,98	3,48	2,67	1,51	-						
	1,05	0,53	0,97	1,56	1,75	2,02	2,44	2,82	3,04	3,54	3,93	4,20	3,34	4,31	4,12	3,60	2,77	1,57	-						
	1,2	0,55	1,00	1,62	1,81	2,09	2,52	2,92	3,14	3,66	4,07	4,35	4,48	4,46	4,25	3,73	2,86	1,62	-						
	1,5	0,57	1,03	1,67	1,87	2,15	2,60	3,02	3,24	3,78	4,20	4,49	4,63	4,60	4,39	3,85	2,95	1,67	-						
	>3	0,58	1,07	1,72	1,93	2,22	2,69	3,11	3,35	3,90	4,33	4,63	4,78	4,75	4,53	3,97	3,05	1,73	-						
180	1	0,59	1,09	1,76	1,97	2,27	2,74	3,16	3,40	3,93	4,32	4,54	4,58	4,40	4,00	3,13	1,81	-	-						
	1,05	0,61	1,12	1,82	2,04	2,35	2,83	3,27	3,52	4,07	4,47	4,70	4,74	4,56	4,14	3,24	1,87	-	-						
	1,2	0,63	1,16	1,88	2,10	2,43	2,93	3,38	3,63	4,20	4,62	4,86	4,90	4,71	4,28	3,34	1,94	-	-						
	1,5	0,66	1,20	1,94	2,17	2,51	3,03	3,50	3,75	4,34	4,77	5,02	5,06	4,87	4,42	3,45	2,00	-	-						
	>3	0,68	1,24	2,00	2,24	2,59	3,12	3,61	3,87	4,48	4,92	5,18	5,22	5,02	4,56	3,56	2,06	-	-						
v [m/s]		5			10			15			20			25			30			35			40		
Belt pulley – balancing					static							dynamic													

APPENDIX: 8 Service Factor (k_f) from the “Service Factors of V-belt drives”

Driven Equipment; I V	Operating Period /day								
	< 8 h	< 16 h	> 16 h	< 8 h	< 16 h	> 16 h	< 8 h	< 16 h	> 16 h
	Driving Machine: Smooth Starting torque 100% - 150% FL			Driving : Moderate Vibration Starting torque 150% - 250% FL			Driving Machine: Heavy Vibration Starting torque 250% - 400% FL		
	Electric Motors -Star Delta DC motors-shunt wound IC engines over 8 cyl's Water Turbines Steam Turbines			AC motors starting torque IC engines with 4-6 cylinders			AC Motors (DOL) Two stroke Engines IC engines under 600 rpm,		
Instrumentation Office display equipment Medical Equipment	1	1.2	1.4	1.1	1.3	1.5	1.2	1.4	1.6
Domestic Appliances Oven Screens Woodworking Drills Woodworking Drills Lathes	1.1	1.3	1.5	1.2	1.4	1.6	1.3	1.5	1.7
Liquid agitators, Heavy Woodworking Tools, Belt conveyors	1.2	1.4	1.6	1.4	1.6	1.8	1.6	1.8	2
Sludge Agitators, Conveyors, Milling Machines Shaper Machines Grinding Machines	1.3	1.5	1.7	1.5	1.7	1.9	1.6	1.8	2

APPENDIX: 9 Principal dimension of radial ball bearing

Table 10 principal dimension of radial ball bearing

<i>Bearing No.</i>	<i>Bore (mm)</i>	<i>Outside diameter</i>	<i>Width (mm)</i>
200	10	30	9
300		35	11
201	12	32	10
301		37	12
202	15	35	11
302		42	13
203	17	40	12
303		47	14
403		62	17
204	20	47	14
304		52	14
404		72	19
205	25	52	15
305		62	17
405		80	21
206	30	62	16
306		72	19
406		90	23
207	35	72	17
307		80	21
407		100	25
208	40	80	18
308		90	23
408		110	27
209	45	85	19
309		100	25
409		120	29
210	50	90	20
310		110	27
410		130	31
211	55	100	21
311		120	29
411		140	33
212	60	110	22
312		130	31
412		150	35

