ADAMA SCIENCE AND TECHNOLOGY UNIVERSITY

School of Mechanical, Chemical and Materials Engineering

DESIGN AND MANUFACTURING A MANUAL OPERATION CLOTH WASHING MACHINE

A project submitted in partial fulfillment of the requirement for the award of the degree of

Master of Science

In

Manufacturing Engineering

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DECLARATION

We hereby declare that the work which is being presented in this project entitle **"DESIGN AND MANUFACTURING A MANUAL OPERATION CLOTH WASHING MACHINE",** is our original work and has not been presented for a diploma /degree of any other Institution/University and all the materials used for the project have been duly acknowledged.

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SCHOOL OF MECHANICAL, CHEMICAL AND MATERIAL ENGINEERING

MSc. PROJECT

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TABLE OF CONTNETS

Content **Page**

LIS TO FIGURES

Page

LIST OF TABLES

Page

LIST OF SYMBOLS AND ABBREVIATION

CWT:	Clothes washer technology
RPM:	Revolution Per Minuit
BAT:	Best Available Technology
BNAT:	Best Not (yet) Available Technology
VA:	vertical axis
HE:	high efficiency
ATP:	Adenosine triphosphate
ICE:	Internal Combustion Engine
PDA:	Personal digital assistants
SSF:	Slow Sand Filtration
UC:	Uniformity coefficient
DBPs:	Disinfection By-Products
WHO:	World Health Organization
Al:	Aluminium
Cl:	Chlorine
2D:	Two Dimensional
3D:	Three Dimensional
FEM:	Finite Element Method
FEA:	Finite Element Analysis
HPCWM:	Human Powered Cloth Washing Machine
EPCWM:	Electrical Powered Clothe Washing Machines
PPCWM:	Pedal Powered Clothe Washing Machines
σ_u:	Tensile strength
σ_y:	Yield strength
N_f :	Safety Factor

L_{sh} :	The distance between the shafts
n_G :	The rpm of the driver gear
n_P :	The rpm of the driven pinion
F_h :	Applied load on crank handle
L_h :	The length of the handle
Φ:	Pressure angel
BHN:	Hardness, Brinell
σ_o:	Allowable static stress
σ_{es}:	Surface endurance limit
T_n:	normal torque
T_{max}:	starting Torque
ω_G:	Angular velocity of driver gear
P_G:	Power at driver gear
V.R:	Velocity ratio
D_p:	pitch circle diameter of pinion
D_G:	Pitch circle diameter of gear on crank handle
V_P:	Pitch line velocity of the pinion
C_V:	The velocity factor
Y_p:	Lewis factor for the pinion
W_T:	Tangential force
m:	Modul
Z_p:	number of teeth on pinion
Z_G:	number of teeth on gear
W_D:	dynamic load
E_p:	young’s modulus of the pinion material
E_G:	young’s modulus of the gear material
W_S:	Static Tooth load

W_W: Wear tooth load

A : Addendum

D: Dedendum

Wd: Working depth

M_{Td}: Minimum tooth depth

t: Tooth thickness

m_c : Minimum clearance

r_f : Fillet radius at root

d_{ap}: Tip (outside) diameter of pinion

d_{aG}: Tip (outside) diameter of gear

W_N: Normal load

W_{RG}: Resultant load on gear

W_{RP}: Resultant load on pinion

M_G: Bending moment of gear shaft

M_P: Bending moment of pinion shaft

T_{eG}: Equivalent torque for gear shaft

T_{eP}: Equivalent Torque for pinion shaft

D_{GS}: Diameter of the gear shaft

D_{PS}: Diameter of the pinion shaft

L_S: minimum required key length

W_K: Width of the key

τ: Permissible shear stress

σ_v: Von Mises stress

C_p: Pitch of chain

D_1: Pitch circle diameter of smaller sprocket

D_2: Pitch circle diameter of larger sprocket

K: Number of chain links

ABSTRACT

All of the washing machines available on the market are electrical power driven, which need continuous electric power from the grid. So that this Manual Operation Clothe Washing Machine has been continuing to replace the usage of electric power by human power to drive a machine. And also the machine solves the problem with regarded to working time, efficiency, simplicity, cost effectiveness and environmental pollution.

In operating principles, the machine is operated manually and easily assembled and dismantled by the user. it has the following working stapes : Firstly add appropriate amount of cloth, water & detergent then crank the handle or drive the pedal to rotate the washing drum, in this time the water and the detergents are mixed & washing action will be performed. Secondly drain the Waste water & add pure water again in order to perform rinsing & spin drying process respectively. Finally Bring out the clean cloths manually from the drum & filter the waste water by rapid and slow sand mechanism. The washing capacity of the machine is an average of 3Kg of clothes with 15L water in 40 minutes. And it primarily filtered 10L water in 15 minutes. the design and manufacturing of a Manual Operation Clothe Washing machine; also introduce ultrasonic cleaning feature to laundry service which previously limited in industrial applications only.

Keywords: *Manual Operation, Washing Machine, Hand Cranking, Pedal Power, ultrasonic cleaning, water filtration.*

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Laundering by hand involves beating and scrubbing dirty textiles. Clothes washer technology (CWT) developed as a way to reduce the manual labor spent, providing an open basin or sealed container with paddles or fingers to automatically agitate the clothing. A washing machine (laundry machine, clothes washer, or washer) is a machine designed to wash laundry, such as clothing, towels, and sheets. The term is mostly applied only to machines that use water as the primary cleaning solution, as opposed to dry cleaning (which uses alternative cleaning fluids, and is performed by specialist businesses) or ultrasonic cleaners. Washing entails immersing, dipping, rubbing, or scrubbing in water or other liquids, usually accompanied by soap, detergent, or bleach because water often had to be hand carried, heated on a fire for washing, then poured into the tub, the warm soapy water was precious and would be reused, first to wash the least soiled clothing, then to wash progressively dirtier laundry. Removal of soap and water from the clothing after washing was originally a separate process. After rinsing, the soaking wet clothing

Throughout history, human has applied energy through the use of arms, hands and back. With the invention of bicycle and pedaling, legs also began to be considered as a means to develop power from human muscles. A person can generate four times more power by pedaling than by hand cranking. At the rate of 1/4hp, continuous pedaling can be done for only short periods, about 10 minutes. However, pedaling at half this power (1/8hp) can be sustained for around 60 minutes. A human powered washing machine would allow individuals to wash cloth faster and with less strain.[1]

More over the cleaning industry is currently in a struggle to replace solvent degreasing with alternative “environmentally friendly” means of cleaning. Although substitute water-based, semi-aqueous and petroleum based chemistries are available, they are often somewhat less effective as cleaners than the solvents and may not perform adequately in some applications unless a mechanical energy boost is added to assure the required levels of cleanliness. Ultrasonic energy is now used extensively in critical cleaning applications to both speed and enhance the cleaning effect of the alternative chemistries.

1.2 Statement of the problem

In developing countries, rural women are among the least privileged. Women are both essential to the family unit and integral to the economy, yet they rarely have equal opportunities for education, career development, or social status when compared to men.

One factor behind the inequality is the long list of responsibilities that traditionally fall to women. Second, appropriate technologies are unevenly distributed because women are often considered less technically competent than men. Factors like these tend to prevent the development of improved technology for women's uncompensated, time-consuming, and laborious tasks.

An average women may do two to three loads per week for a family of about five children and her husband. It generally takes at least 8 hours of washing time, not including the extra time needed to walk to the public washing reservoir or hang up clothes to dry. Additionally, while washing clothes by hand, women spend hours leaning over a concrete or metallic basin. Clothes are washed by laboriously scrubbing each section of cloth over a cement washboard with their hands immersed in detergents that are harmful to the skin.

Existing solution are either designed for industrialized nation with running water and electricity, or they are not practical rural setting were replacement parts are difficult to find. Commercial washing machines have existed for many years, but they are expensive and require electricity from the grid to operate. Sometimes, they are available in urban settings, but the average family cannot afford to purchase one. In rural areas, commercial washing machines are not an option because electricity may be available or extremely expensive.
The modern electronic washing machines as well as the previous pedal powered washing machines doesn't consider the recycling of the drained waste water, which play a great role in environmental pollution, poor water management and both are still dependent on the mechanical agitation action of wet clothes with more water and detergent.

1.3 Objectives of the study

1.3.1 General objective

The general objective of the project is to design and manufacture Manual Operation Clothe Washing Machine which operated by mechanical and ultrasonic energy.

1.3.2 Specific objectives

The specific objective of the project is to:

- Design a functional Manual Operation Clothe Washing Machine which uses mechanical and ultrasonic energy.
- Manufacture components.
- Assemble/fabricate parts.
- Test the machine.
- Generate documentation that offers process-oriented as well as technical details.

1.4 Significance of the study

Since Manual Operation Clothe Washing Machine is basic in domestic chores it have following benefit:

- It will help to improve the traditional way of cloth washing of the community.
- Provide an opportunity for disable people in cloth washing activity.
- It will provides a job opportunity for Micro and small enterprise.
- It will lay a foundation for the research and development activity in higher education institutes towards ultrasonic cleaning of cloths.
- Improve consumption of water and energy.

1.5 Scope of the Study

This project work is delimited to design and manufacture of cloth washing machine which has a mechanism of hand cranking, pedal powered and introduce on ultrasonic energy in the laundry service. It also discusses the design and manufacturing of waste water filtration system on the Manual Operation Clothe Washing Machine. Dry and chemical cleaning is not considered in this work. The ultrasonic cleaning mechanisms are assumed integrated with outer drum of the machine in design phase. However, it is fabricated in stand-alone and prototype mode.

1.6. Limitation of the study

There was shortage of latest research works and materials for ultrasonically clothe washing machine.

There is a limitation of an accurate and precise machine that brings the required tolerance and surface finish value as expected during manufacturing.

There is time and financial constraint to integrate the ultrasonic & the mechanical washing system.

CHAPTER TWO

LITRATURE REVIEW

2.1 Introduction

Washing laundry is one of the most widespread forms of housework in the world. In the past, it was generally hard and used to be a time-intensive mechanical kind of work, and for many households in the world, it still is. The common purpose of washing machines is to provide hygienically clean laundry and to preserve its value as well as to reduce the required time and effort. As this is one of the basic needs, saturation of washing machines is generally high in industrialized countries. Within these countries, most households own a washing machine, while at the same time a high growth rate can be observed in developing and especially in newly industrializing countries. In many industrialized countries, washing machines are among the highest energy-using appliances in the average home, after refrigerators. With focus on the user perspective, this project presents the potential energy, water and cost savings, which can be achieved by the most efficient appliances currently available (Best Available Technology,) and from designs that are technically feasible with what we know today, but which are not yet commercialized (Best Not (yet) Available Technology) for common types of washing machines.

2.2 What are washing machines?

The main task of all types of washing machines, also known as ‘clothes washers’, is to provide hygienically clean laundry and to preserve its value. Washing machines use energy to heat the washing water, to run the motor and the (electronic) control system.[2] Washing machines can be defined by two product performance parameters. The first parameter is the capacity (kg) or the volume (expressed in litters or cubic-feet) of the appliance. The second parameter defines the product’s cleaning performance or the service provided by the appliance. In principle, the same water and detergent based technology is used worldwide although there are some significant differences regarding categories and types of domestic washing machines as well as energy efficiency standards.

2.3 Main types of 'washing' technologies, technical background

All contemporary automatic domestic washing machines work on the same principle. In an automatic washing machine, the load is fully treated by the machine without the need for user intervention at any point during the programmed prior to its completion. They use water, electricity, chemical substances (detergents) and process time as resources and provide mechanical work to clean laundry. After the cleaning process, all automatic washing machines remove most of the remaining water from the clothes by spinning and then pumping the water out of the machine.

Energy- and water-efficient washing machines incorporate numerous saving technologies and features. Horizontal axis front- and top-loading washers are generally more efficient than top loading vertical axis models. Horizontal-axis machines don't completely submerge clothes, so they use on average 30 to 50 % less water than vertical-axis models. The less water a washing machine uses, the less energy is needed to heat it up for the washing process or to remove the water after rinsing and during spinning.[3]

In contrast, most traditional and less efficient top-loading vertical axis models fill the tub to fully submerge the clothes. Agitator washing machines use an agitator to swirl the water and clothes around. There are also other top-loading vertical-axis models that use a moving plate (Impeller washing machine) in the bottom of the tub, in place of an agitator, to bounce clothes through the water .

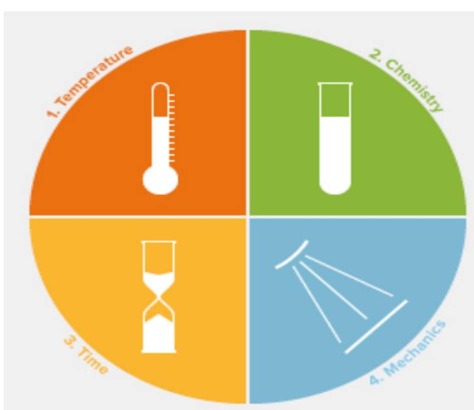


Figure 2:1 In washing machines the mechanical action is provided by the drum, agitator or impeller movement **Source: based on glasswashing.biz 2012**

Apart from the electricity and water consumption of washing machines, the effectiveness of the washing process is determined by additional relevant factors. Thereby, good cleaning performance needs a minimum amount of energy input, which includes mechanical work, thermal energy, chemicals and time. These parameters for the cleaning performance can be described as segments of the “Sinner Circle” (Figure2.1).Presuming a constant cleaning performance (circular area) this means: In order to reduce one of these four components, the segment areas of the others have to be increased. This can be achieved either by enlarging the amount or by raising the efficiency of the respective parameter of cleaning performance.

Although the electricity consumption per wash cycle of these washing machines is low (if cold water is used), the environmental impact of the entire washing process may be much higher. Pre- and post-treatment processes, which are mostly done manually, increase the consumption of energy (when done with warm water), water, detergents as well as time spent on laundry washing, due to the drawbacks of vertical-axis washing machines, worldwide development tends towards high efficient horizontal axis washing machines with the capability of compensating for the reduced energy consumption (especially due to lower washing temperatures) by more efficient mechanical work and more extensive wash cycles in combination with high efficient detergents. Hence, the design options to further reduce the environmental impacts of washing machines usually refer to this type of machines.[3]

2.4 Energy and cost savingpotential

The three major types of ‘domestic washing machines’ can be assigned in two categories:

Horizontal axis machines: In horizontal axis machines (see Figure2.2), only the bottom of the washtub is filled with water. Compared to vertical axis machines, significantly less water per wash cycle is used. Horizontal axis machines are commonly equipped with an internal electric water heating system. Hence, the energy consumption heavily depends on the chosen washing temperature. Modern washing machines with horizontal axis technology have an automatic load sensing function in order to reduce water and electricity consumption in response to consumer loads that are smaller than the rated capacity. [4]

Figure 2:2 Horizontal axis washing machines, Front load configuration, Source: Stock photo 2013

Vertical axis machines:

Traditionally, the tub is entirely filled with water, but most modern vertical axis machines (see Figure2.3) also have automatic water level settings or the user can set the water level manually. Nevertheless, even present-day vertical axis machines often consume about twice as much water per wash cycle as horizontal axis machines. Although vertical axis machines are usually not equipped with an integrated water heating system, warm washes can be done by using hot water from external sources. The additional energy needed to heat up water from the tap is hard to estimate, because it can be done by electricity or other energy sources like gas, coal, oil or solar power. In addition to these ‘automatic domestic washing machines’, in some regions of the world laundry is still done manually or with semi-automatic washing machines.

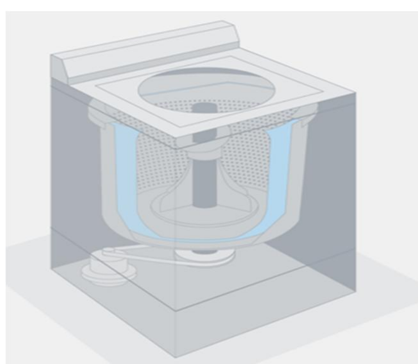


Figure 2: 3 Vertical axis washing machine (Agitator type) Source: Wuppertal Institute 2013

Manual laundry:

The energy and water consumption for manual clothes washing and pre- and post-treatments of laundry has not been taken into consideration in this context because reliable data is not commonly available. However resource consumption for manual laundry washing is considered as an important and interesting future research area with respect to the global resource consumption for laundry washing. Although no reliable information on the exact share is available, manual laundry washing may contribute significantly to the domestic hot water consumption in many households.[3]

Semi-automatic washing machines:

A ‘semi-automatic’ washing machine requires user intervention at one or more points during the program to enable the machine to proceed to its next operation. Examples of user intervention could include manual filling (water and detergents), non-automatic water leveling, transfer of the load between a washing drum and a spin extractor drum or manual draining at single and twin-tub semiautomatic washing machines. Twin tub machines are typically side-by-side two tub units where one tub provides the washing service and the second tub spins the load. The user is required to transfer the load between tubs. Although the energy consumption per wash cycle is low (if cold water is used), these units are considered to be significantly less efficient than automatic washing machines as their overall resource consumption (energy, water, detergents) is highly dependent on the individual operator. Consequently, exact and reliable data is commonly not available, but high levels of washing treatments with relevant amounts of water, chemicals and energy outside the washing machine indicate a low level of washing performance by these machines. Semi-automatic washing machines account for only a small and falling proportion of the market for washing machines in industrialized countries. Nevertheless, in some regions of the world (especially in Africa, Latin-America and Asia), this type is still very common as an entry-level washing machine. Because semi-automatic machines are also commonly referred to as “vertical axis (VA)”washing machines, the available stock data for some countries may include both types of VA washing machines (automatic and semi-automatic). [5]

Appliances vary greatly in their configurations and the range of options. The most common types of automatic washing machines worldwide are:

- Horizontal axis, front- or top loading washing machine
- Vertical axis, top loading agitator washing machine
- Vertical axis, top loading impeller washing machine

Table 2:1 Comparison of washing machine categories and types

Source: Further developed illustration, based on http://indiahometips.com and www.energywise.govt.nz 2011

Category	**Horizontal axis**	**Vertical axis**		
Type	Drum-type front or top loading (fully automatic)	Semi-automatic (single- or twin tub)	Top loading agitator (fully automatic)	Top loading impeller (fully automatic)
Capacity	4 to 9 kg	4 to 8 kg	5.5 to 6 kg	5.5 to 10 kg
Wash Quality	Excellent	Low to Average	Good	Good
Energy consumption	Electricity: Low to High (Depends on chosen washing temperature)	Electricity: Low, but overall consumption (including external sources) is highly user dependent	Electricity: Low to Average, but overall consumption (including external energy sources): Average to High	Electricity: Low to Average, but overall consumption (including external energy sources): Average to High
Water consumption	Average to Low	(Very) High (User dependent)	(Very) High	(Very) High
Standard Wash Cycle Duration	Average to Slow (typically 60 - 90 minutes or more)	Fastest (< 30 min, Highly user dependent)	Fast (typically 30 to 45 minutes)	Fast (typically 30 to 45 minutes)
Internal heat generator (Hot Wash option)	All (Some: Cold wash option and/or Hot water inlet	No (Manual fill only)	Some (Usually external heat sources)	Some (Usually external heat sources)
Delicate Clothes Treatment	Excellent	Average	Rough	Good
Water Connection	Required with pressure	Not required	Required	Required
Acquisition costs	Average to High	Low	Average	Average

2.4.1 Agitator washing machine (Vertical axis)

Vertical axis, top loading agitator washing machines show large energy- and water savings compared to inefficient models on the market, especially in North- and Latin America as well as in Australia, as such washing machines are popular in these regions. However, vertical axis machines often consume about twice as much water per wash cycle as horizontal axis machines.

2.4.1.1 Comparing inefficient models and BAT on the worldwide market

Table 2:2 Energy consumption, impeller washing machines with cold water use

Washing capacity		Energy (kWh/cycle with cold water) in accordance with Chinese Standard GB/T 4288 2008 GB 12021.4-2004	Energy class	Energy saving potential compared to inefficient model	Energy cost savings versus inefficient model (EUR in 15 years, 3300 cycles at 12 EUR Cent/ kWh)
Small - Medium ≤ 6 kg	BAT level	0.06	Chinese National energy efficiency grade 1	66 %	47
Large > 6 kg	BAT level	0.07	Chinese National Energy efficiency grade 1	53 %	32

Source: top10.cn 2012 for energy consumption (kWh/year) of typical inefficient model and example of BAT model, energy saving potential and energy cost savings

Please note: The reported energy consumption of horizontal axis drum type washers (see table 2.3) is almost ten times higher compared to the impeller-type machines. The difference in the reported energy use is largely due to the difference in test procedures: Impeller models are only tested with an inlet water temperature of 20°C, while HA drum models are tested with input water of 15°C which is internally heated to 60°C. [6]

Table 2:3 Energy consumption, impeller washing machines with cold water use

Washing capacity		Water consumption (L/cycle)	Energy Class	Water saving Potential versus Inefficient model	Water cost savings versus inefficient model (EUR in 15 years, 3300 cycles) at 2.64 €/m3)
Small < 6kg	BAT level	106	Chinese National energy Efficiency grade 1	27 %	340
Large > 6kg	BAT level	111	Chinese National energy Efficiency grade 1	53 %	1078

Source: EuP-study lot 25, Task 2 for water costs (€/liter); top10.cn 2012 for water consumption (L/cycle) of typical inefficient model and example of BAT model, water saving potential and water cost savings.

Table 2:4 Combined energy and water lifetime cost savings, impeller washing machines with

Washing capacity		Energy Class	Energy and water cost savings versus inefficient model (EUR in 15 years,330 cycles)
Small to Medium ≤ 6 kg	BAT level	Chinese National energy efficiency grade 1	388
Large > 6 kg	BAT level	Chinese National energy efficiency grade 1	1,109

Source: Calculated, based on Table 2 and Table 3

The prices of efficient models have been steadily coming down. While they cost more than those with out-dated designs that use large amounts of energy and water, consumers should also consider their hot water heating costs, their water bills and their local need for water efficiency as they compare prices.

2.4.2 Horizontal axis front- and top loading washing machines

Horizontal axis washing machines (also known as 'front-loader' or 'drum type' machines) show both large energy and water savings compared to inefficient models on the market, especially in Europe as such washing machines are most popular in this region. Additionally, the share of horizontal axis machines is also steadily rising in most other markets worldwide. Switching from vertical axis to horizontal axis machines offers another important water and energy saving potential, because horizontal axis machines usually consume about half as much water per wash cycle as vertical axis machines (or even less).

2.4.2.1 Comparing inefficient models and BAT on the worldwide market with future BNAT potential

Table 2: 5 Horizontal axis washing machines, energy consumption for 60 °C hot wash cycle

Washing capacity		Energy consumption (kWh/cycle at 60°C wash cycle)	Energy class	Energy Saving potential versus Inefficient model	Energy cost Savings versus Inefficient model (EUR in 15 years, 3300 cycles at 12 EUR Cent/kWh)
Small < 6 kg	BAT level	0.94	Chinese National Energy efficiency grade 1	24 %	117
	BNAT (wash temperatures between 20 and 40°C max.)	0.34		73 %	355
Medium 6 kg	BAT level	0.90	Chinese National Energy efficiency grade 1	32 %	166
	BNAT (wash temperatures Between 20 and 40°Cmax.)	0.43		67 %	352
Large > 6 kg	BAT level	0.98	Chinese National energy efficiency grade 1	46 %	325
	BNAT (wash temperatures Between 20 and 40°C max.)	0.49		73 %	517

Source: top10.cn 2012 for energy consumption (kWh/year) of typical inefficient model and example of BAT model, own calculations of BNAT level, energy saving potential and topten.eu 2012 for energy cost savings.

Please note: The reported energy consumption of horizontal axis drum type washers is almost ten times higher compared to the impeller-type machines (see 2.2). The difference in the reported energy use is largely due to the difference in test procedures: Impeller models are only tested with an inlet water temperature of 20°C, while HA drum models are tested with input water of 15°C which is internally heated to 60°C.

Table 2: 6 Horizontal axis washing machines, water consumption for 60 °C hot wash cycle

Washing capacity		Water consumption (L/cycle)	Energy Class	Water saving potential versus inefficient model	Water cost savings versus inefficient model (EUR in 15 years, 3300 cycles) at 2.64 €/m3)
Small < 6 kg	Inefficient model	64	Chinese National energy efficiency grade 2		
	BAT level	55	Chinese National energy efficiency grade 1	14 %	78
	BNAT	44		31 %	172
Medium 6 kg	Inefficient model	75	Chinese National energy efficiency grade 2		
	BAT level	59	Chinese National energy efficiency grade 1	22 %	141
	BNAT	44		41 %	270
Large > 6 kg	Inefficient model	96	Chinese National energy efficiencygrade1		
	BAT level	69	Chinese National energy efficiency grade1	28 %	233
	BNAT	49		49 %	409

Source: EuP-study lot 25, Task 2 for water costs (€/litre); top10.cn 2012 for water consumption (L/cycle) of typical inefficient model and example of BAT model, own calculations of BNAT level, water saving potential and water cost savings.

Table 2: 7 Horizontal axis washing machines, combined energy and water lifetime cost savingsfor 60 °C hot wash cycle

Washing Capacity		Energy Class	Energy and Water cost savings versus inefficient model (EUR in 15 years, 3300 cycles)
Small < 6 kg	BAT level	Chinese National energy efficiency grade 1	195
	BNAT		528
Medium 6 kg	BAT level	Chinese National energy efficiency grade 1	307
	BNAT		623
Large > 6 kg	BAT level	Chinese National energy efficiency grade 1	557
	BNAT		926

Source: top10.cn 2012 for energy and water consumption of typical inefficient model and example of BAT model, own calculations of BNAT level cost savings

The prices of energy- and water-efficient models have been steadily coming down. While they cost more than those with out-dated designs that use large amounts of energy and water, consumers should also consider their hot water heating costs, their water bills and their local need for water efficiency as they compare prices.

2.5 Human –Powered Energy System

Human power is work on energy that is produced from the human body. It can also refer to the power (rate of work per time) of a human. Power comes primarily from muscles, but body heat is also used to do work like warming shelters, food, or other humans. World records of power performance by humans are interest to work planners and work-process engineers. The average level of human power that can be maintained over a certain duration of time, say over the extent of one minute or one hour is interesting to engineers designing work operations in industry .

Traditionally human-powered products were aiming at user scenarios in which the user wanted to be independent from the grid. Contemporary human powered products are largely marketed from the viewpoint of being beneficial to the environment due to the absence of batteries. This can be concluded from the fact numerous pro-environment websites currently supply human-powered products as sustainable options for battery-powered products. The human-powered products marketed in the former century show an identifiable differentiation in both technical realization and intended or perceived user scenario. [7]

2.5.4 Optimal Design of Bicycle Frame Parameters Considering Biomechanics

The design of bicycle frame is the most important in bicycle design. The relative positions among the saddle, handlebar and central axis are defined as the bicycle three pivot, they are the main parameters in bicycle frame design. In conventional bicycle design, frame parameters are merely relevant to bicycle types. Biomechanics concerns with the human and the instruments, equipment, and environment that relate to the human in exercises. With the development of the biomechanical study, more and more human factor is infiltrated into bicycle design for riding comfort.

Therefore, the study of human machine system has high theoretical and practical value based on biomechanics. There have been many relative researches in this field around the world.[8] studied the bicycle saddle systematically based on the theories of ergonomics, medicine, mechanics and aesthetics. They developed a scientific design method of bicycle saddles by which the innovation scheme was obtained, designed the relative positions among the handlebars, saddle and pedals according to ergonomics, so that each joint of the rider is at a comfortable angle during riding.[9] The human posture which has some effect on the arm and lower limb muscle during riding slopes through electromyography signal picture. They analyzed the relationship between muscle and joint activities and the force that the pedal and saddle is suffered. The hip muscle injury that is caused by the reaction force on the saddle during riding. Their study provides theoretical guidance to the saddle design. Antagonism relationship of lower limb muscles based on the electromyography signal and the force of lower limb muscles during cycling. [10]

Frame is the necessary part of bicycle. It takes weight of the rider and connects the handlebar, the fork, and wheels. Therefore, the cycling performance is directly determined by frame structure parameters, which are traditionally obtained by experience. Different bicycle types match with the different frame parameters. However, because of difference in height, weight, and limb length of different people, the designed products may not always be suited to the human bodies.

The relative positions among the saddle, handlebar, and central axis are defined as the bicycle three pivots. They are main parameters in bicycle frame design. On the basis of the dynamic simulation, biomechanical principles, and knowledge of ergonomics, the design method of three pivot position is discussed considering the feature parameters of the rider in this paper. The method provides universal theoretical guidance for the customized design of the bicycle.

In this paper, firstly the optimal frame parameters for the specific rider are obtained based on biomechanics. Secondly a serial of optimal frame parameters for different rider are obtained with the same method, and a function between the height of rider and frame parameters is set up by regression analysis. Then the relationship between frame parameters and bicycle design is described.

2.5.4.1 Frame Parameters for the Specific Rider

The relative positions among the saddle, handle and pedal have much effect on the riding posture which is essential to riding comfort. Since the handle is symmetrical to the main frame and the pedal moves circularly around the axis, the three pivot is defined according to the relative positions among saddle *A*, bottom bracket *B*, and the midpoint of handlebar *C*, as shown in Fig. 2.8. The relative position between the handle and the saddle affects the torso posture of the rider,

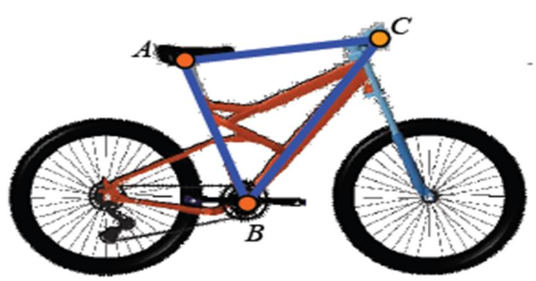


Figure 2:4 Three pivot position of the bicycle

which determines the bending state of the spine. The relative position between pedals and the saddle affects the lower posture which determines the leg muscle tension during cycling.[11]

2.5.4.2 Design theory of three pivot position

In Fig. 2.9 curve B shows the natural bending state of the human spine when the human body is in lateral recumbent posture; Curve C shows the sitting posture at which the human spine is the closest to its natural bending state; The other curves indicate the situation that the pressure on the inter-vertebral discs is not normally distributed. Therefore, the body is the most comfortable when the back muscles are in a relaxation state, when the spine is natural and the human body is at the sitting posture during cycling.

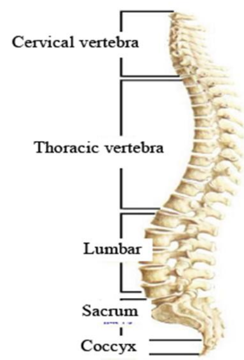


Figure 2: 5 Structure of human spine

According to the theory of ergonomics, the most comfortable cycling posture occurs when the angle between upper arm and upper thoracic is 50º. [9]Hence the optimal distance between saddle and handlebar, and the angle that is between the horizontal and the line connecting handle and saddle (marked as α in Fig. 2.11) can be obtained thereby. For riders with a height of 1 600 mm, α=1 0.2 °.

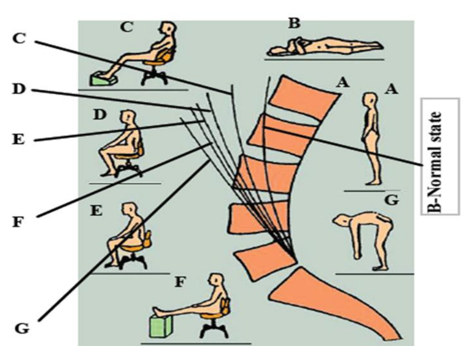


Figure 2: 6 Lumbar curves in various postures

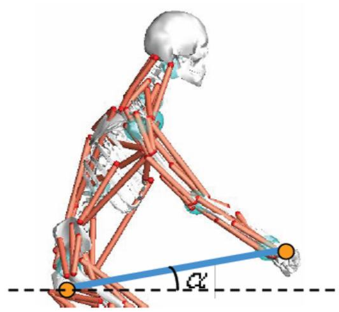


Figure 2: 7 Upper posture of the human body

The rider is a power source for the bicycle. The lower muscles of the rider play a major role during riding.

2.6 The Ultrasonic Energy

2.6.1 The Theory of Sound Waves

In order to understand the mechanics of ultrasonics, it is necessary to first have a basic understanding of sound waves, how they are generated and how they travel through a conducting medium. The dictionary defines sound as the transmission of vibration through an elastic medium which may be a solid, liquid, or a gas. Sound Wave Generation – A sound wave is produced when a solitary or repeating displacement is generated in a sound conducting medium, such as by a "shock" event or "vibratory" movement. The displacement of air by the cone of a radio speaker is a good example of "vibratory" sound waves generated by mechanical movement. As the speaker cone moves back and forth, the air in front of the cone is alternately compressed and rarefied to produce sound waves, which travel through the air until they are finally dissipated. We are probably most familiar with sound waves generated by alternating mechanical motion. There are also sound waves which are created by a single "shock" event. An example is thunder which is generated as air instantaneously changes volume as a result of an electrical discharge (lightning). Another example of a shock event might be the sound created as a wooden board falls with its face against a cement floor. Shock events are sources of a single compression wave which radiates from the source [12].

2.6.1.1The Nature of Sound Waves

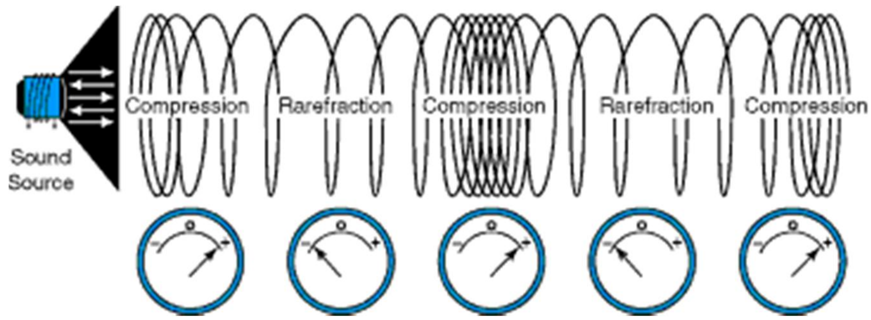


Figure 2: 8 The nature of sound waves

The diagram above uses the coils of a spring similar to a Slinky toy to represent individual molecules of a sound conducting medium. The molecules in the medium are influenced by adjacent molecules in much the same way that the coils of the spring influence one another. The source of the sound in the model is at the left. The compression generated by the sound source as it moves propagates down the length of the spring as each adjacent coil of the spring pushes against its neighbor. It is important to note that, although the wave travels from one end of the spring to the other, the individual coils remain in their same relative positions, being displaced first one way and then the other as the sound wave passes. As a result, each coil is first part of a compression as it is pushed toward the next coil and then part of a rarefaction as it recedes from the adjacent coil. In much the same way, any point in a sound conducting medium is alternately subjected to compression and then rarefaction. At a point in the area of a compression, the pressure in the medium is positive. At a point in the area of a rarefaction, the pressure in the medium is negative.

2.6.1.2 Cavitation and Implosion

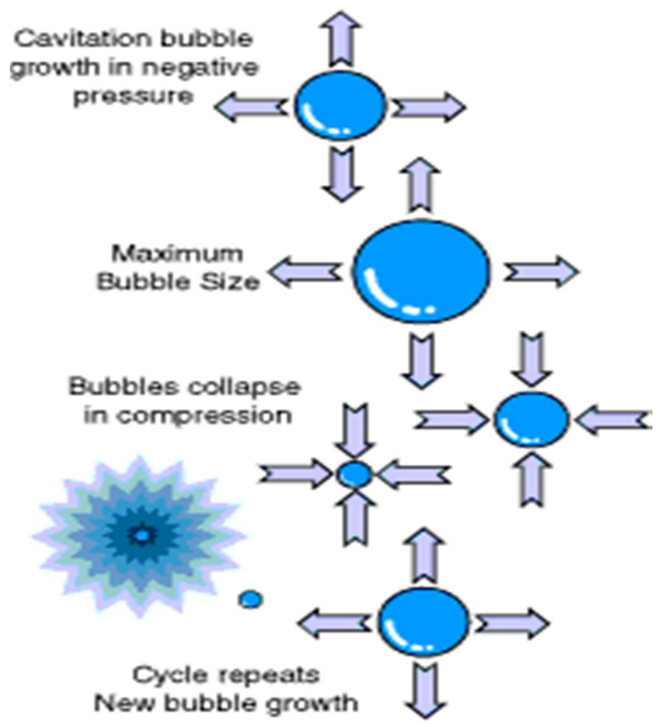


Figure 2: 9 The nature of sound waves

In elastic media such as air and most solids, there is a continuous transition as a sound wave is transmitted. In non-elastic media such as water and most liquids, there is continuous transition as long as the amplitude or "loudness" of the sound is relatively low. As amplitude is increased, however, the magnitude of the negative pressure in the areas of rarefaction eventually becomes sufficient to cause the liquid to fracture because of the negative pressure, causing a phenomenon known as cavitation. Cavitation "bubbles" are created at sites of rarefaction as the liquid fractures or tears because of the negative pressure of the sound wave in the liquid. As the wave fronts pass, the cavitation "bubbles" oscillate under the influence of positive pressure, eventually growing to an unstable size. Finally, the violent collapse of the cavitation "bubbles" results in implosions, which cause shock waves to be radiated from the sites of the collapse. The collapse and implosion of myriad cavitation "bubbles" throughout an ultrasonically activated liquid result in the effect commonly associated with ultrasonics. It has been calculated that temperatures in excess of 10,000°F and pressures in excess of 10,000 PSI are generated at the implosion sites of cavitation bubbles. [13]

2.6.2 The ultrasonic cleaning

The cleaning industry is currently in a struggle to replace solvent degreasing with alternative "environmentally friendly" means of cleaning. Although substitute water-based, semi-aqueous and petroleum based chemistries are available, they are often somewhat less effective as cleaners than the solvents and may not perform adequately in some applications unless a mechanical energy boost is added to assure the required levels of cleanliness. Ultrasonic energy is now used extensively in critical cleaning applications to both speed and enhance the cleaning effect of the alternative chemistries. Ultrasonic cleaning offers several advantages over conventional methods. Ultrasonic waves generate and evenly distribute cavitation implosions in a liquid medium. The released energies reach and penetrate deep into crevices, blind holes, and areas that are inaccessible by other cleaning methods. The removal of contaminants is consistent and uniform regardless the complexity and geometry of the part being cleaned. Additional features: 1) Speed, cleaning usually completed in 1 to 3 minutes 2) Labor, Tremendous labors savings over conventional cleaning methods. 3) Chemical, use lower concentration and milder chemicals to complete cleaning task. Does not have to be a low foaming chemical as required in most spray, agitation cleaners .[14]

2.6.4 Ultrasonic Equipment and parameters

To introduce ultrasonic energy into a cleaning system requires an ultrasonic transducer and an ultrasonic power supply or "generator." The generator supplies electrical energy at the desired ultrasonic frequency. The ultrasonic transducer converts the electrical energy from the ultrasonic generator into mechanical vibrations.

2.6.4.1 Transducers

Ultrasonic transducers may be made from a number of materials. The most common piezoelectric material used is a ceramic called lead zerconatetitanate. During the manufacturing process the ceramic is subjected to a high electrical potential causing the ceramic to develop dipoles and become polarized (to have a positive and negative side). This polarization will give the ceramic a unique feature. When the transducer ceramic is put into service and has an electrical potential applied to it from an ultrasonic generator it will swell and change dimension. When the electrical potential is removed the ceramic will return to its original state and will continue to expand and contract or resonate (like a tuning fork) until itself dampens and stops. Each time the transducer expands it emits a sound wave or pressure wave. Both the resonant frequency that the transducer was manufactured for and the output frequency of the generator determine the frequency of this pressure wave. The generator must be designed to emit an electrical pulse at precise intervals so as to compliment the movement of the transducer, not to hinder its movement; this is referred to as automatic tuning .[15]

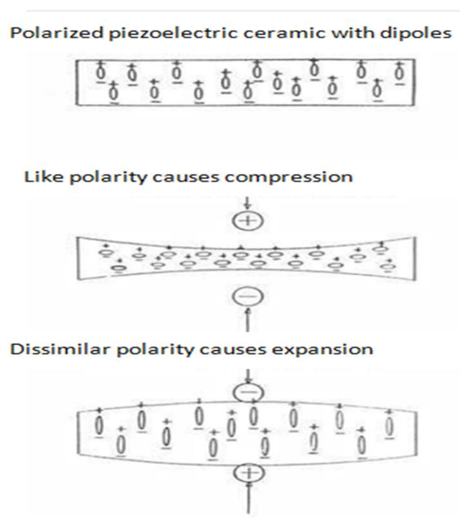


Figure 2:10 Compression and expansion of polarized piezoelectric ceramic with dipoles

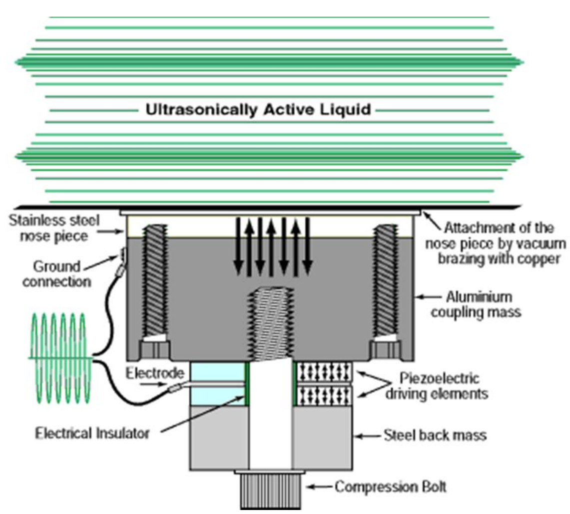


Figure 2:11 Ultrasonically active liquid

Two types of transducer bonding are used to secure the transducers to the cleaning tank or immiscible, one being epoxy (aircraft quality) and the other being brazed. In the epoxy bonding technique the transducer may be designed with electrical isolation from the tank or cleaning system (no high voltage potential will be grounded through the tank or cleaning system). The epoxy adhesion is more than sufficient for bonding the piezoelectric transducer to the tank wall or bottom and gives uniform attachment on surfaces that are not perfectly flat or level. Epoxy bonding is so reliable that most manufacturers will guarantee the bond for 10 years or longer. The second type is brazing bonding. This technique was first used to bond the heavy electromagnetic (magnetrostrictive) transducers do to their heavy weight and small surface contact area. This bonding technique was carried over to some piezoelectric transducers with no real advantage over epoxy bonding because the bonding strength was not required and there may be a reduction in cleaning performance do to the higher-pressure readings. Brazing also indicates the transducer sandwich mounting surface is steel not aluminum. The acoustical velocity (mm/microseconds) in steel is 5.79 as compared to aluminum at 6.45. This indicates a significant energy loss by using steel in place of aluminum. Also a brazed transducer cannot be easily isolated from being grounded to the tank. .[14]

2.6.4.2 Ultrasonic Generators

Ultrasonic generators differ in the waveforms they emit and their output ratings. Three forms of output may be used, full wave, half wave, and continuous wave. When discussing generator output power always refer to the average output power, not the peak output those without electrical knowledge may be easily misled so again request average power output. The manufacturer or supplier of the cleaning system should have a frequency/watt meter available to verify the output frequency and output wattage of the generator. Checking the input power to the ultrasonic generator is of little value when you are interested in the output power, don't be fooled. To protect the generator from electrical fluctuations and spikes the generator output may be de tuned by as much as 10% but never any more. The frequency/watt meter is the best way to check output frequency and wattage.

1. Virtually all-Industrial ultrasonic generators have automatic frequency tuning.
2. Generators with constant power output hold power output when input voltage changes.
3. Generators should have a power intensity control to control output power.

4. It is advisable to have sweep frequency.
5. It is advisable to have a control to adjust the sweep repetition rate

2.6.4.3 Frequency

The lower the operating frequency the larger the implosion bubble.

The higher the operating frequency the smaller the implosion bubble.

As we lower the operating frequency the implosion bubble becomes larger and releases more energy when they implode but we also lower the number or amount of events. As we increase the operating frequency we reduce the size of the implosion bubble releasing less energy when they implode but we also increase the number or amount of events. The maximum size of the cavitation event is proportional to the applied frequency. At equal power inputs to a 25 KHz tank, a 40 KHz tank, and a 68 KHz tank the 40 KHz tank will have 60% higher number of events than the 25 KHz tank, and the 68 KHz tank will have 70% higher number of events than the 40 KHz tank. As we increase the frequency we increase the amount of cleaning events and cleaning is more homogeneous but less power is released in each event so cleaning ability may be reduced.[15]

2.7 Water purification

2. 7.1 Filtration

The household water treatment and safe storage interventions improve water quality. Some of these proven options are – chlorination, solar disinfection, ceramic filtration, sand filtration (slow sand filtration &Rapid sand filter and flocculation/disinfection –are implemented in developing countries. The decision of selecting which options are most appropriate for a community is often difficult, depending on existing water and sanitation conditions, cultural acceptability, implementation feasibility, availability of technology, and other local conditions. Most, if not all, water purification systems contain a filter stage.

One of the most widely used of these filtration methods is the sand filter. As the name implies, sand filters filter water through sand and gravel, There are two types of sand filters:

- Slow sand filter and
- Rapid sand filter

2.7.1.1. Slow sand filter

Slow sand filters however, use no chemicals or electricity to function, but they are often large and require large areas if used municipally. Slow sand filters consist of a layer of fine grain sand supported on a layer of gravel, the topmost layer consisting of a bio-film.

When flow rate becomes too low, the filter has to be cleaned by emptying the filter and scraping off the top layer of sand. Because slow sand filters are slow, the water needs a long time to get through the sand and capacity is limited, although they are relatively easy to manage.[16]

Commonly recommended design criteria for SSF are:

Table 2:8 Design Criteria of Slow Sand Filtration

Design Criteria		**Recommended Level**
Design period		10-15 years
period of operation		24h/d
Filtration rate in the filters		0.1-0.2 m3/m2h 5-200m2 per filter, minimum of 2
Filter bed area		units
Height of filter bed	Initial	0.8-0.9m
	Minimum	0.5-0.6m
Specification of sand	effective size	0.15-0.30mm
	Uniformity coefficient	<5, preferable below 3
Height of under drains (including gravel layer)		0.3-0.5m
High of supematant water		1m
Detention time	in supematant water	5-10h
	In filter bed	2.5-9h

Source: AWWA, 1991, modification of a bios and filter

2. 7.1.2. Mechanisms of Filtration

The filtration process is accomplished by passing the used water slowly through a sand bed. The substances in the water will go through a process of transport, attachment, and purification.

Transport Mechanisms. The particles within the water are brought into contact with sand grains through the following processes: straining, sedimentation, inertial and centrifugal forces, and other forces of molecular scale, such as diffusion, mass attraction, and electrostatic attraction. Molecules diffuse through water by Brownian movement. Diffusion occurs independently of flow rate, throughout the whole filter, and helps particles to come in contact with grains, even when the water is not flowing. Mass attraction (Van der Waals force) has even less contribution to transport, but would work supplementary when particles are at very close proximity.

2.7.2 Design and Operation of Slow Sand Filtration

2. 7.2.1 Filter Medium

The filter medium that is commonly used in SSF is fine sand. sand specifications are commonly assessed by effective size and uniformity coefficient. The Manual of Design for Slow Sand Filtration gives an overview of sand characterizations developed by Allen Hazen. The effective size (d10) and uniformity coefficient (UC) are defined as, d10 = the size of grain such that 10 percent by weight of the total sample is smaller.

UC = the ratio of the size of grain that has 60 percent of the sample finer than itself to the size that has 10 percent finer than itself, that is, d60/d10 The effective size is important because:

The grain size determines the surface area and void space within the bed, the smaller grains would occupy the void space created by the larger grains, and the water would be forced between the smaller particles. The uniformity coefficient provides the ratio between larger grains and smaller grains, and determines the size of pore openings and surface area. Therefore, the grain size and uniformity would affect the required sand depth. Recommended the effective size of sand grains for slow sand filtration to be 0.15 0.35 mm. This is based on the fact that the grain size should be small enough to produce good quality filtrate and to also keep the penetration within the top layer, so that the scrapping of the sand would be minimum. The filtrate quality would be better with smaller grain size. The sand should be slightly rounded, as from a river bed. [17]

2 .7.2.2 Flow Rate

The recommended flow rate for SSF is 0.1-0.2 m3/m2/h. slower flow rates enable longer contact time and fewer shears on the biofilms. Therefore, slower flow rates would be beneficial in general. However, if the flow rate is too slow, enough dissolved oxygen would not be provided to the microorganisms, and therefore make anaerobic processes to proceed. This will produce undesirable taste and odor, and the bacteriological effluent quality will decline.[18]

2.7.3. Rapid sand filters

Rapid sand filters filter water through sand, but speed up the process by using chemicals as well. Rapid sand filters may use flocculation with aluminium and iron.

2.7.3.1 Flocculation

Is elements such as Aluminium (Al) can be used in a process called flocculation. Flocculation is a process where colloids come out of suspension in a solute, such as water. Aluminium, which is positively charged attracts negatively charged bacteria and viruses, all this then sinks to the bottom (Sedimentation) and can then be filtered out.

2.7.3 2 Chemical disinfection

In most developed countries the standard process of filtrating water is speeded up with chemicals, in some instances, with less turbid water, chemicals can be used alone. The most common chemical used to disinfect water is chlorine (Cl). Chlorine is a very effective disinfectant and also provides some residual disinfection; it remains in water to stop recontamination. Chlorine is more than 3 times more effective in disinfecting water than the equivalent concentration of bromine and 6 times more effective than iodine. Drawbacks of using chlorine can be: strange taste and smell of water (usually associated with shock chlorination with much higher concentrations), as well as a slight risk of naturally occurring organic compounds combining with chlorine to form carcinogenic compounds, Disinfection By-Products (DBPs). However, the WHO states that that health risks associated with DBPs are much smaller than risks associated with inadequate disinfection. Chlorine can be used by itself, but as it is a naturally volatile gas it is usually used in compounds such as hypo-chloric acid or chloroamines. Chloroamines may produce slightly lower levels of DBPs, but chlorine is toxic to fish and aquatic organisms and should be kept out of natural water systems. Chlorine is only toxic to humans after long exposure and at concentrations much greater than those used for disinfecting drinking water.[16]

2.8. The Design Process

The first step in the manufacturing process is *design*—the determining in rather precise detail what it is that we want to produce and, for each component of the product or assembly, what properties it must possess, what to make it out of, how to make it, how many to make, and what conditions it will see during use.

Design usually takes place in several distinct stages: (1) conceptual, (2) functional, and (3) production. During the conceptual-design stage, the designer is concerned primarily with the functions that the product is to fulfill. Several concepts are often considered, and a determination is made that the concept is either not practical, or is sound and should be developed further. Here the only concern about materials is that materials exist that could provide the desired properties. If such materials are not available, consideration is given to whether there is a reasonable prospect that new ones could be developed within the limitations of cost and time.

At the functional- or engineering-design stage, a workable design is developed, including a detailed plan for manufacturing. Geometric features are determined and dimensions are specified, along with allowable tolerances. Specific materials are selected for each component. Consideration is given to appearance, cost, reliability, reducibility, and serviceability, in addition to the various functional factors. It is important to have a complete understanding of the functions and performance requirements of each component and to perform a thorough materials analysis, selection, and specification. If these decisions are deferred, they may end up being made by individuals who are less knowledgeable about all of the functional aspects of the product.

Often, a prototype or working model is constructed to permit a full evaluation of the product. It is possible that the prototype evaluation will show that some changes have to be made in either the design or material before the product can be advanced to production. This should not be taken, however, as an excuse for not doing a thorough job.

It is strongly recommended that all prototypes be built with the same materials that will be used in production and, where possible, with the same manufacturing techniques. It is of little value to have a perfectly functioning prototype that cannot be manufactured economically in the desired volume or one that is substantially different from what the production units will be like.

In the production-design stage, we look to full production and determine if the proposed solution is compatible with production speeds and quantities. Can the parts be processed economically, and will they be of the desired quality? As actual manufacturing begins, changes in both the materials and processes may be suggested. In most cases, however, changes made after the tooling and machinery have been placed in production tend to be quite costly. Good up-front material selection and thorough product evaluation can do much to eliminate the need for change. As production continues, the availability of new materials and new processes may well present possibilities for cost reduction or improved performance. Before adopting new materials, however, the candidates should be evaluated very carefully to ensure that all of their characteristics related to both processing and performance are well established. [19]

Remember that it is indeed rare that as much is known about the properties and reliability of a new material as an established one. Numerous product failures and product liability cases have resulted from new materials being substituted before their long-term properties were fully known.