**APPENDIX: 10: Standard value of bearing house& shaft dimension
(Catalogue Oko 2005)**

HOUSING NUMBER	SHAFT DIA			D	a	b	c	g H12	h js11	L	w	m	S Bolt	U	V	d2 H12	d3 H12	fl
	mm	Inches																
SNG 507-606	30	1 ¹ / ₈	1 ³ / ₁₆	72	185	52	22	34	50	82	92	150	M12	15	20	46.5	54.5	5
SNG 508-607	35	1 ³ / ₁₆	1 ³ / ₈	80	205	60	25	39	60	85	106	170	M12	15	20	51.5	59.5	5
SNG 509	40	1 ¹ / ₂	1 ⁹ / ₁₆	85	205	60	25	30	60	85	109	170	M12	15	20	56.5	64.5	5
SNG 510-608	45	1 ¹¹ / ₁₆	1 ³ / ₄	90	205	60	25	41	60	90	112	170	M12	15	20	62	70.5	5
SNG 511-609	50	1 ¹⁵ / ₁₆	2	100	255	70	28	44	70	95	127	210	M16	18	23	67	75.5	5

APPENDIX: 11 International Tolerance grade (ISO) standard

BASIC SIZES	TOLERANCE GRADES					
	IT6	IT7	IT8	IT9	IT10	IT11
0-3	0.006	0.010	0.014	0.025	0.040	0.060
3-6	0.008	0.012	0.018	0.030	0.048	0.075
6-10	0.009	0.015	0.022	0.036	0.058	0.090
10-18	0.011	0.018	0.027	0.043	0.070	0.110
18-30	0.013	0.021	0.033	0.052	0.084	0.130
30-50	0.016	0.025	0.039	0.062	0.100	0.160
50-80	0.019	0.030	0.046	0.074	0.120	0.190
80-120	0.022	0.035	0.054	0.087	0.140	0.220
120-180	0.025	0.040	0.063	0.100	0.160	0.250
180-250	0.029	0.046	0.072	0.115	0.185	0.290
250-315	0.032	0.052	0.081	0.130	0.210	0.320
315-400	0.036	0.057	0.089	0.140	0.230	0.360

From text book of shaft design, page 7

APPENDIX: 12 Fundamental deviation of shafts (ISO)

No.	Basic sizes	UPPER- DEVIATION LATTER					LOWER- DEVIATION LATTER				
		c	d	f	g	h	k	n	p	s	u
1	0-3	-0.060	-0.020	-0.006	-0.002	0	+0	+0.004	+0.006	+0.014	+0.018
2	3-6	-0.070	-0.030	-0.010	-0.004	0	+0.001	+0.008	+0.012	+0.019	+0.023
3	6-10	-0.080	-0.040	-0.013	-0.005	0	+0.001	+0.010	+0.015	+0.023	+0.028
4	10-14	-0.095	-0.050	-0.016	-0.006	0	+0.001	+0.012	+0.018	+0.028	+0.033
5	14-18	-0.095	-0.050	-0.016	-0.006	0	+0.001	+0.012	+0.018	+0.028	+0.033
6	18-24	-0.110	-0.065	-0.020	-0.007	0	+0.002	+0.015	+0.022	+0.035	+0.041
7	24-30	-0.110	-0.065	-0.020	-0.007	0	+0.002	+0.015	+0.022	+0.035	+0.043
8	30-40	-0.120	-0.080	-0.025	-0.009	0	+0.002	+0.017	+0.026	+0.043	+0.060
9	40-50	-0.130	-0.080	-0.025	-0.009	0	+0.002	+0.017	+0.026	+0.043	+0.070
10	50-65	-0.140	-0.100	-0.030	-0.010	0	+0.002	+0.020	+0.032	+0.053	+0.081
11	65-80	-0.150	-0.100	-0.030	-0.010	0	+0.002	+0.020	+0.032	+0.059	+0.102
12	80-100	-0.170	-0.120	-0.036	-0.012	0	+0.003	+0.023	+0.037	+0.071	+0.124
13	100-120	-0.180	-0.120	-0.036	-0.012	0	+0.003	+0.023	+0.037	+0.079	+0.144

From text book of shaft design, page 8