2.8.1 General consideration of design

The following are the general consideration in design:

Type of load and stress caused by the load

the load, on a machine component, may act in several ways due to which the internal stresses are set up.

Motion of the parts or kinematics of the machine

The successful operation of any machine depends on largely upon the simplest arrangement of the parts which will give motion required.
The motion of the part may be:

a. Rectilinear motion which includes unidirectional and reciprocating motions
b. Curvilinear motion which includes rotary oscillation and simple harmonic
c. Constant velocity
d. Constant of a variable acceleration

Selection of a material: it is essential that a designer should have a thorough knowledge of the properties of the material and their behavior under working conditions. Some of the important characteristics of the materials are:

- Strength
- Durability
- Flexibility
- Weight
- Resistance to heat and corrosion
- Weld or hardened
- Machinability etc.

4) Form and size of the part: The form and size are based on judgment. The smaller practicable cross sectional may be used, but it may be checked that the stresses induced in the designed cross-section may be used are reasonably safe. In order to design any machine part for form and size, it is necessary to know the forces which the part must sustain. It is also important to anticipate any suddenly applied or impact load which may cause failure.

5) Frictional resistance and lubrication.

There is always a loss of power due to frictional resistance and it should be noted that the friction of starting is higher than that of running friction. It is, therefore, essential that a careful attention must be given to the matter of lubrication of all surfaces which move in contact with others, whether in rotating, sliding, or rolling bearing.

6) Convenient and economical features.

In designing, the operating features of the machine should be careful studied. The starting controlling and stopping levers should be located on the basis of convention handling. The adjustment for wear must be provided employing the various take up devices and arranging them so that the alignment of the parts is preserved. If the parts are to be changed for different products or replaced on account of wear or breakage, easy access should be provided and the necessity of removing other parts to accomplish this should be avoided if possible.

7) Use of the standard parts: The use of standard parts is closely related to the cost, because the cost of standard or stock parts is only a fraction of the cost of similar parts made to order.

The standard stock or parts should be used whenever possible; parts for which patterns are already in existence such as gear, bearing and parts which may be selected from regular shop stock such as power screw, nut and pins.

8) Safety operation: some machines are dangerous to operate, especially those which are speed up to insure production at a maximum rate. Therefore, any moving part of a machine which is within the zone of a worker is considering.

9) Workshop facility: a design engineer should be familiar with the limitations of his employer's workshop, in order to avoid the necessity of having work done in some other workshop.

10) Modification: modify the size of the member to agree with the past experience judgments to facilitate manufacture. The modification may also be necessary by consideration of manufacturing to reduce overall cost.

11) Detailed drawing: draw the detail drawing of each component and the assembly of the machine with complete specification for the manufacturing process suggested. A designer engineer is faced with two important responsibilities in the evaluation of a product from concept to completion. Those are material selection and understanding fabrication process associated with design.

2.9. Material Selection and Manufacturing Processes

The interdependence between materials and their processing must also be recognized. New processes frequently accompany new materials, and their implementation can often cut production costs and improve product quality. A change in material may well require a change in the manufacturing process. Conversely, improvements in processes may enable a revaluation of the materials being processed. Improper processing of a well-chosen material can definitely result in a defective product.

If satisfactory products are to be made, considerable care must be exercised in selecting both the engineering materials and the manufacturing processes used to produce the product.

There are materials and manufacturing processes interrelationships between the structure and properties of engineering materials, the processes used to produce a product, and the subsequent performance. An engineering material may possess different properties depending upon its structure. Processing of that material can alter the structure, which in turn will alter the properties. Altered properties certainly alter performance. The objective of manufacturing, therefore, is to devise an optimized system of material and processes to produce the desired product [19].

2.9.1 Material selection

The selection of a proper material, for engineering purposes, is one of the most difficult problems for the designer. The aim of material selection in manufacturing is to create products and components that perform properly under operating conditions. When selecting materials for a machine, first consideration is what materials are suitable for the product, the way the product will be made, and method of construction and cost are all vital elements.

The following factors should be considered while selecting the material:
1. Availability of the materials,
2. Suitability of the materials for the working conditions in service, and
3. The cost of materials

The important properties, which determine the utility of the material are physical (include luster, color, size and shape, density, electric and thermal conductivity, and melting point.), chemical (oxidation, corrosion, and diffusion) and mechanical properties (include strength, stiffness, elasticity, plasticity, ductility, brittleness, malleability, toughness, resilience, creep and hardness.) Thus most important goals of the material selection are to:

- Minimize the cost of manufacturing, by reducing the time spent in the design stage.
- Minimize the cost of the material.
- Maximize the performance of the product.

Conclusion

There are existing solutions to the clothes washing problem, but no existing technology is both practical and affordable for people in our target community. Existing solutions are either designed for industrialized nations with running water and electricity, or they are not practical for rural setting where replacement parts are difficult to find.

Commercial washing machines have existed for many years, but they are expensive and require electricity to operate. Sometimes, they are available in urban settings, but the average family cannot afford to purchase one. In rural areas, commercial washing machines are not an option because electricity may be unavailable or extremely expensive.

A number of groups have modified commercial washing machines to power them with human power. They attached a pedal-drive mechanism to the washing machine drum and attached a suspension system. This technique is not feasible in rural areas of developing nations because washing machines and their old components are usually difficult to find.

Commercial hand-cranked washing machines do exist, but they are not intended for continuous use; they are designed for traveling or camping trips. The “Wonder wash” produced by the

Laundry Alternative, Inc. only washes 5lb (2.78kg) of clothes and is not designed to hold up to the rigors of constant use. Priced at about1050birr, it is likely to arrive in rural areas at a much higher price, and its use will be limited by the lack of replacement parts.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Material

To achieve the objectives of this study, the relevant methodologies have been used. Literatures of relevant materials related to Clothe Washing Machine are assessed and its resource assessment methods are reviewed in order to identify and define the problem.

3.2 Methods (methodology)

To accomplish the thesis successfully feasibility of the project has been analyzed thoroughly and this is achieved by making need assessment of the project through comparing the existing and alternative available machines. To do so exploratory research method is best in developing or constructing the research in which it might involve a literature search or conducting focus group interviews. The exploration 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. The objective of exploratory research is to identify key issues and key variables. Some data gathering techniques are used to understand current problems of washing process and for the need of this machine; different type's data are collected, direct observation, document analysis and after the quantitative data are gathered from those sources, analysis is made to use as input for designing and manufacturing a Manual Operation Clothe Washing Machine.

The following methodologies were used to achieve the thesis objectives:-

- Literature survey on the subject matter: the sources used at most are books, journals, and websites.
- Consultations and informal discussions: Consultations were detained with the study team advisor, and informal discussions were conducted with other individuals
- Data collection: data has been collected from expert individuals through observations.
- Study of ultrasonic cleaning mechanism and waste water filtration

- Design of critical components of the machine: Critical components of the machine are designed to perform the required function using calculations.
- Material selection: the proper materials have been selected for the components of the machine according to the required properties.
- Detail and assembly drawing will develop by using CATIA.
- Manufacturing of the components: each components of the machine are produced to the required design in the work shop.
- Assembly of the components: All components of the machine are assembled step by step according to the assembling procedure.
- Testing the performance of the machine: checking for proper functioning of the machine.

3.2.1. Data Collection

Both primary and secondary data were used in the study .The primary data were collected through observation. In addition, secondary data were collected from books, literature, journal and websites.

3.2.1.1. Direct observation

Direct observation method was also used for collecting the required data and information. pedal powered washing machine model has been observed from ASTU manufacturing shop, electrical launder machines from the market in Adama town, internet and some documents of previous researches and respective institutional profile also have been observed.

3.2.2. Data analysis

Statistical tools are used to analyze for quantitative data which enables drawing a sensible interpretation from the analysis. As the team members replied according to their experiences, there were no Manual Operation Clothe Washing Machine which have hand cranking and filtration of water rather they used pedaling and electricity. These machines have their own limitation and this show or assure as if there is potential to find other means or types of clothe washing system.

3.3 Material selection process

Material choices will always be governed by martial properties and manufacturing issues. However, the material selection process for a new product development differs slightly from the process for material substitution in an existing design. The procedure for selection is establishing the link between material and functions. A design demand a certain profile of attributes which include density, strength, cost, resistance to corrosion, etc.

Material selection for critical mechanical components

3.3.1. Material selection of the Handel

Table 3:1 Weighting factors for the Handel (selection of material and manufacturing processes for engineering design, 1989)

properties	Number of Decision										Weight factor
	1	2	3	4	5	6	7	8	9	10	
Tensile strength (MN/m^2)	1	1	0	0							0.2
Yield strength (MN/m^2)			1	1	0	0					0.2
Brinell hardness					1	1	0	0			0.2
Density (g/cc)							1		0	0	0.1
Cost (Birr/Kg)								1	1	1	0.3

Table 3:2 Candidate materials for the Handel

Material	Tensile strength (MN/m^2) (X0.2)	Yield strength (MN/m^2) (X0.2)	Brinell hardness (X0.2)	Density (g/cc) (X0.1)	Cost (Birr/Kg) (X0.3)	Overall satisfaction
Carbon steel SAE 1025 annealed	12.52	17.06	12.18	9.99	30	81.75
Carbon steel SAE 1045	16.08	14.28	15.74	10	28.26	84.36
AISI 1340 alloy steel	20	20	20	9.92	26.22	96.14

Table 3:3 Normalized outcomes for the Handel

Material	Tensile strength (MN/m^2)	Yield strength (MN/m^2)	Brinell hardness	Density (g/cc)	Cost (Birr/Kg)
Carbon steel SAE 1025 annealed	62.6	85.3	60.9	99.9	100
Carbon steel SAE 1045	80.4	71.4	78.7	100	94.2
AISI 1340 alloy steel	100	100	100	99.2	87.4

Table 3:4 Values of outcome and overall satisfaction

Material	Tensile strength (MN/m^2) (X0.2)	Yield strength (MN/m^2) (X0.2)	Brinell hardness (X0.2)	Density (g/cc) (X0.1)	Cost (Birr/Kg) (X0.3)	Overall satisfaction
Carbon steel SAE 1025 annealed	12.52	17.06	12.18	9.99	30	81.75
Carbon steel SAE 1045	16.08	14.28	15.74	10	28.26	84.36
AISI 1340 alloy steel	20	20	20	9.92	26.22	96.14

The result shows that on the basis of allocating weight factor, AISI 1340 alloy steel gives the highest overall satisfaction among those materials. Therefore, this material is preferable for the production of the handle.

3.3.2 Material selection of the Gears

Table 3:5 Weighting factors for the gears

properties	Number of Decision										Weight factor
	1	2	3	4	5	6	7	8	9	10	
Tensile strength (MN/m^2)	1	1	0	0							0.2
Yield strength (MN/m^2)			1	1	0	0					0.2
Brinell hardness					1	1	0	0			0.2
Density (g/cc)							1		0	0	0.1
Cost (Birr/Kg)								1	1	1	0.3

Table 3:6 Candidate materials for the gears

Material	Tensile strength (MN/m^2)	Yield strength (MN/m^2)	Brinell hardness	Density (g/cc)	Cost (Birr/Kg)
Carbon steel SAE 1025 annealed	440	370	126	7.86	340
Carbon steel SAE 1045	565	310	163	7.87	361
AISI 1020 alloy steel	395	295	111	8.03	215

Table 3: 7 Decision matrix for the gears

Material	Tensile strength (MN/m^2)	Yield strength (MN/m^2)	Brinell hardness	Density (g/cc)	Cost (Birr/Kg)
Carbon steel SAE 1025 annealed	440	370	126	7.86	340
Carbon steel SAE 1045	565	310	163	7.87	361
AISI 1020 alloy steel	395	295	111	8.03	205

Table 3: 8 Normalized outcome for the gears

Material	Tensile strength (MN/m^2)	Yield strength (MN/m^2)	Brinell hardness	Density (g/cc)	Cost (Birr/Kg)
Carbon steel SAE 1025 annealed	77.9	100	77.3	97.9	60.3
Carbon steel SAE 1045	100	83.8	100	98	56.8
AISI 1020 alloy steel	70	79.7	68.1	100	100

Table 3: 9Values of outcome and overall satisfaction

Material	Tensile strength (MN/m^2) (X0.2)	Yield strength (MN/m^2) (X0.2)	Brinell hardness (X0.2)	Density (g/cc) (X0.1)	Cost (Birr/Kg) (X0.3)	Overall satisfaction
Carbon steel SAE 1025 annealed	15.58	20	15.46	9.79	18.1	78.93
Carbon steel SAE 1045	20	16.76	20	9.8	17	83.56
AISI 1020 alloy steel	14	16	13.62	10	30	83.62

The result shows that on the basis of allocating weight factor, AISI 1020 alloy steel gives the highest overall satisfaction among those materials. Therefore, this material is preferable for the production of both gears.

3.3.3 Material Selection for Shafts

Table 3: 10 Weighting factors for the Shafts (selection of material and manufacturing processes for engineering design, 1989)

properties	Number of Decision										Weight factor
	1	2	3	4	5	6	7	8	9	10	
Tensile strength(MN/m^2)	1	1	0	0							0.2
Yield strength (MN/m^2)			1	1	0	0					0.2
Brinell hardness					1	1	0	0			0.2
Density (g/cc)							1		0	0	0.1
Cost (Birr/Kg)								1	1	1	0.3

Table 3:11 Candidate materials for shafts

Material	Tensile strength (MN/m^2)	Yield strength (MN/m^2)	Brinell hardness	Density (g/cc)	Cost (Birr/Kg)
Carbon steel SAE 1025 annealed	440	370	126	7.86	340
Carbon steel SAE 1045 water quenched	742	518	248	7.81	380
Nickel alloy Steel oil quenched	712	511	262	7. 75	410

Table 3: 12 Decision matrix for Shafts

Material	Tensile strength (MN/m^2)	Yield strength (MN/m^2)	Brinell hardness	Density (g/cc)	Cost (Birr/Kg)
Carbon steel SAE 1025 annealed	440	370	126	7.86	340
Carbon steel SAE 1045 water quenched	742	518	248	7.81	380
Nickel alloy Steel oil quenched	712	511	262	7. 75	410

Table 3: 13Normalized outcome for Shafts

Material	Tensile strength (MN/m^2)	Yield strength (MN/m^2)	Brinell hardness	Density (g/cc)	Cost (Birr/Kg)
Carbon steel SAE 1025 annealed	59.2	71.4	48.1	100	100
Carbon steel SAE 1045 water quenched	100	100	94.6	99.4	89.5
Nickel alloy Steel oil quenched	95.9	98.6	100	98.6	82.9

Table 3: 14 Values of outcome and overall satisfaction

Material	Tensile strength (MN/m^2) (X0.2)	Yield strength (MN/m^2) (X0.2)	Brinell hardness (X0.2)	Density (g/cc) (X0.1)	Cost (Birr/Kg) (X0.3)	Overall satisfaction
Carbon steel SAE 1025 annealed	11.84	14.28	9.62	10	30	75.74
Carbon steel SAE 1045 water quenched	20	20	18.92	9.94	26.85	95.71
Nickel alloy Steel oil quenched	19.18	19.72	20	9.86	24.87	93.63

The result shows that on the basis of allocating weight factor, Carbon steel SAE 1045 water quenched gives the highest overall satisfaction among those materials. Therefore, this material is preferable for the production of both shafts for spur gears.

3.3.4 Material for Outer Drum

In this top-loaded washing machine, the outer drum cylinder is arranged horizontally and it is open from one of its bases at the top, which connects to the door. The open base of the cylinder, called top cover, is designed with a large hole to allow entry and exit of laundry in the washer. The material used in its manufacture is Aluminium composite 5251 H24, and its functions are:

- To enable input and output of water, detergent.
- To form a container where the water is placed.

The gap between the inner drum and the outer drum has a great influence the water usage efficiency, i.e. when the gap between the outer drum and inner drum increases the required amount of water also increased.

Aluminium composite (5251 H24) and Benefits of Honeycomb Sandwich Constructions

Aluminium composite (5251 H24) is used in the cylinders of washing machines and offers numerous advantages to its users; beyond the high resistance to water, soaps, detergents, etc., it ensures a surface smooth and free of lashings and cutting, avoiding the deterioration of the clothes in the washing process, caused by irregular surfaces.

The facing skins of a sandwich panel can be compared to the flanges of an I-beam, as they carry the bending stresses to which the beam is subjected. With one facing skin in compression, the other is in tension. Similarly the honeycomb core corresponds to the web of the I-beam. The core resists the shear loads, increases the stiffness of the structure by holding the facing skins apart, and improving on the I-beam, it gives continuous support to the flanges or facing skins to produce a uniformly stiffened panel. The core-to-skin adhesive rigidly joins the sandwich components and allows them to act as one unit with a high torsional and bending rigidity. [20]

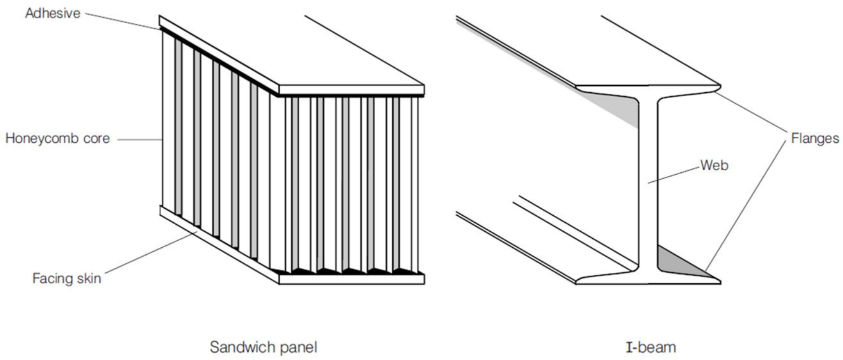


Figure 3:1 Shows the construction of a sandwich panel compared to an I beam

Table 3:15 The relative stiffness and weight of sandwich panels compared to solid panels

	Solid Material	Core Thickness t	Core Thickness 3t
	t	2t	4t
Stiffness	1.0	7.0	37.0
Flexural Strength	1.0	3.5	9.2
Weight	1.0	1.03	1.06

The honeycomb sandwich construction can comprise an unlimited variety of materials and panel configurations. The composite structure provides great versatility as a wide range of core and facing material combinations can be selected. The following criteria should be considered in the routine selection of core, facing, and adhesive.

Structural Considerations

Strength:

Honeycomb cores and some facing materials are directional with regard to mechanical properties and care must be taken to ensure that the materials are orientated in the panel to take the best advantage of this attribute.

Stiffness:

Sandwich structures are frequently used to maximize stiffness at very low weights. Because of the relatively low shear modulus of most core materials, however, the deflection calculations must allow for shear deflection of the structure in addition to the bending deflections usually considered.

Adhesive Performance:

The adhesive must rigidly attach the facings to the core material in order for loads to be transmitted from one facing to the other. Suitable adhesives include high modulus, high strength materials available as liquids, pastes or dry films. As a general rule, a low peel-strength, or relatively brittle adhesive should never be used with very light sandwich structures which may be subjected to abuse or damage in storage, handling or service.

Economic Considerations:

Composite sandwich panels can provide a cost effective solution. Value analysis should include assessment of production and assembly costs; and installation costs including supporting structure.

Environmental Considerations

Temperature:

As in any materials system the thermal environment will play an important role in the selection of materials. All systems are basically operational at Room Temperature and materials are readily available to give performance up from -55°C to 170°C. Material selection should also take account of available manufacturing facilities, especially cure temperature capability.

Flammability:

Materials used in bonded sandwich construction are usually classified into three categories:

1. Non-burning - which means that the product will not burn.
2. Self-extinguishing - which means that the material will burn while held in a flame but will extinguish when the flame is removed.
3. Flammable. Flammable materials are sometimes further defined by determining the flame spread rate under specified conditions.

Heat Transfer:

The transfer of heat through a sandwich panel is dependent upon the basic principles of convection, conduction and radiation. Metallic cores with metallic facings maximize heat flow characteristics.

Moisture/Humidity:

Some core and facing materials offer excellent resistance to degradation due to moisture and humidity.

Adhesive Solvents and Out gassing:

Some adhesives give off gases or solvent vapors during cure which can interact with resin systems in some non-metallic cores, or with the node adhesive in some metallic honeycombs. The entire bonding process must be checked to ensure that no reduction in mechanical properties has occurred due to incompatibility of the materials or process actually used.

Mechanical Performance

Honeycomb strength and stiffness (compression and shear) is proportional to density. Relative performance of the material types is shown in comparison to PVC foam.

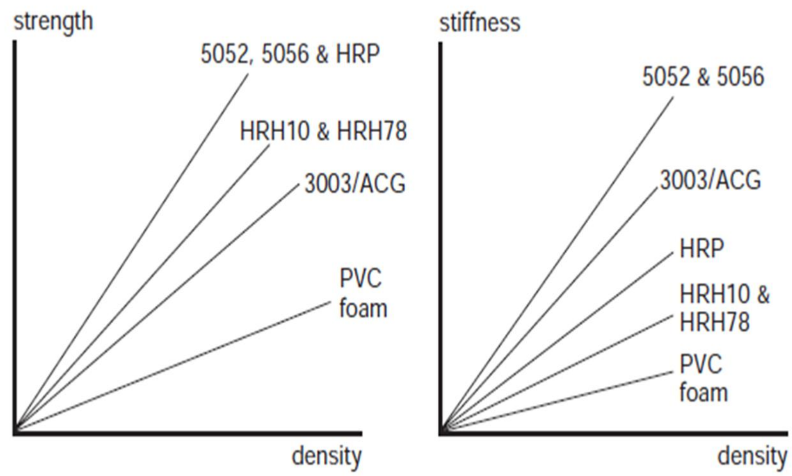


Figure 3: 2 Mechanical Performance of Honeycomb material

3.3.5 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.

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 machineable.
- it should be tough enough-it should be cashable.
- it should be light in weight.

Aluminum alloy is selected for bearing house because it satisfies the above requirements.

CHAPTER FOUR

DESIGN ANALAYSIS

4.1 Introduction

Engineering design process or mechanical engineering design process is a series of steps that each designer have to go through, to reach to the solution of the problem or to satisfy the need. Figure4.1 shows the steps or phases of a general engineering design process. [21]

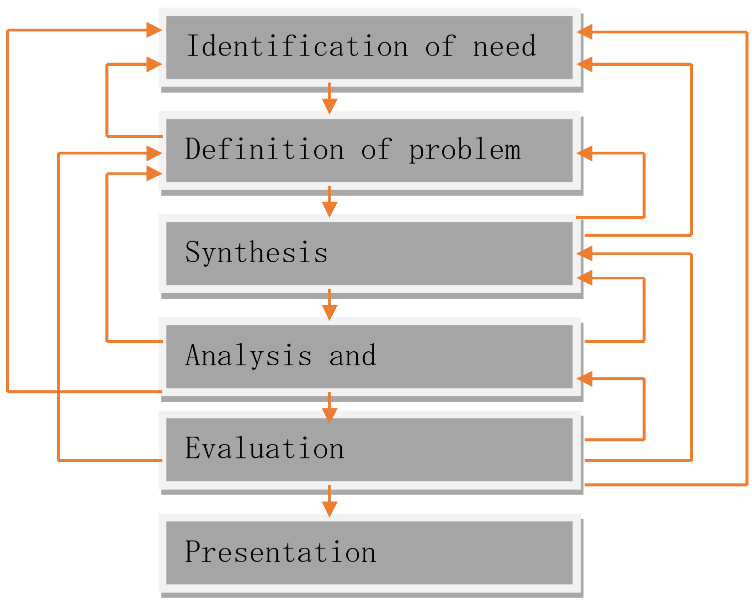


Figure 4:1 Steps in the Design

4.2 Over all function of the machine

Manual Operation cloth washing machines is advantageous and an alternative for most medium and low level of standard of living. In our country still most of the people wash their cloth by hand instead of using machines that functional with appropriate technology. When the concept of humane powered cloth washing machine becomes practical mainly reduce human effort to wash cloths, save time and money.

It is operated either hand cranking for small and medium load or pedal powered for heavy load cloth washing, rinsing and spin drying. The ultrasonic cleaning also a comfortable way of wash clothes to healthy as well as disable person. Waste water treatment and recycling system on the machine also enable the user to utilize the waste water for reuse and plays a great role to save water and protect environment against pollution.

Figure 4:2 Function of the machine

4.3 Description of the machine for design analysis

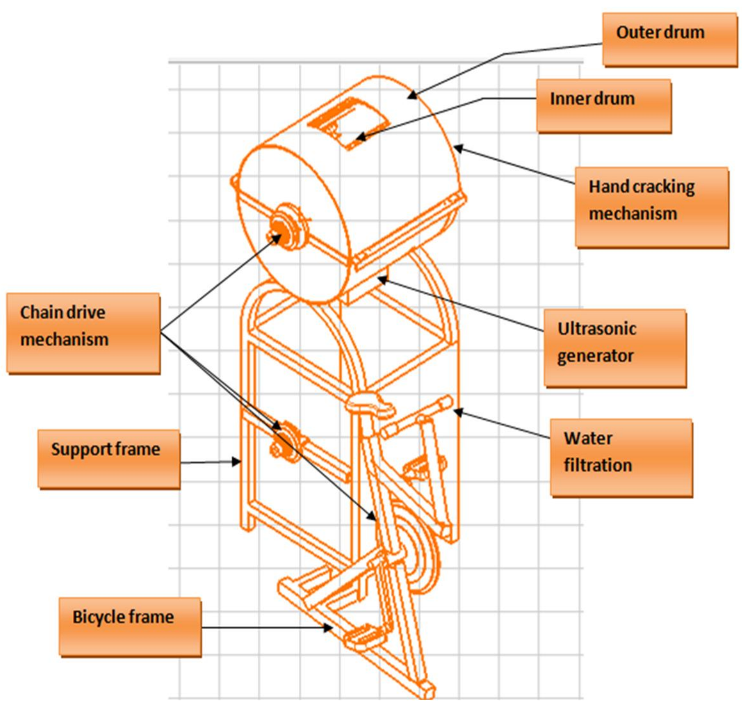


Figure 4: 3 Manual Operation washing machines

1. The machine has three major parts which are categorized according to their function.
    - The Mechanical Drives and Structural parts
    - The hand cranking mechanism
    - The pedal drive mechanism
    - The outer drum
    - The inner drum

- The stationary Bicycle frame structure
- The portable support frame structure

2.The Waste Water Treatment Device

- Flocculation chamber
- Bio-sand filtration

3. The Ultrasonic Cleaning Device

4.4. Operation of the Manual Operation Clothe washing Machine

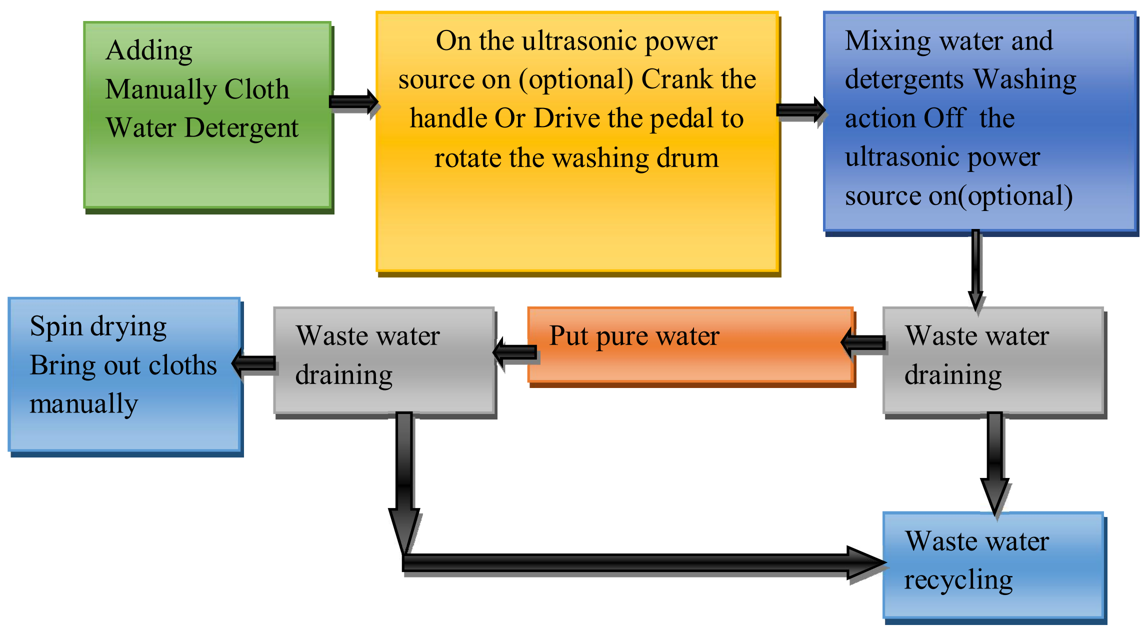


Figure 4: 4 Operation Steps

4.5 Design for the critical component of the machine

4.5.1 Design of Handel

Calculation

Tensile strength (σ_u) = 702 MPa

Yield strength (σ_y) = 434 MPa

Design Factor = Safety Factor = 6 length, L = 188 mm

Maximum bending stress

$\mu = F_h.L = (150 \text{ N}) (0.188\text{m})$

$= 28.2 \text{ Nm}$

Compute the desire stress from;

$$\sigma_d = \sigma_y / N_f \text{ --- } (1)$$

$= 434 \text{ MPa} / 6$

$= 72.333 \text{ MPa}$

Based on formula; $\sigma = \mu / S$;

$$S = \mu / \sigma \text{ --- } (2)$$

$= 28.2\text{Nm} / 72.333\text{MPa}$

$= 3.89 \times 10^{-7} \text{ m}^3$

In relationship between S, t and h is; and h = 3t

$$S = (t.h^2) / 6 \text{ -- } (3)$$

$= 9t^3 / 6$

$= 1.5 t^3$

$1.5 t^3 = 3.89 \times 10^{-7} \text{ m}^3$

$t = 6.37 \times 10^{-3} \text{ m} = 6.37\text{mm}$

Therefore; $h = 3t = 3(6.37 \times 10^{-3} \text{ m}) = 19.11 \times 10^{-3} \text{ m} = 20\text{mm}$

4.5.2 Design of Spur Gears

Design Overview

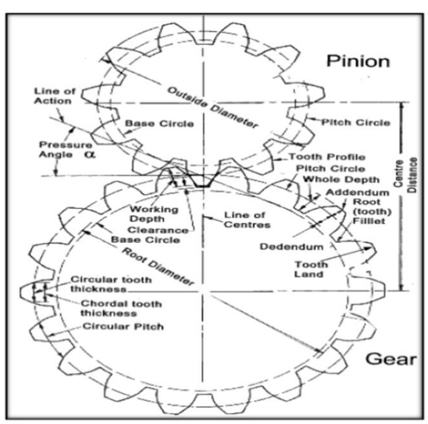


Figure 4:5 Gear mechanism with legend

Calculation

The distance between the shafts (L_{sh}) = 72 mm = 0.072m

The rpm of the driver gear (n_G) = 60 rpm

The rpm of the driven pinion (n_P) = 210 rpm

Applied load on crank handle (F_h) = 150 N

The length of the handle (L_h) = 188mm = 0.188m

Pressure angel (Φ) = 20^0

Material for both pinion and gear is AISI 1020 steel

Tensile strength (σ_u) = 395 MPa

Yield strength (σ_y) = 295 MPa

Hardness, Brinell (BHN) = 111

Allowable static stress (σ_o) = the allowable static stress (σ_o) for steel gears is approximately one-third of the ultimate tensile strength (σ_u) .[21]

$$(\sigma_o) = \frac{\sigma u}{3} = \frac{395 \text{ MPa}}{3} = 132 \text{ MPa} = 132 \text{ N/mm}^2$$

Young's modules for both ($Ep = E_G$) = $200X10^3$ N/mm^2

Flexure endurance limit (σ_e) = 1.75 X BHN (in MPa)

= 1.75 X 111

= 194 MPa = 194 N/mm^2

Surface endurance limit (σ_{es}) = 650 MPa = 650 N/mm^2

$$\text{Torque } (T_n) = F_h \text{ X } L_h \text{ -- (4)}$$

= 150N X 0.188m = 28.2 Nm = 28.2 X 10^3 N.mm

Since the starting Torque is 25% more than the normal torque

$$T_{max} = 1.25\, T_n \text{ -- (5)}$$

= 1.25 X 28.2 X 10^3 N.mm = 35.25 N.mm

Angular velocity of driver gear ($\boldsymbol{\omega}_G$) = $\frac{2\pi n}{60}$ = $\frac{2x3.14x60}{60}$ = 6.28 rad/sec.

Power at driver gear (P_G) = $T_{max}\ \varphi_G$ = 35.25 N.mm X 6.28 rad/sec = 221.4 W

Velocity ratio (V.R) = $\frac{\mathbf{nG}}{\mathbf{nP}} = \frac{\mathbf{60}}{\mathbf{210}}$ =0.286

Let D_p = pitch circle diameter of pinion on drum shaft

D_G = pitch circle diameter of gear on crank handle

We know the center distance between the shafts (L_{sh}) = 72 mm

$$72 \text{ mm} = \frac{Dp}{2} + \frac{DG}{2} \text{ or } = D_p + D_G = 72 \text{ mm X } 2 = 144\text{mm} \text{------------------------------ } (6)$$

$$\text{Velocity ratio (V.R)} = \frac{\mathbf{Dp}}{\mathbf{DG}} = 0.286 \text{ or } D_p = 0.286\ D_G \text{ -- } (7)$$

Let substitute the value of D_p in equation (6) we have

$0.286\ D_G + D_G = 144\text{mm}$

$1.286\ D_G = 144\text{mm}$

$D_G = 144 \text{ mm}/ 1.286 = 111.9 = 112\text{mm}$

$D_p = 0.286\ D_G = 0.286 \text{ X}112\text{mm} = 32 \text{ mm}$

Note: when both the pinion and the gear are made of the same material, then the pinion is the weaker.

We know that the pitch line velocity of the pinion (V_p)

$V_P = \frac{\boldsymbol{\pi Dpnp}}{\mathbf{60}} = \frac{\mathbf{3.14\ x\ 0.032\ x210}}{\mathbf{60}} = 0.35$ m/s

Therefore the velocity factor (C_V) = $\frac{\mathbf{3}}{\mathbf{3+\boldsymbol{v}}} = \frac{\mathbf{3}}{\mathbf{3+0.35}} = 0.89$

Let as assume the pinion and the gear made from the same material AISI 1020 steel, therefore the design should be based upon the pinion.

Let us take the allowable static stress for pinion material is

(σ_{op}) = 132 MPa = 132 N/mm^2

We know that for 20^0 stub teeth, Lewis factor for the pinion

$Y_p = \mathbf{0.175} - \frac{\mathbf{0.814}}{\boldsymbol{Tp}}$

$= \mathbf{0.175} - \frac{\mathbf{0.814}\boldsymbol{m}}{\boldsymbol{Dp}}$ ----------------- ($Tp = \frac{\boldsymbol{Dp}}{\boldsymbol{m}}$)

$= \mathbf{0.175} - \frac{\mathbf{0.814}\boldsymbol{m}}{\mathbf{32}} = \mathbf{0.175} - \mathbf{0.026}\boldsymbol{m}$

And the maximum tangential force on the pinion

$W_T = \frac{2Tmax}{Dp} = \frac{2 \, x 35.25 x \, 103 \; N.mm}{32} = 2203N$

We also know that the maximum tangential force on the pinion

$W_T = \sigma_w b\pi m Y_p = (\sigma_{op} \, C_V) \, b\pi m Y_p$ --------------- $(\sigma_w = \sigma_{op} \, C_V)$

2203N= (132 N/mm^2 X 0.89) X $10m$ X 3.14 $(0.175 - 0.026m)$

2203N= $646m^2 - 96m^3$

Solve the equation by hit and trial method, and let $m = 2.25$

b=10 x 2.25= 22.5 mm

Number of teeth and pitch circle diameter of each gear

We know that number of teeth on pinion

$Z_p = \frac{Dp}{m} = \frac{32}{2.25} = 14.2$

$Z_G = \frac{DG}{m} = \frac{112}{2.25} = 49.77$

In order to have the exact velocity ratio

$Z_G = \frac{20}{0.286} = 69.9 = 70$

Therefore: $Z_p = 20$ and $Z_G = 70$

Calculate the dynamic load (W_D) on tooth by using Buckingham equation:

$$W_D = W_T + W_I \quad \text{--} \; (8)$$

$$= W_T + \frac{21v(bc+WT)}{21v+\sqrt{bc+WT}} \quad \text{--} (9)$$

$C = \frac{Ke}{\frac{1}{Ep}+\frac{1}{EG}}$, where $k = 0.115$ for 20^0 stub system

$E_p = E_G$, young's modulus of the material= $200X10^3$ N/mm^2

$$e = 0.051$$

$C = \frac{0.115 \, x 0.051}{\frac{1}{200x103}+\frac{1}{200x103}} = 586.5 = 587$

$W_D = 2203N + \frac{21(0.35)(22.5x587+2203)}{21(0.35)+\sqrt{22.5x587}+2203}$ $W_D = 862$ N

Find the static tooth load

For safety, against tooth breakage, the static tooth load (W_S) should be greater than the dynamic load (W_D). Buckingham suggests the following relationship between W_S and W_D

For steady loads, $W_S \geq 1.25\ W_D$:

W_S= 1.25 x 862N = 1078N or

$W_S = \sigma_e b\pi m y$ --- (10)

y= 0. **175** - 0.025(m) = 0.119

= 194 N/mm^2 x 22.5 mm x 3.14 x 2.25 x 0.119

= 3670 N

$W_S > W_D$

Wear tooth load

$W_W = D_p bQK$ -- (11)

Where W_W = maximum or limiting load for wear in Newton's

D_p = pitch circle diameter of the pinion in mm

b = face width of the pinion in mm

Q = ratio factor = $\frac{2\ V.R}{V.R+1} = \frac{2ZG}{ZG+Zp}$ for external gear

K = load- stress factor (aka material combination factor) in N/mm^2

$= \frac{(\sigma es)^2 \sin\Phi}{1.4}\left[\frac{1}{Ep}+\frac{1}{EG}\right]$

Z_G = **7**0, Z_p = 20

Q= $\frac{2\ x\ 70}{70\ +20}$ = 1.55

K= $\frac{(650N/mm2)^2\ \sin 20}{1.4}\left[\frac{1}{200x103}+\frac{1}{200x103}\right]$

$= \frac{422{,}500\ x\ 0.342}{1.4}\ \boldsymbol{x\ 1x\ 10^{-5}}$

$= 1.03$

$W_W = D_p bQK$

$= 32 x 22.5 x\ 1.55 x 1.03$

$= 1{,}150$ N

The wear load (W_W) should not be less than the dynamic load (W_D)

$W_W > W_D$

Addendum (A) = 0.8m = 0.8 x 2.25= 1.8mm

Dedendum (D) = 1m = 1x 2.25= 2.25mm

Working depth (Wd)= 1.6m= 3.6mm

Minimum tooth depth (M_{Td}) = 1.8m = 1.8x 2.25 = 4.05 mm

Tooth thickness(t)= 1.5708m= 1.5708 x 2.25= 3.53mm

Minimum clearance (m_c) = 0.2m= 0.2 x 2.25= 0.45mm

Fillet radius at root (r_f) = 0.4m = 0.4 x 2.25= 0.9mm

Tip (outside) diameter (d_a)

Tip (outside) diameter of pinion (d_{ap}) = m(T_p +2) = 2.25 (20+2) = 49.5mm

Tip (outside) diameter of gear (d_{aG}) = m(T_p +2) = 2.25 (70+2) = 162mm

(Finite Element Analysis Results for Gear and Pinion Mentioned at Appendix A1 &A2)

4.5.3 Design of Shaft for Spur Gears:

Calculation

In order to find the diameter of shafts for the spur gears, the following procedure followed:

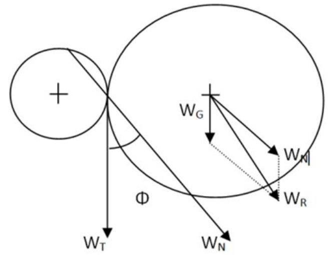


Figure 4: 6 Load actions on the gears

Finding the normal load (W_N), acting between the tooth surfaces. it is given by

$$W_N = \frac{W_T}{Cos\ \Phi} \text{ -- (12)}$$

$$= \frac{2203N}{Cos\ 20} = 2344N$$

The Wight of the gears given as:

$W_G = 0.00118\ Z_G\ b\ m^2$ (in N) = 0.00118x70x22.5x $(2.25)^2$ = 9.4N

$W_P = 0.00118\ Z_p\ b\ m^2$ (in N) = 0.00118x20x22.5x $(2.25)^2$= 2.6N

The resultant load acting on the gears

$$W_{RG} = \sqrt{\boldsymbol{W_N^2} + \boldsymbol{W_G^2}} + 2W_N \text{ x } W_G\cos \boldsymbol{\Phi} \text{ --------------------- (13) for gear}$$

$= [(2344N)^2 + (9.4N)^2 + 2(2344N) \text{ x } 9.4\cos 20^0]^{1/2}$

$= (5{,}499{,}121)^{1/2}N$

=2,345N

$$W_{RP} = \sqrt{\boldsymbol{W_N^2} + \boldsymbol{W_p^2}} + 2W_N \text{ x } W_p\cos \boldsymbol{\Phi} \text{ ----------------------- (14) for pinion}$$

$= [(2344N)^2 + (2.6\ N)^2 + 2(2344N) \text{ x } 2.6\cos 20^0]^{1/2}$

$= (5{,}499{,}033)^{1/2}$ N

= 2,345N

The gears are overhung on the shafts, then the bending moment on the shaft due to the resultant load,

$M_G = W_{RG}$ x X_G ------------------------- (15) bending moment of gear shaft

= 2,345N x 55.25mm

= 129,561N.mm

$M_P = W_{RP}$ x X_P --------------------------- (16) bending moment of pinion shaft

= 2,345N x 20.25mm

= 47,486N.mm

Since the shafts are under the combined effect of torsion and bending, therefore we shall determine the equivalent torque.

The equivalent torque for gear shaft

$$T_{eG} = \sqrt{\boldsymbol{M_G^2}} + \boldsymbol{T_G^2} \text{ -- (17)}$$

$T_G = W_T\frac{\boldsymbol{daG}}{\boldsymbol{2}} = 2203\text{N x } \frac{\boldsymbol{162mm}}{\boldsymbol{2}} = 178{,}443$ N.mm

$T_{eG} = [(129{,}561)^2 + (178{,}443)^2]^{1/2}$

$= 220{,}518$N.mm

The equivalent torque for pinion shaft

$$T_{eP} = \sqrt{\boldsymbol{M_P^2}} + \boldsymbol{T_P^2} \text{ --- (18)}$$

$T_P = W_T\frac{\boldsymbol{dap}}{\boldsymbol{2}} = 2203\text{N x } \frac{\boldsymbol{49.5mm}}{\boldsymbol{2}} = 54{,}524$ N.mm

$T_{eP} = [(47{,}486)^2 + (54{,}524)^2]^{1/2}$

$= 72{,}303$N.mm

Now the diameter of the gear shafts(d) is determined by using the following relation

The diameter of the gear shaft:

$$T_{eG} = \frac{\boldsymbol{\pi}}{\boldsymbol{16}} \boldsymbol{x\ \tau\ x\ d_{GS}^3} \text{ -- (19)}$$

220,518N.mm = 3.14/16 x 80N/mm^2 x$\boldsymbol{d_{GS}^3}$

$d_{GS} = \sqrt[3]{\boldsymbol{14,046}}$ mm

$= 24\text{mm} \approx 30\text{mm}$

The diameter of the pinion shaft:

$$T_{eP} = \frac{\boldsymbol{\pi}}{\boldsymbol{16}} \boldsymbol{x\ \tau\ x\ d_{PS}^3} \text{ --- (20)}$$

72,303N.mm = 3.14/16 x 80N/mm^2 x$\boldsymbol{d_{PS}^3}$

$d_{PS} = \sqrt[3]{\boldsymbol{4,605}}$ mm

$= 16.6\text{mm} \approx 20\text{mm}$

Bending Moment and Shear Force Diagram of Shafts

1. Bending Moment and Shear Force Diagram of Gear Shafts

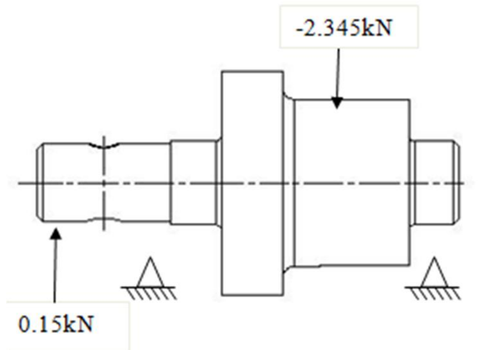


Figure 4:7 Shafts for gear

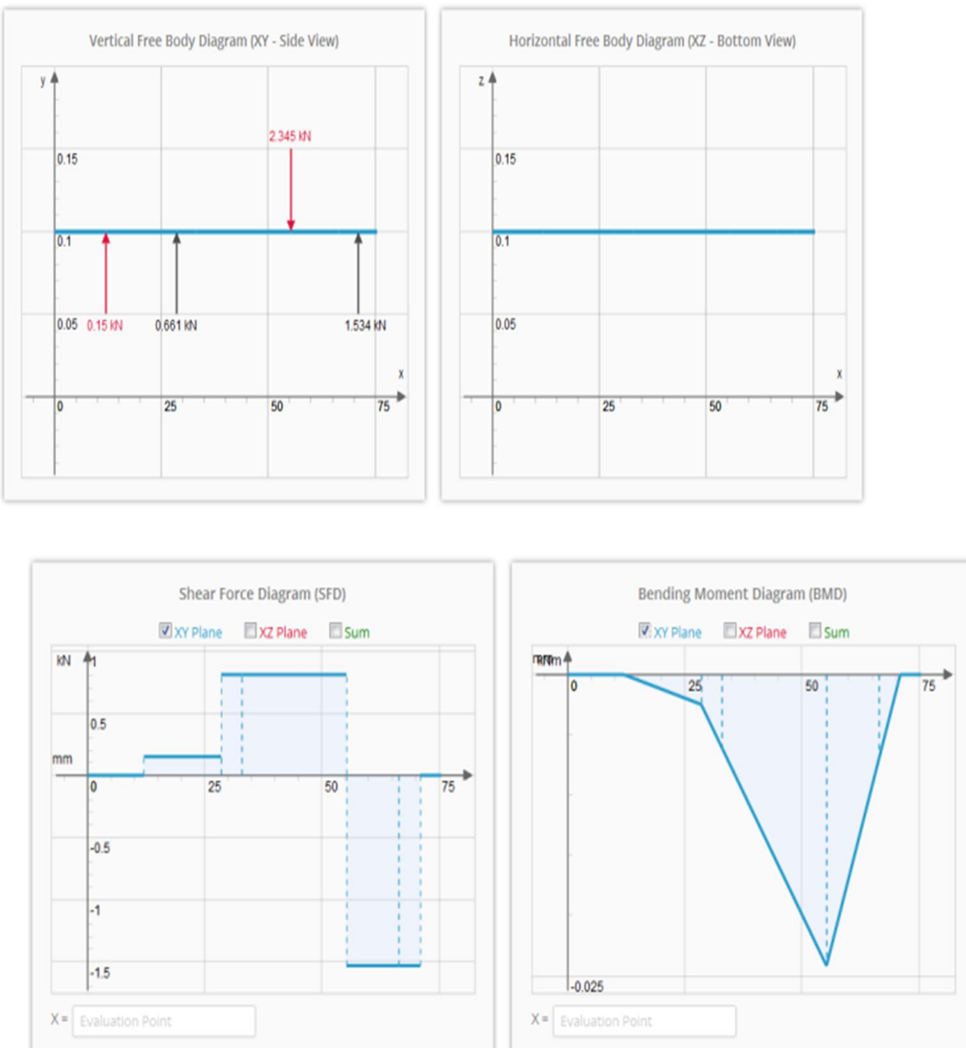


Figure 4:8 Bending Moment and Shear Force Diagram of gear Shaft

2. Bending Moment and Shear Force Diagram of Pinion Shafts

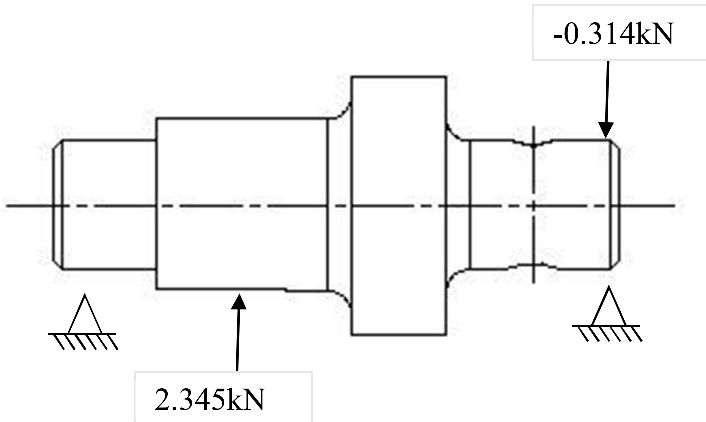


Figure 4:9 Shafts for pinion

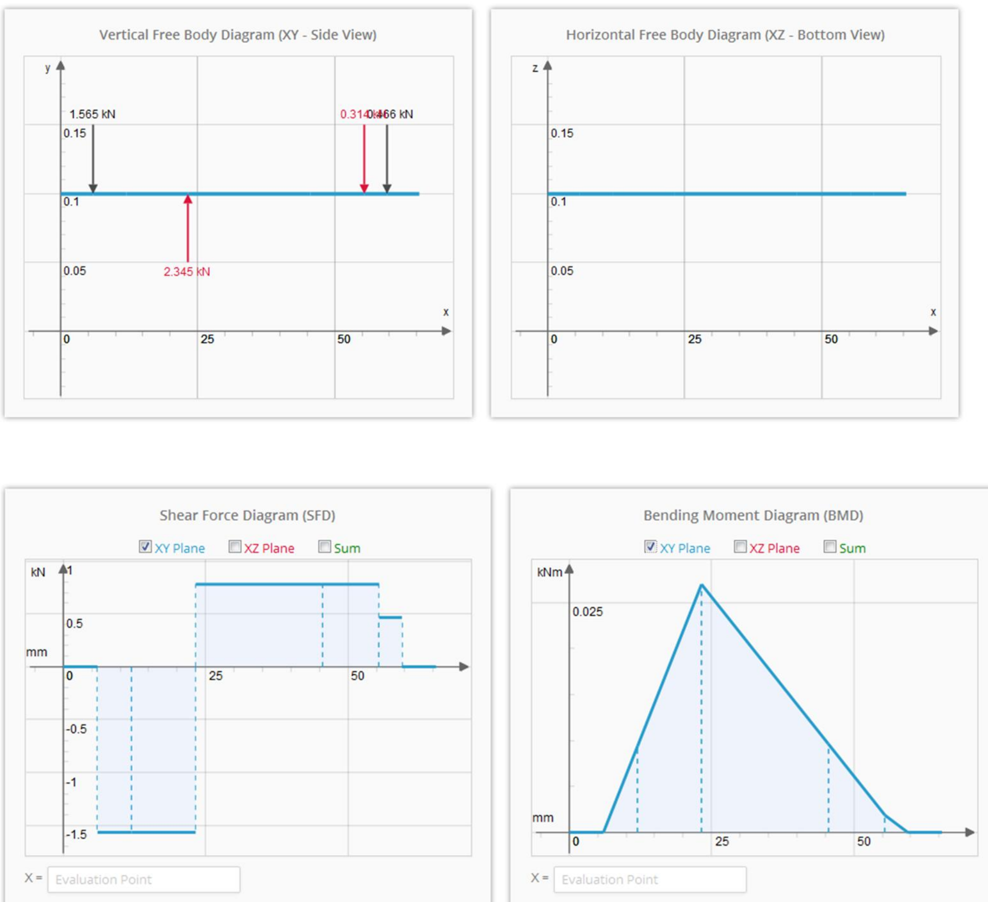


Figure 4: 10Bending Moment and Shear Force Diagram of pinion Shaft

(Finite Element Analysis Results for Gear shaft and Pinion shaft Mentioned at Appendix A2)

4.5.4 Design of Key for Shafts

Key and keysets calculations

In order to allow the gear transmit its rotational power to the shaft effectively and without any slipping, keys are used for all the pinions and gears in our design. In our design, profile rectangular keys are used as they are most common used keys in industry as well as due to a lower cost required. Profile rectangular keys can ensure that the shaft and gear interlock each other in all direction, which is better to prevent the gear from moving in any direction.

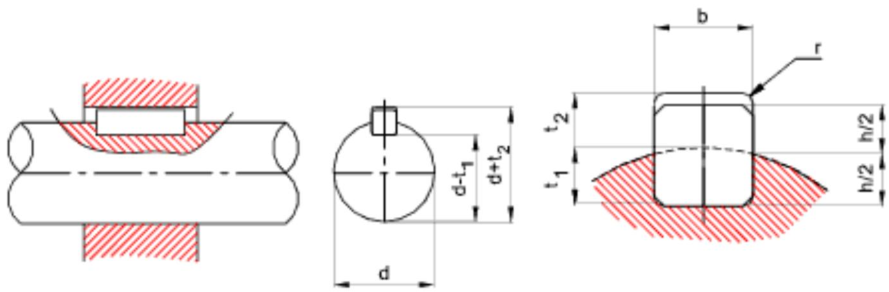
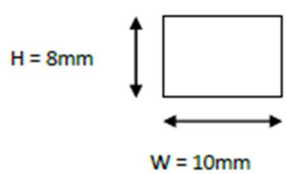


Figure 4: 11Rectangular sunk key

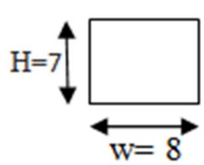
Shaft 1. for gear

for a shaft of 30 mm diameter [22]



Shaft 2. for Pinion

Find that for a shaft of 20 mm diameter .[22]



Key for Gear

Bearing and Shear Stress Analysis

Since for gear 1, the diameter of shaft where the pinion 1 mounted on it is 30.00mm.[22], the standard width and height of the key are 10.00mm and 8.00mm respectively.

Width of the key, W_K = 10.00mm

Diameter of the shaft, d_{GS} = 30.00mm

The key is expected to withstand sudden shock or impact, thus the safety factor used is (*f*s) 6.

From calculation for shaft 1, the torque transmitted is (T_G) 178 N m

Tensile strength of shaft 1, σ_u = 742M Pa.

The minimum required key length can be calculated using the formula as below:

$$L_S = (4\ T_G fs)/\sigma_u d_{GS\,W_K} \text{ -- } (21)$$

$$= \frac{4\ x178x6}{742\text{x}10^6\ x0.03x0.01}$$

$$= 0.019\text{m} \approx 19\text{mm}$$

Key for Pinion

Bearing and Shear Stress Analysis

Since for gear 1, the diameter of shaft where the pinion 1 mounted on it is 20.00mm.[22], the standard width and height of the key are 8.00mm and 7.00mm respectively.

Width of the key, W_K = 8.00mm

Diameter of the shaft, d_{PS} = 20.00mm

The key is expected to withstand sudden shock or impact, thus the safety factor used is (*f*s) 6.

From calculation for shaft 1, the torque transmitted is (T_P) 55 N m

Tensile strength of shaft 1, σ_u = 742M Pa.

The minimum required key length can be calculated using the formula as below:

$$L_S = (4\ T_P fs)/\sigma_u d_{PS\,W_K}$$

$$= \frac{4\ x55x6}{742\text{x}10^6\ x0.02x0.008} = 0.011\text{m} \approx 11\text{mm}$$

4.5.5 Design of Socket and Spigot Cotter (Pin) Joint

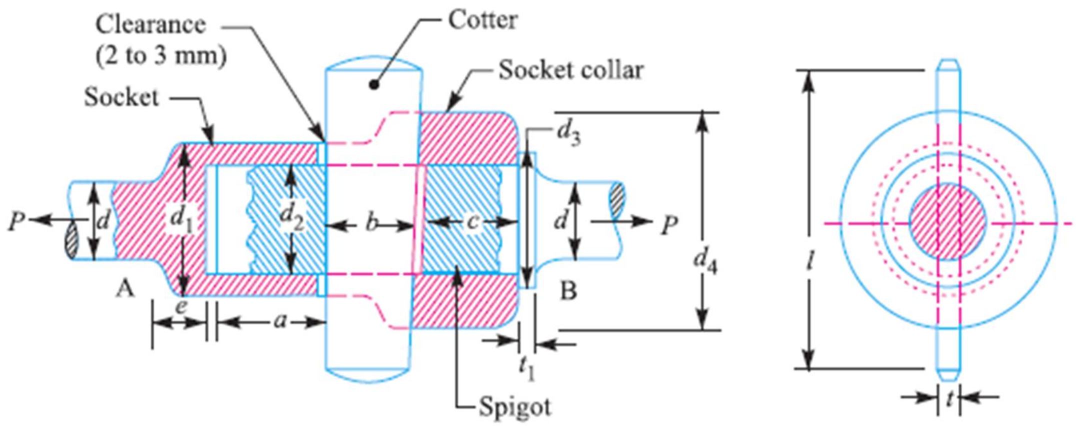


Figure 4: 12 Socket and spigot cotter joint

The socket and spigot cotter joint is shown in Fig. 4.12.

Let P = Load carried by the rods,

d = Diameter of the rods,

$d1$ = Outside diameter of socket,

$d2$ = Diameter of spigot or inside diameter of socket,

$d3$ = Outside diameter of spigot collar,

$t1$ = Thickness of spigot collar,

$d4$ = Diameter of socket collar,

c = Thickness of socket collar,

b = Mean width of cotter,

t = Thickness of cotter,

l = Length of cotter,

a = Distance from the end of the slot to the end of rod,

σt = Permissible tensile stress for the rods material,

τ = Permissible shear stress for the cotter material, and

σc = Permissible crushing stress for the cotter material.

Assume

- The cotter joint to support a load varying from 2,345N in compression to 2,345N in tension.
- The material used is carbon steel for which the following allowable stresses may be used. The load is applied statically.
- Tensile stress = compressive stress (σ*t*) = 20 MPa = 20 N / mm^2
- Shear stress (τ) = 35 MPa = 35 N / mm^2
- Crushing stress (σ*c*) = 90 MPa = 90 N/mm^2

1. Diameter of the rods

Let *d* = Diameter of the rods. Considering the failure of the rod in tension. We know that load (*P*),

$2{,}345\text{N} = \frac{\pi}{4} \text{ x } d^2 \text{ x } \sigma t = 0.785 \text{ x } 20\ d^2$

$d^2 = 2{,}345/15.\ 7$

d = 12.2mm

2. Diameter of spigot and thickness of cotter

Let d_2 = Diameter of spigot or inside diameter of socket, and

t = Thickness of cotter. It may be taken as d_2 / 4.

Considering the failure of spigot in tension across the weakest section. We know that load (P),

$2{,}345\text{N} = [\frac{\pi}{4} \text{ x } (d_2)^2 - d_2 \text{ x} d_2/4]\ \sigma t = 10.7(d_2)^2$

$(d_2)^2 = 2{,}345/10.7$

$d_2 = 14.8$ mm

And thickness of cotter, t = d_2 / 4 =14.8/4 = 3.7mm

Let us now check the induced crushing stress. We know that load (*P*),

$2{,}345\text{N} = d_2 \text{ x t x } \sigma c = 14.8\text{mm x } 3.7\text{mm x } \sigma c$

$\sigma c = 2{,}345\text{N}/54.76 = 42.8\text{N/mm}^2$

Since this value of σ*c* is less than the given value of σ*c* = 90 N/mm2, therefore the dimensions *d*2 = 14.8 mm and *t* = 3.7mm are safe.

The length of cotter (*l*) is taken as 4 *d*.

l= 4d = 4x12.2mm = 48.8mm

4.5.6 Design of Cylinder Covers (Bering House)

1. Design of bolts or studs

In order to find the size and number of bolts or studs, the following procedure may be adopted.

Let D = Diameter of the cylinder = 59mm

P = Pressure in the cylinder = $p/\frac{\pi}{4}xD^2$ = 2,345N/ 0.785 x3,481 mm^2= 0.85N.mm2

dc = Core diameter of the bolts or studs =Assume that the studs of nominal diameter 6 mm are used.[19], find that the corresponding core diameter (*dc*) of the bolt is 4.773 mm.

σtb = Permissible tensile stress for the bolt or stud material=33 MPa = 33 N/mm^2

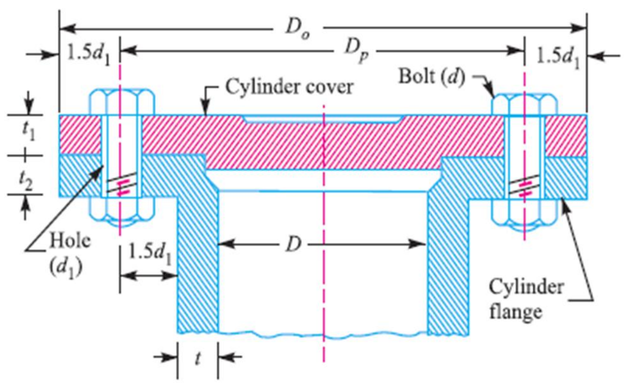


Figure 4: 13 Arrangement of securing the cylinder cover with bolts

Resisting force offered by *n* number of studs,

$P = \frac{\pi}{4}\ xd_c^2\ x\ \sigma_t$ x n --(22)

2,345N = 0. 785x (4.773 mm)^2 x 33 N/mm^2 x n

n= 2,345/590 = 3.9 ≈ 4

pitch circle diameter of the studs,

Dp = D + 2t + 3d$_1$ -- (23)

First for all, let us find the thickness of the cylindrical flange. According to Lame's equation,

t= r[$\sqrt{\frac{\sigma_{t+p}}{\sigma_{t-p}}}$ -1] = 29.5[$\sqrt{\frac{33+0.85}{33-0.85}}$ -1] = 0. 769 ≈ 10mm

Taking the diameter of the stud hole ($d1$) as 6mm, we have pitch circle diameter of the studs,

$D_p = D + 2t + 3d_1$ = 59mm + 2 x10 + 3 x 6 = 97 mm

∴*Circumferential pitch of the studs

$\frac{\pi\ x\ D_p}{n} = \frac{3.14\ x\ 97}{4}$ =76 mm

We know that for a leak-proof joint, the circumferential pitch of the studs should be between $20\sqrt{d1}$ to $30\sqrt{d1}$, where $d1$ is the diameter of stud hole in mm.

Minimum circumferential pitch of the studs:

$20\sqrt{7}$ = 53mm

And maximum circumferential pitch of the studs:

$30\sqrt{7}$ = 79 mm

Since the circumferential pitch of the studs obtained above lies within 53mm to79 mm,
Therefore the size of the stud chosen is satisfactory.

∴ Size of the stud = M 6

* The circumferential pitch of the studs cannot be measured and marked on the cylinder cover. The centers of the holes are usually marked by angular distribution of the pitch circle into n number of equal parts. In the present case, the angular displacement of the stud hole centre will be 360°/12 = 30°.

4.5.7 Design of Chain

Chain is used for power transmission from one shaft to another shaft. There are three major types of chains are used for power transmission: roller, engineering steel and silent chains. Roller chains are probably the most common and are used in a wide variety of low speed to high-speed drives.

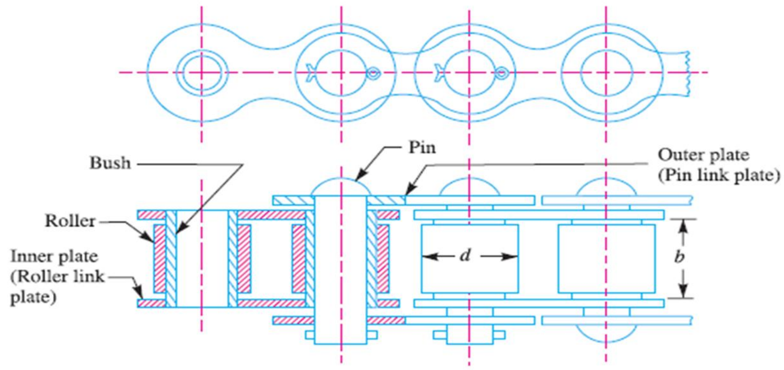


Figure 4: 14 Bush roller chain

Assumption

- Assuming the operator could be holed a steady peace of around 30rpm at pedals and the drum itself would be seeing a maximum rotational speed of 100 rpm.
- Minimum center distance = 400mm
- Operating time 2 hours per day
- Maximum power = 125W
- Velocity ratio : the velocity ratio of chain drive is given by:
- $V_R = N_1/N_2$ where N_1 = speed of rotation of smaller sprocket in rpm
- N_2 = speed of rotation of larger sprocket in rpm

= 100rpm/30rpm = 3

From [22] for the roller chain, the number of teeth on the smallest sprocket or pinion for the velocity ratio of 3:

$T_1 = 25$

The number of teeth on the larger sprocket or gear:

$T_2 = T_1 \times N_1/N_2 = 25 \times 100/30 = 75$

1. Design power = Rated Power X service factor K_s

Service factor $K_s = K_1 \times K_2 \times K_3$

Where K_1= load factor for variable load with mild shock= 1.25

K_2 = lubrication factor for periodic lubrication = 1.5

K_3 = rating factor for continuous factor = 1.5

K_s = 1.25 x 1.5 x 1.5 = 2.8125

Therefore the design power:

P= 125W x 2.8125 = 352 W

The speed of the smaller sprocket is 100rpm, then from.[19] , the power rating is equal to 0.25 KW the chain number B06:

At ISO chain number B06

Pitch(C_p) in mm = 9.525 mm

Roller diameter = 6.35 mm

Minimum width of roller (W) = 5.72mm

Breaking load (W_B) = 8.9 KN

Pitch circle diameter of smaller sprocket or pinion

$$d_1 = P \text{ cosec } (180/T_1) \text{ ---(24)}$$

= 9.525 mm cosec (180/25) = 75.99 ≈80mm

Pitch circle diameter of larger sprocket or gear

$$d_2 = P \text{ cosec } (180/T_2) \text{ ---(25)}$$

= 9.525 mm cosec (180/75) = 227.6 mm

Pitch line velocity of the smaller sprocket

$$V_1 = \pi d_1 N_1/60 \text{ ---(26)}$$

= 3.14 x 0.08 x 100/60 = 0.41 m/s

Load on the chain:

$$W = \text{rated power/Pitch line velocity} \text{ --(27)}$$

= 125W/0.41m/s

= 305N = 0.305KN

Factor of safety for chain drives:

$$= \frac{\boldsymbol{breaking\ strangth(W_B)}}{\boldsymbol{total\ load\ on\ the\ driving\ of\ the\ chain(W)}} \text{ --- (28)}$$

$= \frac{\mathbf{8.9KN}}{\mathbf{0.305}\boldsymbol{KN}}$ =29.2 This value is more than the value given in.[19], which is equal to 41.

The minimum centre distance between the smaller and larger sprockets should be 30 to 50 times the pitch. Let us take it as 45 times the pitch.

Therefore Centre distance between the sprockets,

45p = 45 x 9.525 = 429mm, in order to accommodate initial sage in the chain the value of the center distance is reduced by 2 to 5 mm:

X= 429mm -5mm = 424mm

Number of chain links

$$K= \frac{T_{1+T_2}}{2} + \frac{2X}{P} + \left[\frac{T_{2-T_1}}{2\pi}\right]^2 x \frac{P}{X} \text{---(29)}$$

$$= \frac{25_+ 75}{2} + \frac{2(424)}{9.525} + \left[\frac{75-25}{2\pi}\right]^2 x \frac{9.525}{424}$$

= 140

Therefore L= KP = 140 x 9.525 = 133.3mm

4.5.8 Design of Shaft for Chain Drive

Let d_1 is the diameter of the smaller sprocket

d_1 = 80mm

N_1 = 100rpm

P = 125 W

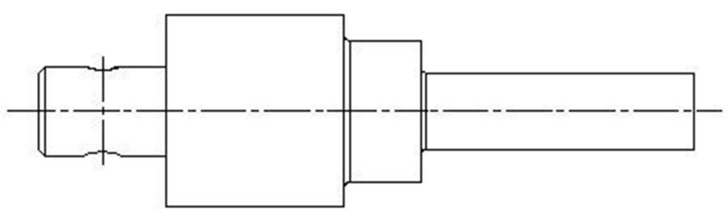


Figure 4:15 Shaft for chain drive

The speed of the smallest sprocket can be calculated as follows

$V_1 = N_1 \text{ x } \frac{d_1}{2}$ = 100 x 0.08m/60 = 0.133 m/s

The torque applied on the shaft T will be

$T = \frac{Px60}{2\pi N} = \frac{125x60}{2\pi 100}$ = 12N-m

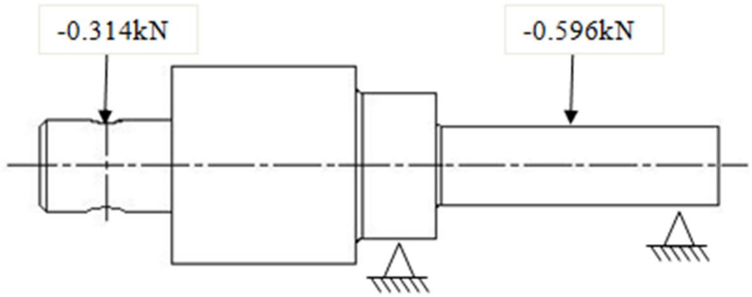


Figure 4:16 Shafts for chain drive

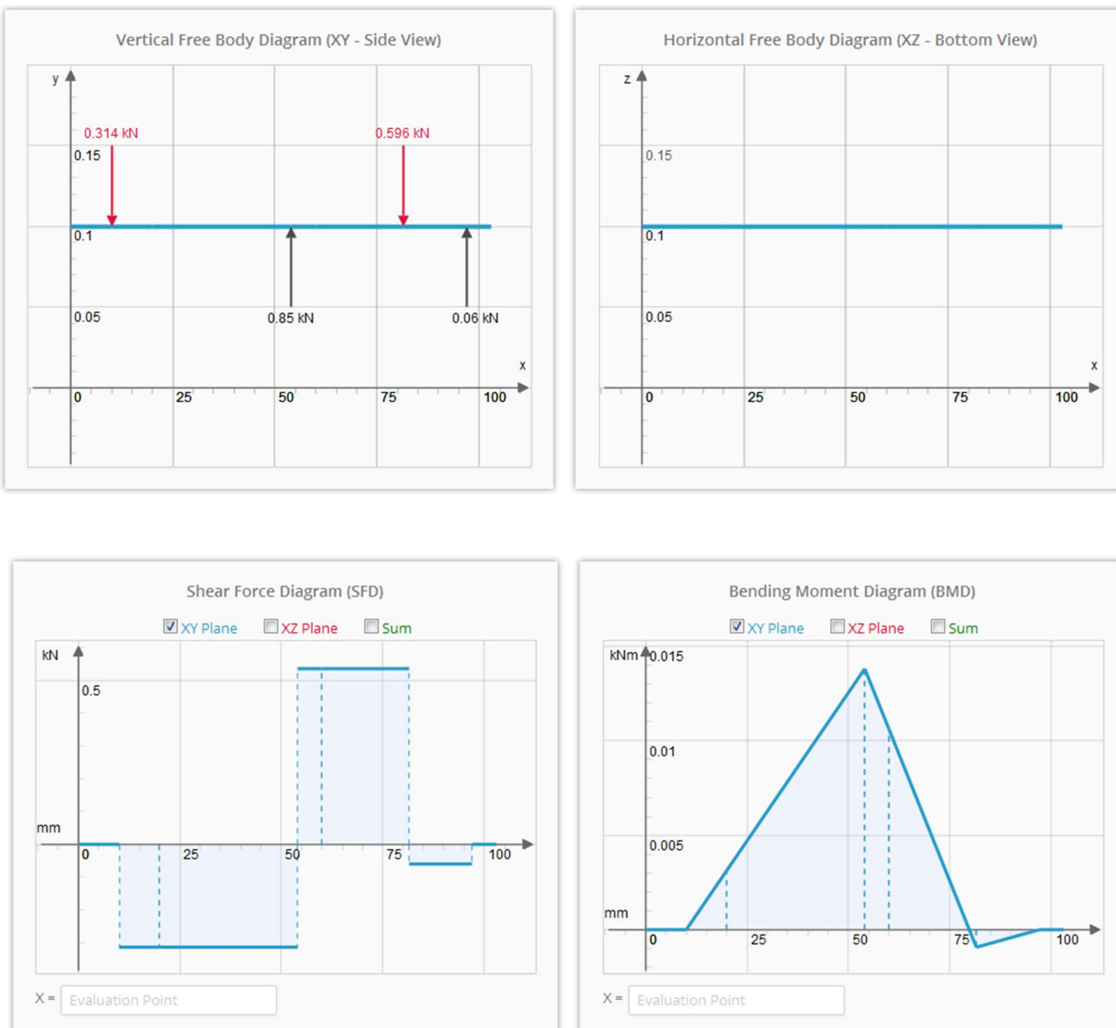


Figure 4: 17 Bending Moment and Shear Force Diagram of pinion Shaft

This material has low notch sensitivity uncorrected endurance straight by using the following equation:

$\sigma_{e'} = 0.5\ \sigma_{ut} = 0.5 \times 469\text{MPa} = 234.5\ \text{MPa}$. This should be reduced by various factors to account for difference between the part and test specimen.

$\sigma_e = C_{load} \times C_{size} \times C_{surface} \times C_{tempratre} \times C_{reliable} \times \sigma_{e'}$

$C_{load} = 1$, $C_{size} = 1$, $C_{surface} = 0.84$, $C_{tempratre} = 1$, $C_{reliable} = 1$, $\sigma_{e'} = 234.5\text{MPa}$

$\sigma_e = (1)(1)(0.84)(1)234.5\text{MPa} = 196.98\ \text{MPa}$

Now the fatigue stress concentration factor is fond from the banding stress as follows

$Kf = 1 + q\ (kt - 1)$

$= 1 + 0.5(3.5 - 1)$

$= 2.25$

For torsion $Kfsm = 1 + q\ (kfs - 1)$

$= 1 + 0.57(2-1) = 1.57$

Let say d is the diameter of the shaft given by the following equation by considering factor of safety, NF =2.5:

$d = \{32NF/\pi\ [(Kf)\ MB/sf)^2 + \frac{3}{4}(Kfsm)\ T/Sy)^2]^{1/2}\}^{1/3}$

Using the following parameters;

NF = 2.5, MB = 14 N-m, Sf = 196.98 MPa, Kf = 1.57, T = 9.55 N-m, Sy = 393 MPa

$d = \{\frac{32 x2.5}{\pi} [(2.25)\frac{14}{196.98})^2 + 3/4(1.57)\frac{9.55}{393})^2]^{1/2}\}^{1/3}$

$= 0.009\text{m} = 9\text{mm} \approx 12mm$

(Finite Element Analysis Results for Gear and Pinion mentioned at Appendix A-1)

4.5.9 Bering selection

- Roller bearing is select mostly to hold the force which comes from the shaft which passes through it. For the design of *Manual Operation* washing machine we select ball bearing type. It support combined radial and thrust load.

- Typically require less space in axial direction so that the bearing has small thickness, low starting and good operating friction conditions are obtained. In this design the bearings are exposed to both radial and axial load, maximum force is applied to the first bearing.

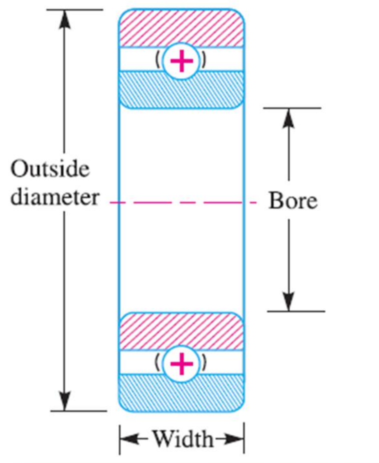


Figure 4: 18 Standard designations of ball bearings

Bering selection for sprocket shaft

Decision and assumption:

A conservative design for light to moderate impact is required

A compressive design for 8hr per day continuous service is required

A 90% reliability is required

A radial bearing ($\alpha = 0^{o}$ should be chosen)

Ball bearing life varies inversely with 10/3 power of the load

Design analysis

Only radial load , F_r is applied

From bearing catalogue Ks = 1 (moderate impact) [22] , and 8hrs ever working day has 30,000 hr life

The shaft rotates 100 rpm

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

L = RPM x Hr life --(30)

$= 100$ rpm x 30,000 x 60 min/hr

$= 18 \times 10^7$ revolutions

From standard catalogue for standard 90% reliability life corresponding to rated capacity ($L_r = 9 \times 10^6$ revolutions)

The required value of rated capacity,(C_{req})

$$C_{req} = F_r \left(\frac{L}{L_r}\right)^{0.3} \quad \text{-----(31)}$$

$$= 590N \left(\frac{180 \times 10^6 \text{ rev}}{9 \times 10^6 \text{ rev}}\right)^{0.3}$$

$$= 2KN$$

From standard catalogue the appropriate radial bearing would be bearing basic no L04, bore = 20mm, outer diameter = 42mm,and width= 15mm

Bering selection for gear and pinion shaft

Decision and assumption:

A conservative design for light to moderate impact is required

A compressive design for 8hr per day continuous service is required

A 90% reliability is required

A radial bearing ($\alpha = 0^{o}$ should be chosen)

Ball bearing life varies inversely with 10/3 power of the load

Design analysis

Only radial load , F_r is applied

From bearing catalogue Ks = 1 (moderate impact) [19] and 8hrs every working day has 30,000 hr life

The shaft rotates 210 rpm

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

L = RPM x Hr life

$= 210$ rpm x 30,000 x 60 min/hr

$= 37.8 \times 10^7$ revolutions

From standard catalogue for standard 90% reliability life corresponding to rated capacity (Lr = 9×10^6 revolutions)

The required value of rated capacity,(C_{req})

$$C_{req} = F_r \left(\frac{L}{L_r}\right)^{0.3}$$

$$= 590N \left(\frac{37.8x\ 10^6\ rev}{9\ x\ 10^6\ rev}\right)^{0.3}$$

From standard catalogue the appropriate radial bearing would be bearing basic no L02, bore = 10mm, outer diameter = 30mm, and width= 9mm

4.5.10 Design of Outer Drum

In this top-loaded washing machine, the outer drum cylinder is arranged horizontally and it is open from one of its bases at the top, which connects to the door. The open base of the cylinder, called top cover, is designed with a large hole to allow entry and exit of laundry in the washer.

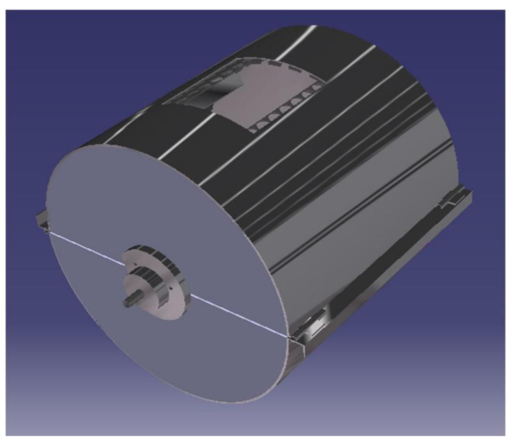


Figure 4:19 The outer drum

Configuration and Data:

Facing Skins Aluminium 5251 H24

Thickness t1 and t2 = 0.50mm

Yield Strength = 150 MPa

Ef Modulus = 70 GPa

Poissins Ratio m = 0.33

Core 5.2 - 1/4 - 3003

Thickness tC = 2.5 mm

EC Modulus = 1000 MPa

Longitudinal shear = 2.4 MPa

GL Modulus = 440 MPa

Transverse shear = 1.5 MPa

GW Modulus = 220 MPa

Stabilized Compression = 4.6 MPa

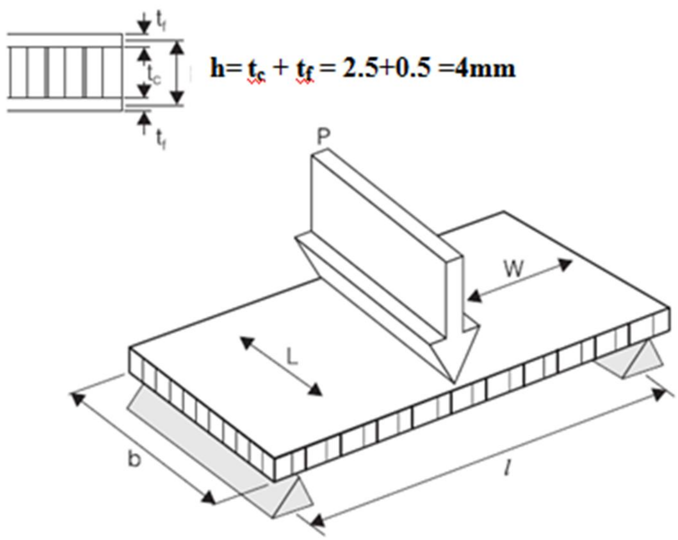


Figure 4:20 Force applied on beam

Considering a center point loaded beam with b = 0.4m and l = 1.256m and P = 150N

P = 15Kg (water) x 10N/m2 = 150N

l(circumference) = 2πr = 6.28 x 0.2m= 1.256m

Bending Stiffness

$$D = \frac{E_f\, t_{f} h^2 b}{2} \text{ -- } (32)$$

$$= \frac{(70\,x\,10^9)(0.5\,x\,10^{-3})(3\,x\,10^{-3})^2\,(0.4)}{2} = 63\text{Nm}^2$$

Shear Stiffness

$$S = b\, h\, G_C \text{ -- } (33)$$

As the core shear here will be taken by the weaker transverse direction - take $G_C = G_W$ shear modulus

$S = (0.4)\,(3 \times 10^{-3})\,(220 \times 10^{6}) = 264 \times 10^{3}$N

Deflection

$$\delta = \frac{K_b P l^3}{D} + \frac{K_s\, Pl}{S} \text{ (Bending plus Shear) -- (34)}$$

$$= \frac{(0.021)(150)(1.256)^3}{63} + \frac{(0.25)(150)(1.256)}{264 \times 10^3} = 0.099 + 0.00018 = 0.09918$$

If excessive, then the most efficient way to reduce deflection is to increase core thickness, and thus increase the skin separation and the value of h.

Facing Stress

$$\sigma_f = \frac{M}{h t_{f\,b}} \text{ --(35)}$$

Where M is Maximum Bending Moment

M= Pl/4 = 150(1.256)/ 4 = 47.1Nm

$$\sigma_f = \frac{47.1}{(3 \times 10^{-3})(0.5 \times 10^{-3})(0.4)} = 78.5\text{MPa}$$

So calculated stress is less than face material typical yield strength of 150MPa. Thus giving a factor of safety.

Core Stress

$$\tau_C = \frac{F}{hb} \text{ --(36)}$$

Where F is Maximum Shear Force

F= P/2 = 150/2= 75N

$$\tau_C = \frac{75}{(3 \times 10^{-3})(0.4)} = 0.0625\text{MPa}$$

So calculated shear is considerably less than core material typical plate shear in the transverse (W) direction of 1.5 MPa, giving a factor of safety, which could allow core density to be reduced.

(Finite Element Analysis Results for outer drum mentioned at Appendix A-3)

4.5.11 Design of Inner Drum

Inner drum is the main part of this washing machine which is used to hold to cloths and to clean or to wash during its rotational motion. The drum is exposed to different types of force and stress during its normal operation and variable sped operation time.

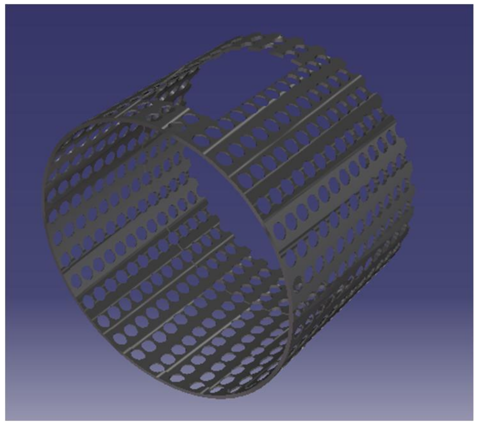


Figure 4:21 Internal Drum

The forces which can be applied on the drum are:

- Crushing force which comes from dead weight of the water and clothes
- Tensional force which comes from rotational motion

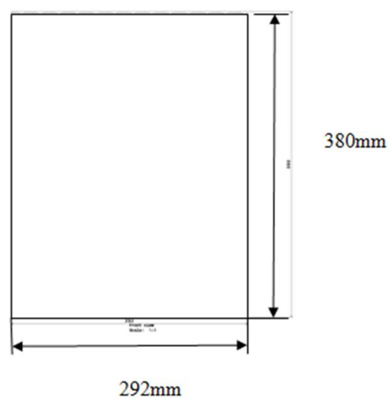


Figure 4: 22 Overall dimension of the internal drum

The ratio of radius is less than 1/10 of the cylinder can be considered thin walled. The stress distribution across the thin wall can be approximated as uniform and the expression for stress simplifying.

$st = {}^{pr}/_{t}$ Where, Sr= 0 -- (37)

From the dead weight the weight of cloth and water is 180N. if this load is distributed over the drum.

$${}^{180N}/_{0.292m} = {}^{616N}/_{m}$$

Torque which is gained from the shaft

T= $\frac{Px60}{2\pi N} = \frac{125Wx60}{2\pi 100}$ =11.94 N-m

There are two forces which is exerted on the drum these are breaking force and torsion force.

Analysis of torsion force

Due to torsion there is shear stress that occur on the drum to check the strength of the drum we should to take the drum like hallow shaft.

The polar area moment of inertial the drum

$$J=\frac{\pi(do^4-di^4)}{32} \text{ --- (38)}$$

Diameter of the internal dimension 380mm. Diameter of outer dimension 284mm

$$J= 3.14\ \frac{0.384^4-0.380^4}{32}$$

$$= 87.5 \times 10^{-6} m^4$$

Jmax = $\frac{TR}{J}$

Where, T= 11.94N-m

R= 190mm= 0.190m

$$Jmax = \frac{11.94Nm\times 0.190m}{87.5x\ 10-6m4}$$

Jmax = 25,927$\frac{N}{m^2}$

Share due to transverse load at a point c on the center of the neutral axis, the normal bending stress and torsional share stress.

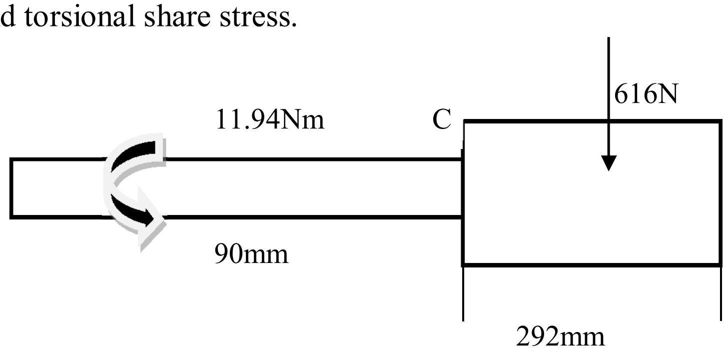


Figure 4:23 Free body diagram of inner drum

$$\sigma x = \frac{MC}{I} \text{ --- (39)}$$

$M_1 = 11.94Nm$

$M_2 = 661N/m \times 292 \times 10^{-3}\ m \times 90 \times 10^{-3}$

$M_2 = 17.4N\text{-}m$

$$I = \frac{\pi(do^4 - di^4}{64}$$

$$I = 3.14\,\frac{0.384^4 - 0.380^4}{64}$$

$$= 0.44 \times 10^{-4} m4$$

$$ox = (\Sigma m - (1)C - 1)/_{I}$$

$$ox = \frac{(11.94 \times 0.19 + 17.4 \times 0.19)Nm^2}{0.44 \times 10^{-4} m^4}$$

$$Ox = \mathbf{126.82Kpa}$$

The maximum shear stress and principal stress that a result from the combination of applied stress is:

$$max = \sqrt{\frac{(\sigma_x - \sigma_y)2}{2}} + \tau_{xy^2} = \sqrt{}\left(\frac{126.82 - 0}{2}\right)2 + 25.\ 927^2$$

$$= 68.5MPa$$

Ultimate tensile strength of the selected material is sheet annelid cold rolled aluminum alloys.

Ssut = 90 Mpa, if the strength reduces by different factors that by:

Ccold = 1, Csize = 1, Ctemp =, Crelieable= 0.84

Se= 90 × 1 ×1 × 10.84

= 75.6 MPa

So that the selected material the capacity to resist the failure due to the shear stress, crushing stress and to torsion.

(Finite Element Analysis Results for inner drum mentioned at Appendix A-4)

4.5.12. The stationary Bicycle frame structure

The bicycle frame is the main load bearing structure of the bicycle and in order to select materials for its construction or to make an efficient frame design the loads carried by the various components must be evaluated under realistic conditions. It is important to determine which components are in tension, which in compression, which experience bending forces, and what the magnitude of the forces and moments on the components are under normal use conditions. This is done by considering the structure as made of tubes with pin-joints rather than welds. The pin joint does not allow a moment transfer from one tube to another and so they are all either in tension or compression. When the system is in static equilibrium under the applied forces, each element must experience zero net force and zero net moment.

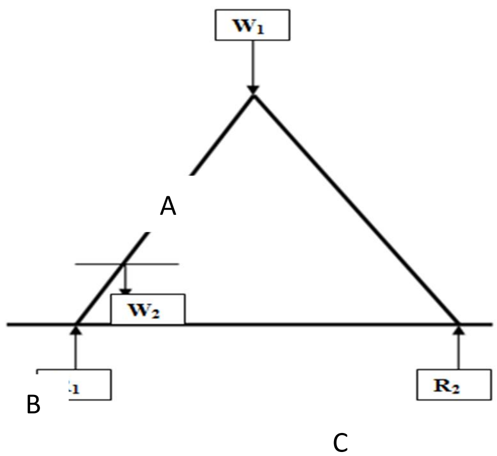


Figure 4: 24 Free body diagram of bicycle frame

The rider produces a force W_1 on the seat and W_2 on the pedals (the weight of the bike is small compared to the rider and is lumped with these forces). Reaction forces at the wheel hubs must balance these weights so that:

$$(R_1+R_2) = (W_1+W_2) \quad (40)$$

Also the moments

(Force x Distance) about the front axle must be zero so that:

$$(W_2 \times L_2) + (W_1 \times L_1) = (R_2 \times L_3) \quad (41)$$

For the traditional bicycle frame, the rear triangle that supports the back wheel is stable if it is treated as a pinned structure. The section bounded by the top, seat, down, and head tubes are not stable in this approximation and depend upon the welded joints being able to resist moments. With the frame dimensions shown in the diagram and considering a rider with a weight of 667 N

Take W_1 as 533.6N and W_2 as 133.4N and use a moment balance about the point B

(133.4N x 87.7mm) + (533.6 N x293.8mm) = (R_2x 483.2mm)

11,699.18 N-mm + 15, 6771.68N-mm = 483.2R_2 mm

R_2 = 348.65N

Using the vertical force balance:
(R_1 +348.65N) = (533.6N+ 133.4N)

= 667N-348.65N

so that: **R_1 =** 318.35N

All the forces acting on the structure are now known and the loads carried by the tubes can be determined.

This location is in equilibrium under the forces F_1 in the seat stay, F_2 in the chain stay, and the reaction force R_2 (348.65N). These forces must be resolved in the horizontal and vertical directions, and equations can then be written for the force balance in each of these directions.

The horizontal force balance gives:

$F_2\cos(11.5^0) = F_1\cos(61.5^0)$ or

$F_1 = 2.05\ F_2$

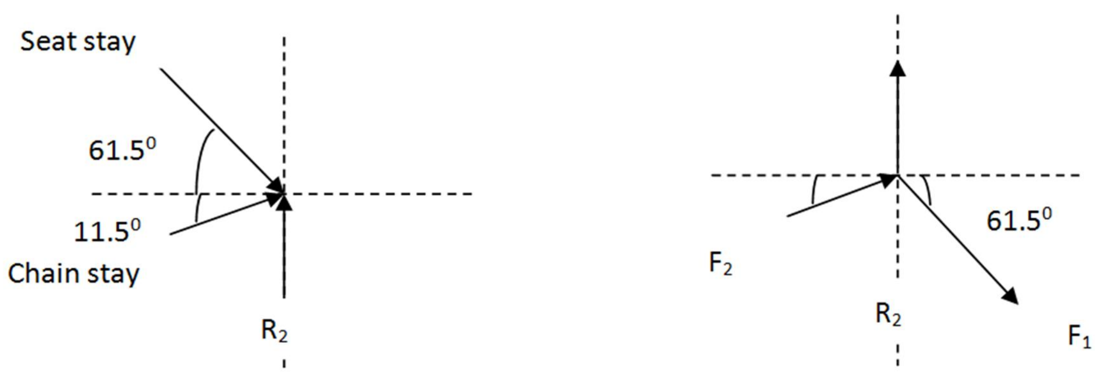


Figure 4: 25 Horizontal and vertical forces of R2

From the vertical balance:

$F_2 \sin(11.5) + F_1 \sin(61.5) = 348.65N$

$F_2 (0.199) + F_1 (0.88) = 348.65N$

Substituting F_1 in terms of F_2 gives:

$0.199 F_2 + (2.05 \times 0.88) F_2 = 348.65N$

$1.9989 F_2 = 348.65N$

$\mathbf{F_2} = 174.4N$

Substituting this value in the horizontal balance equation gives:

$\mathbf{F_1} = 2.05 F_2$

$= 2.05 \times 174.4N$

$\mathbf{F_1} = 357.52N$

The direction of these forces shows that the chain stay is in tension and the seat stay in compression.

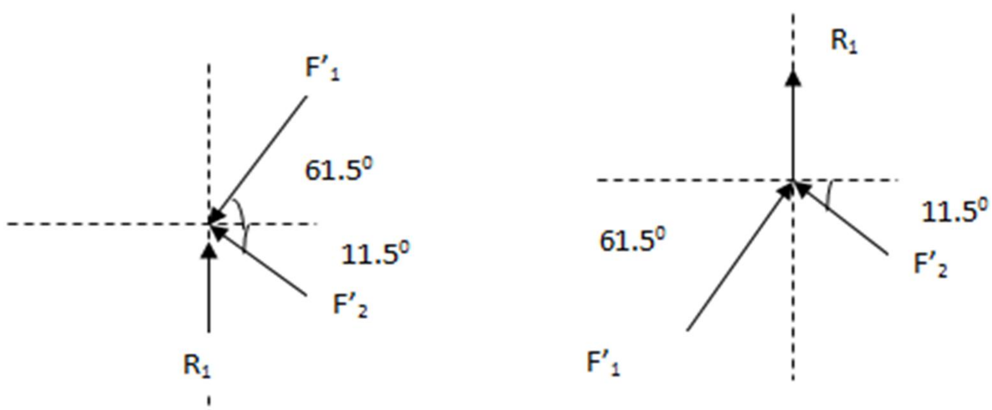


Figure 4:26 Horizontal and vertical forces of R1

This location is in equilibrium under the forces F'_1 in the seat stay, F'_2 in the chain stay, and the reaction force R_1 (318.35N). These forces must be resolved in the horizontal and vertical directions, and equations can then be written for the force balance in each of these directions.

The horizontal force balance gives:

$F'_2\cos(11.5^0) = F'_1\cos(61.5^0)$ or

$F_1 = 2.05\ F_2$

The vertical force balance:

$F'_2 \sin(11.5) + F'_1 \sin(61.5) = 318.35N$

$F_2 (0.199) + F_1 (0.88) = 318.35N$

F'_2 = 159.3Nand **F'_1 =** 326.5N

Out of plane forces acting on a bicycle frame can be large and must be taken into account in frame design. The diagram represents the seat tube and bottom bracket with a force of 667 N being applied to the pedal. The line of action of this force is 127mm out of the plane of the frame. Assuming that the moment is supported by the seat tube, the maximum stress due to the pedaling force can be estimated. The bending moment in the tube, M = (667 N x127mm), and if the geometric moment of inertia of the tube is computed the stress in the tube wall can be estimated.

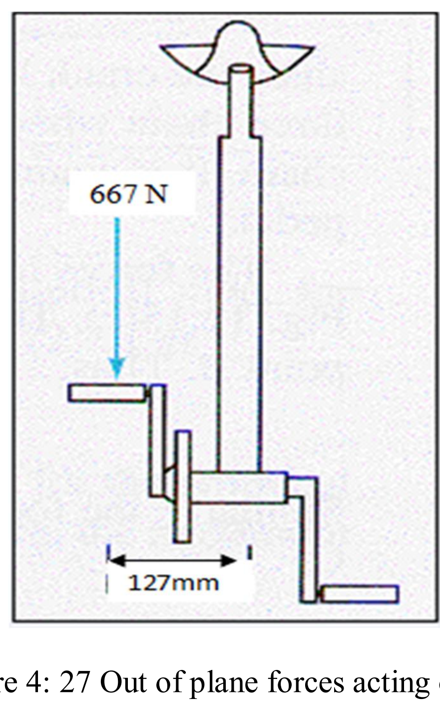


Figure 4: 27 Out of plane forces acting on a bicycle frame

Taking a circular steel tube of diameter, D = 30mm = 0.03m, and a wall thickness of 2.5mm = 0.0025m, gives an inner tube diameter, d, of 0.0275mm.

The geometric moment of inertia:

$I = (\pi/64)\{D^4 - d^4\} = (0.049)\{0.00000081m^4 - 0.000000572\ m^4\} = 117 \times 10^{-6}$

The maximum wall stress:

$\sigma = [M\ D/2\ I] = [84.71 \times 0.03/\ 2 \times 117 \times 10\text{-}6\ ] = 10{,}860.3\ N/m2$

This is much less than the yield stress of the material (Carbon steel SAE 1025 annealed 370MPa).

(Finite Element Analysis Results for stationery bic frame mentioned at Appendix A-5)

4.5.12 Waste Water Filtration

This system has two major objectives; Purifying the drained water from the washing machine to reuse and keeping the machine stable during high rpm. Thus the waste water passes two stages of filtration processes:

4.5.12.1 Rapid filters

Flocculation

Flocculation is a process of rapid filtration of waste water by using elements such as Aluminium (Al) or calcium carbonate can be used in a process called flocculation. Flocculation is a process where colloids come out of suspension in a solute, such as water. Aluminium, which is positively charged attracts negatively charged dirt, bacteria and viruses, all this then sinks to the bottom (Sedimentation) and can then be filtered out. [23]

This process is done in the flocculation chamber which has two compartments; in the first compartment the drained waste water mixed with the flocculation chemical, it takes 8 minutes for 5L waste water to sediment almost all of the impurities and suspended particles, so the filtered pure water makes a layer with the sedimented residue.

When the gate to the second compartment open pure water from the first compartment passes through the filtration wall and stored in to the second chamber. This process gives an advantage on fast filtration and prevents most of the impurities to inter the sand filtration system which tend to close the porosities and a need for frequent cleaning of the entire system.

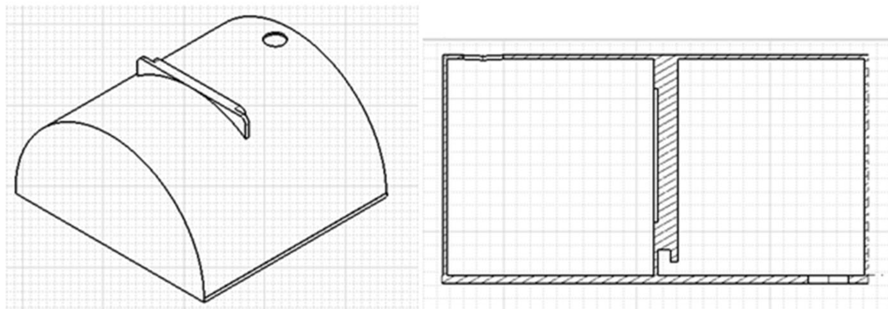


Figure 4: 28 The diagram of flocculation camber

4.5.12.2 Slow sand filter

Slow sand filters consist of a layer of fine grain sand supported on a layer of gravel, the topmost layer consisting of a biofilm. When flow rate becomes too low, the filter has to be cleaned by emptying the filter and scraping off the top layer of sand. Because slow sand filters are slow, the water needs a long time to get through the sand and capacity is limited, although they are relatively easy to manage.

4.5.12.3 Slow sand filter container calculation

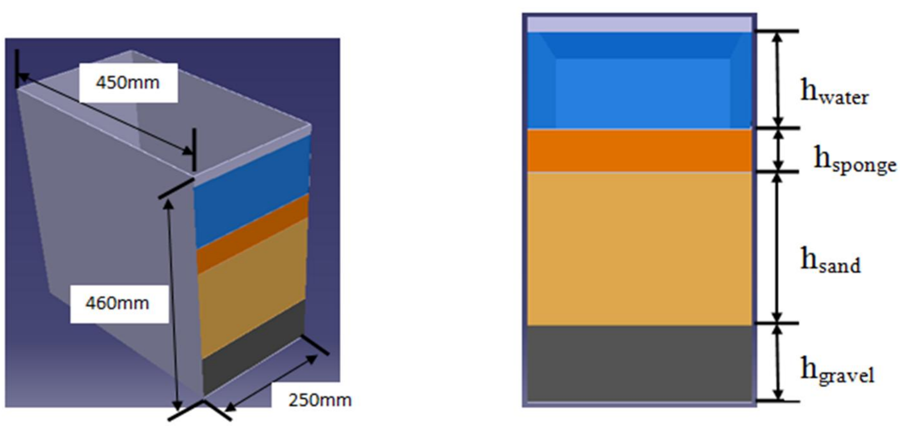


Figure 4: 29 Biosand water filter tank

Total volume of the tanker (V_T) = L x W x H = 0.45m x 0.25m x 0.46m = 0.5175 m^3

The volume of water to be filtered (V_W) = 13L = 0.013m^3

The height of water to be filtered (h_{water}) = V_W/A_w = 0.013m^3/ 0.113m^2 = 0.115m

The mass of water to be filtered (m_W) = ρ_W x V_W = 1021.98 Kg/m^3 x 0.013m^3 = 13.28 Kg

The volume of sponge material (V_{sp}) = 0.45m x 0.25m x 0.05m = 0.005625m^3

The height of the sponge (h_{spong}) = 0.05m

The volume of the sand (V_{sa}) = 0.45m x 0.25m x 0.181m = 0.02m^3

The mass of the sand (m_{Sa}) = ρ_{sa} x V_{sa}= 1441.5Kg/m^3 x 0.02m^3 = 28.83 Kg

The volume of the gravel (V_g) = 0.45m x 0.25m x 0.0.091m = 0.010m^3

The mass of the gravel (m_g) = ρ_g x V_g= 1281.5Kg/m^3 x 0.010m^3= 12.82Kg

Then total mass of the waste water filtration (M_T)

= mass of container + mass of water + mass of sand + mass of gravel

= 3.769Kg + 13.28Kg + 28.83Kg + 12.82Kg

4.5.13 Ultrasonic Cleaning

4.5.13.1 Introduction

Ultrasonic cleaning which is common in industrial application offers several advantages over conventional methods. Ultrasonic waves generate and evenly distribute cavitations implosions in a liquid medium. The released energies reach and penetrate deep into crevices, blind holes, and areas that are inaccessible by other cleaning methods. The removal of contaminants is consistent and uniform regardless the complexity and geometry of the part being cleaned.

This project tries to introduce the use of ultrasonic energy for the laundry purpose, the vibrations emitted from transducers are powerful enough to clean and deodorize a small load of laundry, making the process of washing delicate easier and less damaging than ever before. The ultrasonic device is designed to be attached at the bottom of the outer drum ,water along with detergent to deep-clean textiles all the way through, instead of just rubbing the surface like mechanical washers.

The device can't rinse or spin clothes; this is the reason why it combined with the mechanical drive systems of *Manual Operation* washing machine. Sound waves travel through the water and form microscopic high-pressure bubbles, which implode, creating millions of micro-jet liquid streams that blast dirt out of the fabric. The process takes 3-40 minutes depend up on the laundry load and uses about 80 times less energy than a standard washing machine.

4.5.13.2 Ultrasonic Power

To determine adequate ultrasonic power in a tank both the wattage per square inch of the transducer-radiating surface and the cubic volume measurement of the liquid being ultrasonically activated must know. For water at ambient temperature the minimum amount of energy needed to achieve cavitation was estimated to be 0.3 to 0.5 watts per square centimeter for the transducer-radiating surface operating at 40 KHz. What this means is we must supply adequate power to the transducer to initiate cavitation. Cavitation is the scrubbing force in ultrasonic cleaning. [24]

The ultrasonic tank bottom measures L= 200mm (20cm) by 150mm (15cm) this would give a radiating surface of $300cm^2$

Assume that for$1cm^2$ area a power of 0.5 W is required; therefore, the total required power $300cm^2$ x 0.5W = 150W.

2. A standard volume intensity for ultrasonic tank = $0.022W/cm^3$

The operating volume of the tanker = 20cm x 15cm x 36cm = $10{,}800cm^3$

The required amount of power for this volume = $10{,}800cm^3$ x $0.022W/cm^3$ = 237.6W

Therefore the maximum required power to the ultrasonic will be 250W

4.5.13.3. Specification to select the transducer

Table 4: 1 Specification of transducer **Source:** F. John Fuchs, 2012, Ultrasonic Cleaning Fundamental Theory and Application

No	Specification	Units
1	Frequency	28 $\pm$ 0.5 KHz – 40 KHz / piece
2	Capacitance	5500$\pm$PF
3	Resonant resistance	$\leq 25\Omega$
4	Maximum input power	50W
5	Minimum radiating surface diameter	ᴓ97mm
6	Ceramic diameter	ᴓ45mm
7	Connection torque	25 N.m
8	Height	68mm
9	Weight	639g/piece
10	Others	
	• Sandwich type • High mechanical quality • High electro-acoustic efficiency • Low heat generation • The mechanical connection of the piezoelectric element assures a large amplitude output • Homogeneous sounding board • The piezoelectric ceramic should be polished with sandblasting to obtain the required surface finish(surface roughness) • The faces of both mass (M1) and (M2) should be polished with grinding miller high straightness and flatness required. • The insulation tube made from Teflon tube without gap, thicker wall reliable, will insulative	

CHAPTER FIVE

MANUFACTRING PROCESS, ASSEMBELY AND MAINTENANCE

5.1 Introduction

In today's environment, manufacturing businesses are facing fierce competition and operating in changing markets. Customer demands for higher quality products at lower costs and shorter product lifecycles are putting extra pressure on the product introduction process. Cost and quality are essentially designed into products in the early stages of this process. The designer has the great responsibility of ensuring that the product will conform to customer requirements; comply with specification, and ensuring quality in every aspect of the product, including its manufacture and assembly, all within compressed time-scales. The company that waits until the product is at the end of the line to measure its conformity, performance and cost will not be competitive. The need to understand and quantify the consequences of design decisions on product manufacture and quality has never been greater.[25]

The various activities carried out by the process planer shows the relationship and application of all these activities in taking a component from design to manufacturing will be demonstrated through the use of a detail worked assignment. The drawing for a component will be given along with a basic product design specification (PDS). The drawing and other available data will be analyzed and interpreted. This will form the basis for the material evaluation and the subsequent selection of manufacturing processes, machines, tooling, and work holding devices and setting of appropriate processing parameters. The specification of various QA methods will also be detailed

Documenting all of the decisions with regards to how the component is to be made is the next step. All of the above information will be used to produce a detailed routing sheet for the product. A detailed operation list will also be produced as will a tooling list. Finally the cost of the component will be considered based on the documented process plan.

5.2 Preconditions

As mentioned in section 1.3 on this paper the general objective of the project is to design and manufacture Manual Operation cloth washing machine. The machine which designed and fabricated should also be transferable to small and micro enterprises as stated on the significance of the project at section 1.4. The entire manufacturing process proposed ought to consider the background and capacity of those small and micro enterprises that finally produces the machine. Most of small and micro enterprises in the country can be categorized under Job shop production category it means low volume production with great product variety. The lot sizes are small. They mostly use conventional machines with Product layout: material moves a long work stations and implement traditional methods of production.

5.3 Process selection strategy

In considering alternative design solutions for cost and quality, it is necessary to explore candidate materials, geometries and tolerances, etc., against possible manufacturing routes. This requires some means of selecting appropriate processes and estimating the costs of manufacture early on in product development, across a whole range of options.

In this process a set of so-called manufacturing Process Information Maps (PRIMAs) have been developed. In a standard format for each process, the PRIMAs present knowledge and data on areas including material suitability, design considerations, quality issues, economics and process fundamentals and process variants. Techniques are put forward that can be used to estimate the costs of component manufacture and assembly for concept designs.

5.3.1 PRIMAs (Process Information Maps)

Each PRIMA is divided into seven categories, as listed and defined below, covering the characteristics and capabilities of the process:

- Process description: an explanation of the fundamentals of the process together with a diagrammatic representation of its operation and a finished part.
- Materials: a description of the materials currently suitable for the given process.
- Process variations: a description of any variations of the basic process and any special points related to those variations.
- Economic considerations: a list of several important points including production rate, minimum production quantity, tooling costs, labor costs, lead times, and any other points which may be of specific relevance to the process.

Typical applications: a list of components or assemblies that have been successfully manufactured or fabricated using the process.

- Design aspects: any points, opportunities or limitations that are relevant to the design of the part as well as standard information on minimum section, size range and general configuration.
- Quality issues: standard information includes a process capability chart (where relevant), typical surface roughness and detail, as well as any information on common process faults.

A key feature of the PRIMAs is the inclusion of process capability charts for the majority of the manufacturing processes [25].

5.3.2 Manufacturing process selection

Manufacturing processes represent the main shape generating methods such as casting, molding, forming and material removal processes.

The purpose of this section is to provide a guide for the selection of the manufacturing processes that may be suitable candidates for a component. The manufacturing process selection strategy is

- Given below, but points 4, 5 and 6 apply to all selection strategies:
- Obtain an estimate of the annual production quantity.
- Choose a material type to satisfy the PDS.
- Refer to Appendix D to select candidate PRIMAs.
- Consider each PRIMA against the engineering and economic requirements such as:
- Understand the process and its variations
- Consider the material compatibility
- Assess conformance of component concept with design rules
- Compare tolerance and surface finish requirements with process capability data.
- Consider the economic positioning of the process and obtain component cost estimates for alternatives.
- Review the selected manufacturing process against business requirements.

Finally based on the above principles manufactring process were selected and operation list prepared for each components of the *Manual Operation* washing machine. Mention such procdure for each and every manfactred parts of the machine is repetition, so particularly whole procedure was shown for the following one component and consider that it followed to others; however, operation plane to all parts was mantioned.

5.4 Bearing House- 1

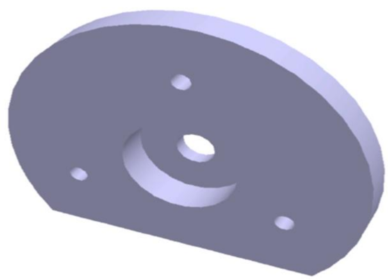


Figure 5:1 Bearing house 1

5.4.1 Background

- The component for manufacturing is a Bearing house. The PDS has also been supplied by the design and is detailed in section 5.4.2. This component is required in a unit quantity for Assume that the component will be made in batches of 45.

5.4.2 Product design specification

Weight- as material costs were one of the main factors, the component should be designed in such a way as to make it as light as possible and thus use little material as possible.

Dimensions- as illustrated in Drg. No part 1.7 (see Appendix-E).

Assembly- on-site assembly using bolts

Condition of use- there are no adverse conditions or substances to be considered. The main consideration is the shearing force acting on the bolts, which has caused problems. It is estimated that this force is approximately 2.345 KN. A factor of safety (FOS) of 2 should be used for any relevant calculations.

Ergonomics- these are specified elsewhere but in summary are:

- Dimensions
- Weight

Appearance (aesthetics)the product should look as symmetrical as is physically possible and gives the impression of precision and efficiency, with some continuity of profile. The surface finish and dimensional tolerance specifications (unless stated on the drawing) are given in table 5.3

Reliability and life the component itself should be free from defects and cope with the operating conditions and is expected to last for the useful lifetime of the machine.

After sales service although the Bering house 1 should be fault free, the belt and other related components may require servicing and therefore access to these will be required. Therefore, the bolting arrangement should incorporate standard parts, thus avoiding the need for any special tooling.

5.4.3 Drawing Interpretation and Material Evaluation

The material has been specified as Aluminum alloy. The detail drawing for the component is given in fig.5.1

Table5: 1 Specification of transducer

Feature	Surface finish(µm)	Tolerance (mm)
General	12.5	±0.5
Holes	1.6	±0.1
Bothe faces	0.8	±0.1
35mm bore	0.1	+0.02

5.4.4. Material Evaluation

The material specified is Aluminum alloy.

From the PDS, there are a number of particularly important criteria to be considered for the material to be used. The attributes that the material must exhibit are:

- Lightweight
- Hard wearing
- Low in cost
- Good Cast ability
- Excellent Machinability

5.4.5 Geometric Analysis

Considering the geometry of the part with the most appropriate classification is (a round geometry that is irregular or complex) this gives an essential list of candidate process of any of the casting process listed, hot forging ,turning ,grinding , honing and lapping on these ,grinding, honing lapping are essentially finished process and can be discounted in terms the formation of initial geometry although the remaining process may be possible candidates the fact that the material has already been the specified narrows the possible candidates further in this case quite obviously a casting process for forming the initial geometry.

5.4.6 Manufacturing Considerations

The manufacturing considerations are basically the process parameters indicated within the drawing .in this instance the critical process parameters are:

- The ø35mmbore cannot deviate from the nominal size by more than+0.02mm.
- The ø 35 diameter bore must also be perpendicular to the flange face with in±0.1mm tolerance zone
- The ø35mm bores must be machined to a surface finish of 0.1µm
- The flange faces must be machined to a surface finish of 0.8µm
- All holes must not deviate by more than±0.01mmof the nominal size
- All holes must have a surface finish of 0.1 µm

- All chamfers are $1X45^0$ unless otherwise stated
- The general dimensional tolerance is ±0.5mm
- The general surface finish is 12.5 µm
- General manufacturing information also included is the batch size of 45 and the material is Aluminium as previously identified.

5.4 7 Process selection and sequencing

In selecting a suitable manufacturing processes there is a number of considerations .the first is to insure that the process selected can actually produce the part to the design specifications with regards to both surface finish and dimensional accuracy. The next most important consideration is ensuring the process is capable of producing the part in the volume required economically .that is 45 batches per month. After this the compatibility of the process with the material selected .In this case Aluminium must be determined. Finally the cost of each process must be considered.

5.4 7.1 Critical Processing Factors

Correlating the above information, the initial process required must:

- Be suitable for use with Aluminium.
- Be able to meet the general dimensional tolerance of ±0.5mm
- Be able to meet the general surface specification of 12.5mm
- Be able to economically produce batches of 45
- Be able to meet the specific dimensional and geometric tolerances stated on the drawing

From the above list it is important that the initial process meets these requirements, however the last requirement less important as it has already been specified on the drawing that machining must be carried out therefore some of specific and dimensional geometric tolerances will be meet through secondary processing, from this it is quite clear that the initial processing will be casting followed by machining.

5.4.7.2 Consult Process Tables

Casting process

The surface finish specification in the PDS stated that the general tolerance was 12.5µm while the flange were 0.8µm The PDs also detailed the dimensional tolerance as±0.5mm in general with flange face to be±0.1mm holes to be 0.1 and the ø35mm bore to be+0.02mmusing these as the initial criteria for selection it can be seen from the above table sand casting can be meet the specification, can also satisfy the production volume.

Table 5:2 Foundry process capabilities

Process	Weight (Kg)	Typical Tolerance(mm)	Surface Finish (µm)	EOQ	Production rate per hour
Sand Casting	1-50	±1.0	3.2-25	<50	1-25
Investment Casting	0.1-100	±0.05	0.4-3.2	100-500	1-200
Impression Forging	0.1-100	±0.5	1.0-25	100-500	10-200
Open Die Forging	0.1-500	±0.5	3.2-25	<100	1-30

Machining Process

Machining process is already specified for ø 35mm bore and it is a case of consulting the process selection tables to determine the suitable process. For the desired geometry milling or turning would normally suffice. However, as stated in section 5.4.7.1 the combination of dimensional and geometric accuracy requires a precession processing terms of these factors grinding is the most suitable process. Machining is also required for the surface finish of the flange face depending on the other process used and the sequence of operations either milling or turning suitable. Drilling is the obvious choice for the production of the holes. As this will meet the required surface finish and dimensional accuracy the process to be used will depend on the formation of the aluminum billet. The slot with the dimension 15x 6.5 made during casting and of Drilling will be required if the billet is cast without the holes .However if the holes included in the initial casting. Then finishing of the holes will be required using reaming, in this case it assumed that drilling will be required. Finally regards the accuracy for the holes a jig will be required if carried out with a standard drill press.

Process Sequencing

1.Produces initial geometry with sand casting

2. Machine the flange faces by turning

3. Machine holes by drilling

4. Machines bore by grinding

The next step is to identify the specific production equipment to be use for each process and then sequence the operations for each individual piece of equipment.

5.4.9 Power or Force Analysis

Turning

In determining the power requirement for the turning operation, a number of assumptions will be made. The first is the maximum depth of cut will equivalent to that of the marching allowance on the casting. This has been specified as 2mm. Although a cut of this magnitude is unlikely to result in the required surface finish, using it will result in the maximum power requirement for any given machine. Similarly the maximum cutting seed and value for specific cutting force will be used for the same reason and these are a rough speed of 100m and 1500N(from Manual) , respectively. One farther assumption is that the maximum width of contact between cutting tool and component is 1mm. The power requirements for the operation are calculated as follows:

F_c =?	$F_c = W\ d_cK_c$
W =1mm	F_c = 1X2X1500
d_c= 2mm	F_c = <u>1700N</u>
$K_c = 850\ Nmm^{-2}$	
P_m =?	P_m = Fc V
F_c= 1700N	P_m = 1700X1.67
$V= 1.67\ ms^{-1}$	P_m = <u>2839W</u>

Drilling

Again, a number of assumptions are made in calculation the power requirement for the drilling operation. The depth of cut 0.3mm based on a feed rate F_r of $0.25mmrev^{-1}$ the cutting speed is taken as $210mmin^{-1}$ based on the use of carbide tooling, which gives a value of 3.5 ms-1from manual. Finally, the maximum contact area between the cutting tool and the component is assumed to be the same as the depth of cut, that is, 0.3mm. The power requirements for the operation are calculated as follows:

F_c =? $F_c = W\ d_c K_c$

W =0.3mm $F_c = 0.3X0.3X1500$

d_c= 0.3mm $F_c = \underline{135N}$

$K_c = 1500\ Nmm^{-2}$

P_m =? $P_m = Fc\ V$

F_c= 135N $P_m = 135X3.5$

$V= 3.5\ ms^{-1}$ $P_m = \underline{472.5W}$

On the basis of this crude power calculation, both drills can carry out the operation. However, the CNC drill is discounted on the basis that the power it has is far greater than required and using it would appear to offer no great advantage.The capability and operational analysis confirm the initial machine selections as the final selection .These are summarized in table 5.4.

Table 5:3 Final machine selection

Operation	Work Centre	Machine
Cast Initial Geometry	Foundry	Sand Casting Line
Turn Bothe Face	Machine Shop	Manual Lathe 2
Drill Holes And Taping	Machine Shop	Drill Press
Grind Bores	Machine Shop	Internal Grinding

5.4.10 Setting the Process Parameter

5.4.10.1 General Information

The process parameter to be calculated are the speed, feeds and times for all operation. These will be calculated using the formula. In general there will be lower cutting speed and higher feeds used for roughing cuts and vice versa for finishing cuts. Finally all calculation will be made on the basis that carbide tooling is being used in line with the general recommendation.

5.4.10.2 Manual lathe 2

Operation 1: rough machine face leaving 0.2mm stock

I. Speed- a surface speed of 60 m min $^{-1}$ has been selected from Manual for roughing the flange face of the part.

D =?	$D = \frac{d1+d2}{2}$
d_1 =110mm	$D = \frac{110+60}{2}$
d_2 =60 mm	D = $\underline{\underline{85mm}}$
V_c = 60 m min^{-1}	$V_c = \frac{\pi DN}{1000}$
D = 85mm	$N = \frac{1000Vc}{\pi D} = \frac{1000x60}{3.14X85}$
N =?	N = $\underline{\underline{225\ rpm}}$

Feed- a feed rate of 1 mm rev^{-1}has been selected from table for roughing the flange faces of the pulley.

f_m = ?	$f_m = f_r N$
f_r = 1mm rev^{-1}	f_m = 1x225
N = 225 rpm	f_m = 225 mm min^{-1}= 0.225 m min^{-1}

Time – using the speeds and feeds calculated in (I) and (II) the time for the operation will be calculated.

T=?	$T = \frac{\frac{D}{2}+A}{frN}$
D= 110mm	$T= \frac{(110/2)+5}{1x225}$
A= 5mm	$\underline{\underline{T= 0.27\ min.}}$
f_r = 1mm rev^{-1}	
N = 225 rpm	since there are two faces the total time will be $\underline{\underline{0.54min.}}$

Operation 2: Finish machine face

Speed –a surface speed of 100m min^{-1}has been selected from table for finishing the flange face of the Bering house 1.

V_c =160 m min^{-1} $V_c=\frac{\pi DN}{1000}$

D =85 mm $N=\frac{1000Vc}{\pi D}$

$N=\frac{1000X160}{3.14X85}$

N=? <u>N=600 rpm</u>

Feed- a feed rate of 0.1 mm/rev^{-1}has been select from table for finishing the flange face of the Bering house 1.

f_m = ? $f_m = f_rN$

f_r = 0.1mm rev^{-1} f_m = 0.1x600

N = 600 rpm f_m = 60 mm min^{-1}= 0.06 m min^{-1}

Time – using the speeds and feeds calculated in (I) and (II) the time for the operation will be calculated.

T=? $T = \frac{\frac{D}{2}+A}{frN}$

D= 110mm $T=\frac{(55/2)+5}{0.1x600}$

A= 5mm <u>T= 1min.</u>

f_r = 0.1mm rev^{-1}

N = 600 rpm since there are two faces the total time will be <u>2min.</u>

5.4.10.3 Drill Press

Operation 1: Drilling ⌀ 6mm holes

Speeds – using carbide tooling the maximum surface speed could be $110ms^{-1}$from Manual. This can be used to calculate the spindle speed.

V_c =110 m min^{-1} $V_c=\frac{\pi DN}{1000}$

D =6 mm $N=\frac{1000Vc}{\pi D}$

$N=\frac{1000X210}{3.14X6}$

N=? <u>N=5839 rpm</u>

This is unachievable, as the maximum spindle speed for the drill press is 600 rpm. Therefore, this will be the spindle speed.

Feed- a feed rate of 0.25 mm/rev^{-1} for ⌀6 has been select from table for drilling the holes of the pulley.

$f_m = ?$	$f_m = f_r N$
$f_r = 0.25$mm rev^{-1}	$f_m = 0.25x600$
N = 600 rpm	$f_m = 150$ mm min^{-1}= 0.15 m min^{-1}

Time – the speeds and feeds determine above will be used to determine the operation time. The allowance is normally calculated from:

$$A=\sqrt{\mathbf{Dd}}$$

Where, D is the tool diameter and d the depth of cut.

In this instance, the depth of cut would be the minimum allowable, which is 0.3 mm. this would give an allowance of 1.5. However, as a hole will be drilled four times, additional time will be incurred.

T=?	$T=\frac{L+2A}{frN}$
L= 12mm	$T=\frac{12+2(1.5)}{0.25X600}$
A= 1.5mm	$\underline{\underline{T= 0.1 \text{ min.}}}$
f_r= 0.25mm rev^{-1}	
N= 600 rpm	

The total time for drilling the three holes will be 0.30 min. In addition, there will be travel time (2sec. /hole) and this has been estimated at 6sec.which brings the total time for the operation to 0.31 min.

5.4.10.4 Internal grinding

Operation 1: Rough machine ⌀35mm bore

The spindle speed can be taken as 955rpm.

Therefore the feed rate can be taken as $f_m = 955$ mm min^{-1}= 0.955 m min^{-1}

Time – using the above the time for the roughing can be calculated.

T=? $T = \frac{L+2A}{frN}$

L= 12mm $T = \frac{12+2(10.5)}{1X955}$

A= 10.5mm T= 0.035 min.

f_r= 1 mm rev^{-1}

N= 955 rpm

As there are three roughing cuts, the total time for machining would be 0.105 min.

Operation 2: Finish machine ⌀35mm bore

The spindle speed can be taken as 2500 rpm.

Therefore, the feed rate can be taken as f_m = 250 mm min^{-1}= 0.25 m min^{-1}

Time – using the above the time for the finishing can be calculated.

T=? $T = \frac{L+2A}{frN}$

L= 12mm $T = \frac{12+2(10.5)}{0.1X2500}$

A= 10.5mm T= 0.132 min.

f_r= 0.1 mm rev^{-1}

N= 2500 rpm

Table 5:4 Summary of process parameters

Machine	Operations	Speed (rpm)	Feed (mm min^{-1})	Set-up time (min.)	Operation time (min.)
Manual Lathe 2	Rough machine faces	225	225	2.000	0.540
	Finish machine faces	600	60	-	2.000
Drill press	Drill 3X ⌀6mm holes	600	150	2.000	0.310
Internal grinding	Rough grind ⌀35mm bore	955	955	2.000	0.105
	Finish grind ⌀35mm bore	2500	250	-	0.132

5.4.11 Selection of quality assurance methods

5.4.11.1 Type of Inspection

The basic decision is whether to carry out variable or attribute inspection. In this case, which of these is the most appropriate can only be decided after location have been determined.

5.4.11.2 Inspection location

- The manufacturer of this component will require process inspection at two crucial points in this process plan.
- The first is after the initial billet, provided there is enough confidence in the capability of sand cast process to produce the component to the required dimensional and geometrical specifications.
- the idea of this inspection would be to collect information on typical casting defect such as identification of inclusion, incomplete casting, porosity and surface marks this would prevent defective casting being processed further, which is the main of process inspection.
- The anther major area is a concern is obviously the grinding of the bores due to the combination of tight dimensional and geometric tolerances and the surface finish.
- Appropriately designed limit gauge both the dimensional and geometry accuracy of the bores can be assessed. Again, if there is confidence in the capability of the grinding process, this type of attribute inspection should be sufficient.
- In summery process inspection based on attribute should be carried out after both the casting and grinding processes. There may also be need for output or final inspection depending on the customer specification and the term of contract.

5.4.11.3 Inspection methods

The sample sizes for attributes tend to be much larger than for variables. In this case, the frequency will be per batch size is so small the inspection method will be 100 per cent inspection for both the attribute studies that is for both casting and grinding. It might also be worthwhile to carry out first-off inspection at the begging of every batch depending on the frequency of set-up for the batch.

5.4.11.4 Measurement instruments/methods

- For the attribute inspection for the cast process a simple visual inspection suffice depending on the characteristics under consideration. However porosity or inclusions are major characteristics under consideration, non-distractive testing such as ultrasound tests may be required to detect such defects.

- For the inspection of the bores, appropriate designed limit gages for Ø35mm bores require to assess both dimensional and geometric accuracy. Depending on the requirements for final inspection, this may require an assessment of surface finish for the bores.

5.4.12 Documenting the process plan

Using the information generated in the various stages detailed in sections 5.4.1-5.4.11, the process plan can now be fully documented. The documentation in this instance will consist of a routing sheet, an operations list and a tooling list. It may also be the case that the speeds/feeds calculation sheet forms part of the total process planning documentation package. However, in this case specifying the speeds and feeds in the operations list is sufficient.

5.4.12.1 Routing Sheet

Table 5:5 Routing Sheet for Bearing House 1

<table>
<tr><td colspan="4">(Routing Sheet)</td></tr>
<tr><td colspan="2">Part name: Bearing House 1</td><td>Part no: 1. 7/16</td><td>Drg. No.: 1</td></tr>
<tr><td>Quantity: 45</td><td colspan="2">Mat: Aluminium</td><td>Planner: Yonas M.</td></tr>
<tr><td>Revision no.:</td><td>Date: 1/6/2016</td><td>Page 1 of 1</td><td>Order no.:</td></tr>
<tr><td>Op.no.</td><td>Description</td><td>Work Centre</td><td>Machine Tool</td></tr>
<tr><td>100</td><td>Casting initial geometry</td><td>Foundry</td><td>Sand casting line</td></tr>
<tr><td>200</td><td>Machine flange faces</td><td>Machine shop</td><td>Manual lathe 2</td></tr>
<tr><td>300</td><td>Drill Ø6mm holes</td><td>Machine shop</td><td>Drill press</td></tr>
<tr><td>500</td><td>Machine Ø35mm bore</td><td>Machine shop</td><td>Internal grinder</td></tr>
<tr><td>600</td><td>Finishing</td><td>Foundry</td><td>S.down and finishing</td></tr>
<tr><td>700</td><td>Final inspection</td><td>inspection</td><td>QA Department</td></tr>
</table>

5.4.12.2 Operations list

Table 5:6 Operation list for Bearing House 1

(Operations List)

Part name: Bearing House 1	Part no: 002/07	Drg. No.: 1

Revision no.:	Date: 1/06/2016	Page 1 of 1	Planner: Yonas M.

Op.no	Description	Machine tool	Tooling	Speed (Rev/min.)	Feed (mm/min)	Set-up Time (min.)	Op.time (min.)	Remark
110	Raw material	-	-	-	-	56.000	26.000	#mould
120	Melting	Furnace(cup	-	-	-	20.000#	27.000	preparation
		ola)	-	-	-	-	29.000	# pattern/sprue
130	Mould &pattern	Flask, sand	-	-	-	-	30.000	ass.
	preparation	mixer	-	-	-	-	10.000	-
140	Fill mould and cool	Fill/cooling						-
150	Remove casting	Shakedown						-
		And	-	-	-	-	10.000	-
		finishing						
160	Fettle/deburr	Shakedown						
		And	-	-	-	-	-	-
	Inspection	finishing						
170		Shakedown						
		And						
		finishing						Visual
210	Rough machining	Manual						inspection
	Flange faces	lathe 2		223	223	2.00	0.500	NDT
220	Finish machining		LH carbide					
	Flange faces		Turn tool LH	910	91	-	1.240	
			carbide					
310	Drill 3Xø6mm holes	Drill press	Turn tool	600	150	2.00	0.530	
			ø7.8mm					
			carbide					Tool for Manual
510	Rough m/c	Internal	Twist drill					lathe2
	ø35mmbore	grinding		955	955	2.000	0.099	
			ø20internal					
520		Internal	grinding					
	finish m/c	grinding	tool	2500	250	-	0.132	
	ø35mmbore							
530		-	ø20internal	-	-	-	2.000	
			grinding					
600	inspect bores	Shakedown	tool	-	-	-	10.000	
		And						
	finishing	finishing	limit gauges					Deburr and
		QA		-	-	-	-	Degrease
700	final inspection	department						
						-		Detail TBC by
	Total Time					**82.000**	**147**	QA deartment

5.4.12.3 Tooling list

Table 5:7 Tool list for Bearing House 1

(Tooling List)					
Page: 1/1	Planner: Yonas M			Partno.002/07	
Drg. No.: 1		Part: Bearing House 1		Material: Aluminium	
Op.no	Tool no.	Offset NO.	Comp. no.	Tool Description	Tool material
210	T112	05	NA	LH turn tool	Carbide insert
220	T112	05	NA	LH turn tool	Carbide insert
310	D110	NA	NA	⌀6 drill	tool steel
510	IG20	NA	NA	⌀20 internal grinding tool	Cubic boron nitride
520	IG20	NA	NA	⌀20 internal grinding tool	Cubic boron nitride

5.5 Operation plan for handle bar

It is one of the machine element used to handle the handle plate which give option to generat *Manual Operation* by hand craking . Since its size is maintioned in the drawing and it is manufactured from alloy still by using machining process.

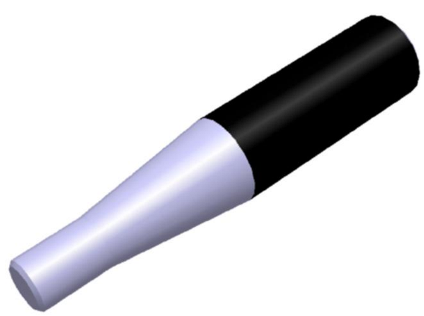


Figure 5: 2 Handle Bar

Table 5:8 Operation for handle bar

No.	Operation	Machine used	Tools & Equipment's used	Dimension
1	Sawing the bar to size	Power hacksaw	Venire caliper, steel rule	Ø =26mm L=124 mm
2	Face both side	lathe	carbide cutter & V. caliper	Ø =26mm L=22 mm
3	Center drilling	lathe	Center drill	Ø =26mm L=22 mm
4	Clamping b/n center	lathe	Lathe center, lathe dog	Ø =26mm L=122 mm
5	Turning	Lathe machine	Roughing, finishing side tool, profile tool for recess	Ø =24mm L=122 mm
6	Step turning from end of left side	Lathe machine	Carbide cutter Vernier caliper	Ø =14 mm L=20 mm
7	Taper turning from end of left side	Lathe machine	Carbide cutter Vernier caliper	Ø =24 mm L=60 mm
8	Step turning & chamfering, fillet	Lathe machine	Carbide cutter Vernier caliper	Ø =14 mm L=24 mm
9	Step turning the other side from the other end, fillet & chamfering.	Lathe machine	carbide cutter & V. caliper	Ø =30 mm L=22.5 mm
10	Boring at the center, threading	Lathe machine	Drill bit & thread taper ,V. caliper	Ø =6 mm D=16 mm
11	Milling a hole in other side.	Milling machine	Drill bit & V. caliper	W=7mm L=12mm

5.6 Operation plan for handle plate

It is one of the cranking component which connect the handle bar and supr gear for cracking purpose and made from alloy still steel plate with 4 mm thickness. It is precisely designed with an angle of 159.81o from the horizontal at both edges.

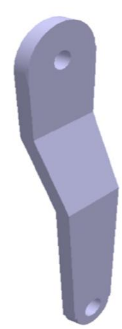


Figure 5:3 Handle Plate

Table 5:9 Operation plan handle plate

No.	Operation	Machine used	Tools & Equipment's used	Dimension
1	Measuring & lay outing, center punching One end	-	Steel rule, scriber, compass, center punch,	Wf= 25.92mm R=11.96mm L= 115.16 mm
2	Measuring & lay outing , center punching the other end	-	Steel rule, scriber, compass, center punch,	Wr=16 mm R=7mm L= 115.16 mm
3	chiseling to size	-	chisel, hammer	Wf= 25.92mm Wr=16mm L= 115.16 mm
4	Filling	Vise	Files, Vernier Caliper	Wf= 23.92mm Wr=14mm L= 113.16 mm
5	Drilling one side	Radial drilling	Drill bit Ø6 mm	Wf= 23.92mm L= 113.16 mm
6	Drilling other side	Radial drilling	Drill bit Ø7 mm	Wr=14mm L= 113.16 mm
7	Bending	Vise	Hammer	ϴ =159.81°
8	Chamfering & Finishing	Vise	File	All side

5.7 Operation plan for pinion gear

It is one of the machine element used to transmit motion from the driver gear to the pinion shaft through key.

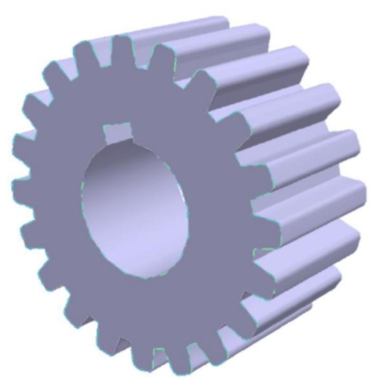


Figure 5: 4 Pinion

Table 5:10 Operation plan for pinion

No.	Operation	Machine used	Tools & Equipment's used
1	Measuring & cutting to size	Power hacksaw	Venire caliper, steel rule
2	Facing on one side	Lathe machine	carbide cutter & V. caliper
3	Turning and chamfering	Lathe machine	Carbide cutter Vernier caliper
4	Facing on the other side	Lathe machine	Carbide cutter Venire caliper
5	Turning a hub and chamfering	Lathe machine	Carbide cutter Venire caliper, micro meter,
6	Drilling	Lathe machine	Center drill, Drill bit And V. Caliper
7	Milling a key way	Milling machine	Slotting attachment with HSS cutte, micro meter
8	Mounting and aligning of the dividing head and the tailstock on horizontal milling machine.	Milling machine	Dividing head tailstock, dial indicator
9	Mounting of gear milling cutter on the cutter arbour and checking for concentric rurning.	Milling machine	Gear cutter module 2.5, 21....25 teeth cutter arbour
10	Clamping of work piece between centers and setting to the center of the cutter	Milling machine	Square , slip gauge , dial indicator,slip gauges, vernier gear tooth caliper r
11	Adjesting the secter arm of the indexing head (dividing head)	Milling machine	-
12	Setting of revelation and feed for milling	Milling machine	-
13	Cutter should shave slightly on the work piece	Milling machine	-
14	Withdrawing of work piece out of range of the cutter and lifting the milling table by the hight of the tooth	Milling machine	_
15	Milling of 1st tooth space	Milling machine	-
16	Withdrawing the workspace from the cut and turning the indexing handle by the tooth pitch, milling of the next tooth space.	Milling machine	_
17	Milling of remaining teeth	Milling machine	_

5.8 Operation plan for Gear

It is a machine element used to transmit power from gear shaft to the pinion.

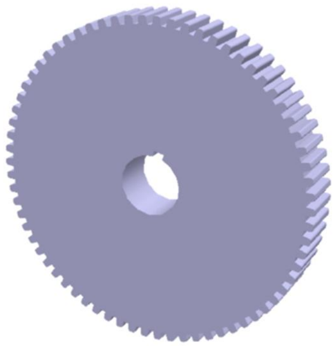


Figure 5: 5 Gear

Note: The operation plan table for the gear is similar to the operation plan of the pinion part mentioned above in terms of tools, machines required and their operation sequences except the size.

5.9 Operation plan for Outer dram

It is the main component of the *Manual Operation* close washing machine which is made from Almunium composite sheet as maintained in the drawing with 3 mm thickness. It is precisely designed with an angle of 360 ° . The main purpose of this outer dram is to create a water career tanker for the inner dram in washing process.

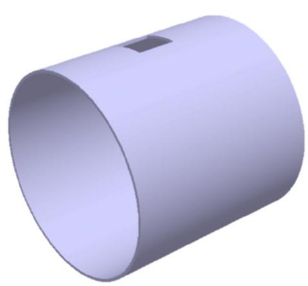


Figure 5:6 Outer Dram

Table 511 Operation plan for Outer dram

No.	Operation	Machine used	Tools & Equipment's used	Dimension
1	Measuring & lay outing,	-	Steel rule, scriber,	W= 40.3mm L= 40.3mm
2	Cutting to size	Hand shear	-	W= 40.3mm L= 40.3mm
3	center punching at the center	-	Steel rule, scriber, compass, center punch,	-
4	Measuring & lay outing from the center	-	Steel rule, scriber,	W=8MM L=8MM
5	Cutting the square opening at the center	-	Chisel, hammer	W=8MM L=8MM
6	Filling	-	Files, Vernier Caliper plastic mallet	W=8MM L=8MM
7	Rolling to size	Rolling	-	$\Theta = 360^o$
8	Joining by rivet	-	Rivet gun	-
9	Finishing & sealing	-	File, Selling material	All side

5.10 Operation plan of Shaft for Gear

It is a machine element used to transmit rotational force which is generated by hand cranking to Gear though key.

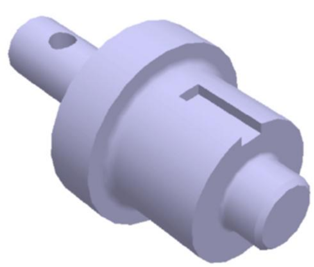


Figure 5:7 Shaft for Gear

Table 5:12 Operation plan of Shaft for Gear

No.	Operation	Machine used	Tools & Equipment's used	Dimension
1	Sawing the bar to size	Power hacksaw	Venire caliper, steel rule	Ø =44mm L=70.5 mm
2	Face both side	lathe	carbide cutter & V. caliper	Ø =44mm L=66.5 mm
3	Center drilling	lathe	Center drill	Ø =44mm L=66.5 mm
4	Clamping b/n center	lathe	Lathe center, lathe dog	Ø =44mm L=66.5 mm
5	Turning	Lathe machine	Roughing, finishing side tool, profile tool for recess	Ø =40mm L=66.5 mm
6	Step turning one side from the end	Lathe machine	Carbide cutter Vernier caliper	Ø =15 mm L=33.5 mm
7	Step turning & chamfering, fillet	Lathe machine	Carbide cutter Vernier caliper	Ø =14 mm L=24 mm
8	Step turning the other side from the other end, fillet & chamfering.	Lathe machine	carbide cutter & V. caliper	Ø =30 mm L=22.5 mm
9	Boring at the center, threading	Lathe machine	Drill bit & thread taper ,V. caliper	Ø =6 mm D=16 mm
10	Milling a hole in other side.	Milling machine	Drill bit & V. caliper	W=7mm L=12mm

5.11 Operation plan of Shaft for pinion

It is a machine element used to transmit rotational force from the pinion to the iner dram though the key.

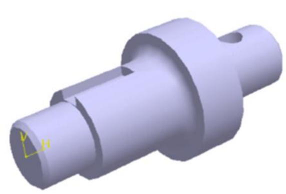


Figure 5: 8 Shaft for pinion

Note: The operation plan table of shaft for pinion is similar to the operation plan of shaft for gear part mentioned above interms of tools, machines required and their operation sequences except the size.

5.12 Operation plan for sprocket shaft

It is a machine element used to transmit rotational force from the slandered sprocket gear which generated by pedaling to the iner dram.

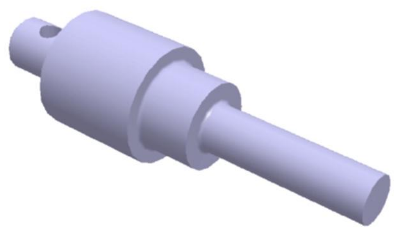


Figure 5:9 Sprocket shaft

Note: The operation plan table for Sprocket shaft is similar to the operation plan of shaft for pinion part mentioned above interims of tools, machines required and their operation sequences except the size.

5.13 Operation plan for Support stand frame

It is one of the components of the project that uses to maintain stability of the whole mechanism of washing machine. Therefore the support hold all the applied force which can get from the dead weight and the operating weight or force. The stand are made from 30mmx30mm square hole sphere as maintained in the detailed drawing.

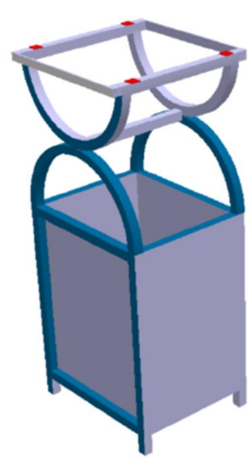


Figure 5:10 Support stand frame

Table 5: 13 Operation plan for Sport stand frame

No.	Operation	Machine used	Tools & Equipment's used	Dimension
1	Preparing jigs & fixture for outer dram supporter by Measuring, cutting & welding the RHS (Arc profile)	SMAW Machine, vice	Meter, hand hacksaw, scriber, Try square, eye shield, chipping hammer	R=17.23cm
2	Measuring & cutting the RHS for the outer dram support (4 peace)	Vice	Hand hacksaw, mater, scriber ,Try square	L=35cm
3	Weld outer dram support inside the jig & fixture(4 peace)	SMAW Machine, vice	Meter, hand hacksaw, scriber, Try square, eye shield, chipping hammer	R=17.23cm
4	Preparing rectangular outer dram stand by measuring & cutting the RHS.	Vice	Hand hacksaw, mater, scriber ,Try square	W=41.38cm D=40cm H=56cm
5	Joining rectangular outer dram stand by Welding	SMAW Machine	Meter, hand hacksaw, scriber, Try square, eye shield, chipping hammer	W=41.38cm D=40cm H=56cm
6	Joining outer dram supporter & rectangular outer dram stand by welding		Meter, hand hacksaw, scriber, Try square, eye shield, chipping hammer	W=41.38cm D=40cm H=96 7cm
7	Finishing & painting	Portable grinder	Wire brush, paint brush	

5.15 Manual assembly

5.15.1 Process description

Manual assembly involves the composing of previously manufactured components and/or subassemblies into a complete product of unit of a product, primarily performed by human operators using their inherent dexterity, skill and judgment. The operator may be at a workstation (bench) or be part of a transfer system that moves the product as it is being assembled. Manual assembly can be further assisted by mechanized or automated systems for feeding, handling, fitting and checking operations.

5.15.2 Process variations

- Feeding: presentation of a component to the handling equipment in the correct orientation by a variety of methods. Parts manually taken from storage bins and then orientated by operator. Orientation can be achieved by vibratory/centrifugal bowl feeders, parts already orientated in pallet/magazine/strip form or use of part-feeding escapement mechanisms.
- Handling: bringing components and/or sub-assemblies together such that later composition can occur. Use of hands, simple lifting aids and jigs and fixtures.
- Fitting: various part placement/location configurations or fastening/joining methods can be utilized, e.g. ‘peg in hole’, press fit, welding, riveting, adhesive bonding, staking and screwing, using a variety of hand operated or mechanized/electrical tools.
- Checking: detection of missing, incorrect, misshapen or wrongly orientated components by high-level sensing and checking capabilities of operators and mechanical/electrical aids. Also detection of foreign bodies, part-failure and machine in-operation.
- Transfer: typically, the various assembly operations required are carried out at separate stations, usually built up on a work carrier, pallet or holder. Therefore, a system for transferring the partly completed assemblies from workstation to workstation is required. In general, the various types of workstation/transfer system for manual assembly are:
- Single-station: assembly at one workstation or bench where a specific or a variety of operations are performed.
- Continuous: work carrier flows without stopping, using conveyors (in-line, rotary dial or carousel), overhead rail or towline.
- Intermittent: synchronous/indexing (moved with a fixed cycle time) or non-synchronous/free transfer (moved as required or when operation/assembly completed by operator) using in-line or rotary systems.

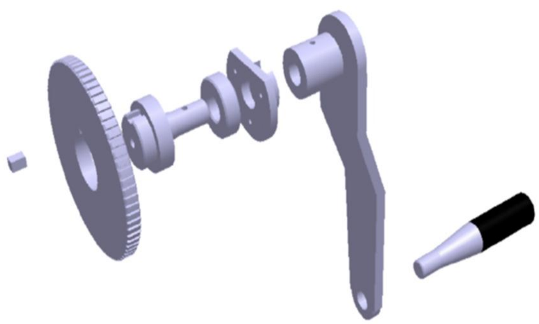
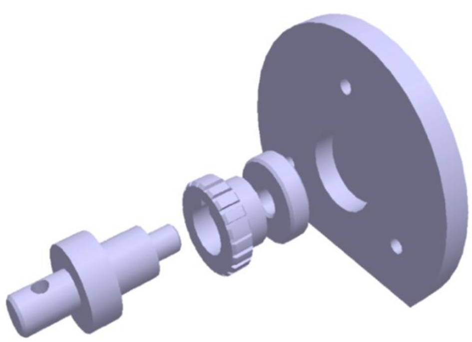
5.15.3 Economic considerations

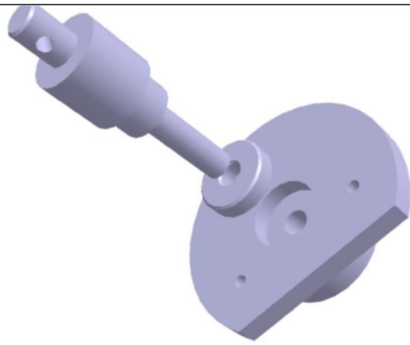
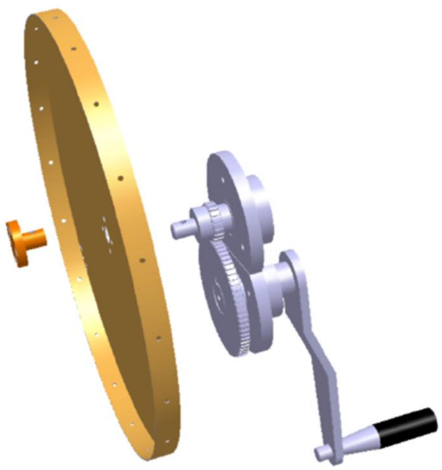
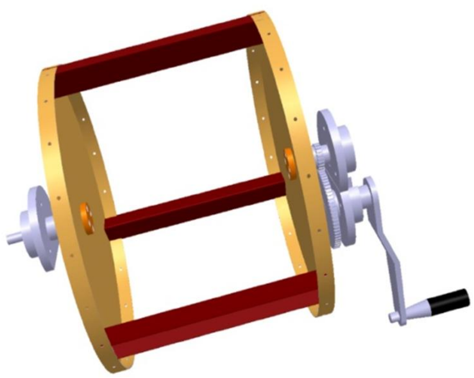
- Production rates low to moderate, depending on complexity, number and size of component parts. These factors also dictate the degree of mechanized assistance needed.

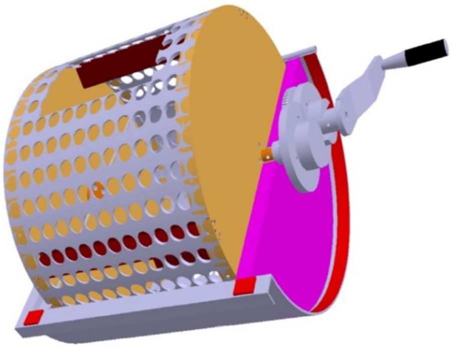
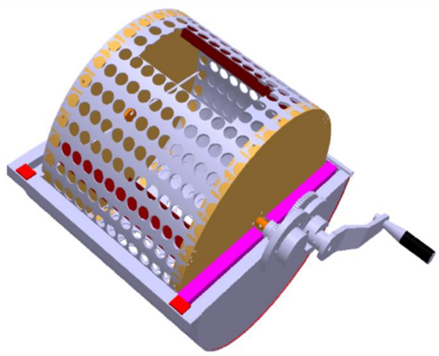
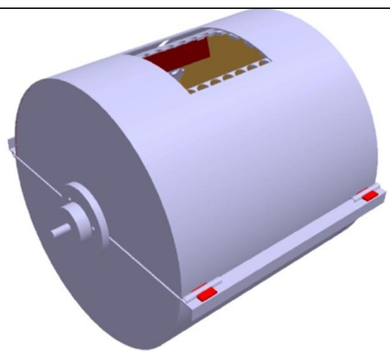
- Extremely flexible assembly system (many product variants) and therefore most common.
- Lead time typically days, higher if mechanized assistance devices used.
- Economical for low to moderate production runs. Can be used for one-offs.
- Tooling costs low to moderate.
- Equipment costs generally low, except where full-mechanized assistance exists.
- Direct labor costs moderate to high. Relatively easy to train operators

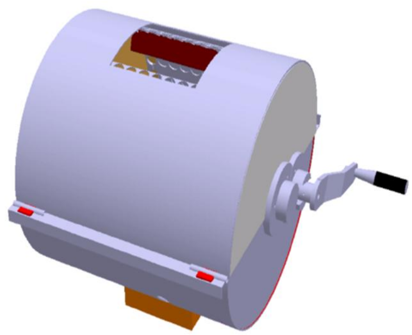
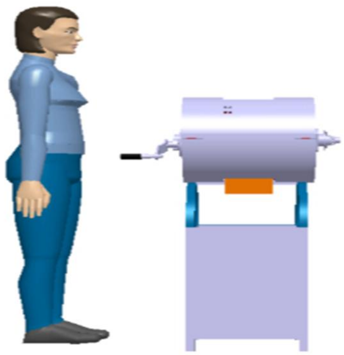
5.15.4 Assembling procedure of components

Table5: 14 Assembling procedure of components

A.No	Procedure	description
001		**Parts**: Gear, key, shaft, bearing, bearing house 1, handle plate, handle bar. **Parts-count:** 7 **Tools &Equipment**: Machine vice, press, A. wrench, R .mallet **Time Required**: 8min. (Average)
002		**Parts**: key, shaft, pinion bearing, bearing house 2 **Parts-count:** 5 **Tools &Equipment**: Machine vice, press, A. wrench, R. mallet **Time Required**: 6min. (Average)

003		**Parts**: shaft, bearing ,bearing house 3 **Parts-count:** **Tools &Equipment**: Machine vice, press, A. wrench, R. mallet **Time Required**: 5min. (Average)
004		**Parts**: sub asse.001,sub asse.002,R.side cover, bushing **Parts-count: 4** **Tools &Equipment**: Machine vice, press, A. wrench, R. mallet **Time Required**: 5min. (Average)
005		**Parts**: sub asse.003,sub asse.004,L.side cover, bushing, fins **Parts-count: 7** **Tools &Equipment**: R. mallet Riveting gun, rivets **Time Required**: 11min. (Average)

006		**Parts**: sub asse.005,internal drum,L1.side cover,R1.side cover, outer drum bottom **Parts-count: 5** **Tools &Equipment**: A. wrench, R. mallet Reverting gun, rivets, silicate **Time Required**: 9min. (Average)
007		**Parts**: sub asse.006,L2.side cover,R2.side cover, **Parts-count: 3** **Tools &Equipment**: A. wrench, R. mallet Reverting gun, rivets, silicate, **Time Required**: 8min. (Average)
008		**Parts**: sub asse.007,L_{u1}.side cover L_{u2}.side cover,R_{u1}.side cover, R_{u2}.side cover, outer drum upper **Parts-count: 6** **Tools &Equipment**: A. wrench, R. mallet Reverting gun,revats,silicate,M6 bolt and nut #6 **Time Required**: 11min. (Average)

009		**Parts**: sub asse.008,Ultrasonic device **Parts-count: 2** **Tools &Equipment**: A. wrench, R. mallet Reverting gun, reverts, silicate, **Time Required**: 9min. (Average)
010		**Parts**: sub asse.009,supporting stand **Parts-count: 2** **Tools &Equipment**: A. wrench, **Time Required**: 3min. (Average)
011		**Parts**: sub asse.010,bicframe, sprocket#2,chain#2,bracket **Parts-count:** 7 **Tools &Equipment**: A. wrench, M12 bolt and nut#4 **Time Required**: 20min. (Average)

5.16. Maintenance

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 should be chosen or preferable?
- ✓ What are the common tasks of PM maintenance for the machines?

5.16.1 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.

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 (Rahim et al. 1996).

5.16.2 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.

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, spur gears, slicing die, and splitting die 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.

5.16.3. General points for maintenance of chain

The general point to take in to account in the maintenance of chain drives are:

- As with belt drives, alignment and proper tensioning are critical to the operation of the drive
- Chain drives should be kept clean and protected from dirt and should be provided with an adequate supply of a suitable lubricant.
- New like should not be installed in chains that have been significantly lengthened by wear.
- New chains should not be installed on badly worn sprockets. Sprockets may be reversed on the shaft to extend their life if necessary.
- New chains should be stored in protective wrappings until ready for use, and protected from interference.
- Cleaning
- Whatever the operating conditions it is advisable to remove the chain and clean it from time to time. The debris of normal wear and gummed lubrication will cause of wear to the pin and bushing s if it is not removed and if the atmosphere is dusty, regular cleaning become even more important.
- Remove the chain.

- Check the chain and the sprocket for wear and corrosion.
- Wash the chain in kerosene or similar cleaning fluid. Soaking may be necessary for a very dirty chain.
- Drain off the cleaning fluid and soak the chain in lubricating oil.
- Hang the cleaning fluid and soak the chain in lubricating oil.
- Clean the sprockets and check alignment.
- Reinstall the chain.
- Lubrication
- Proper lubrication is critical to the operation of chain drives and the achievement of satisfactory service life. The general principle of lubrication applies and the following point should be remembered.
- Lubrication should be regular and the frequency determined by the operating conditions.
- Whatever lubrication system is employed, the lubricant can flow into the joints.
- Chain should be cleaned regularly so that lubrication required.
- Some means of protecting the chain from dirt and other contaminants should be provided.
- The most common methods of chain drive lubrication are:
- Manual: using a brush or oil can suitable for simple drives
- Drip feed: low horsepower and low speed drives
- Automatic: using an oil bath or an oil spray suitable for moderate to speed drives

5.16.4 The expecting problems in chain drive's of the machine

The main expected symptoms and cause of failure in the chain drive operations of *Manual Operation* cloth washing machine that will require maintenance activities are:-

Table 5:15 Symptoms and causes of chain drive failure

Summary of symptoms and causes of chain drive failure		
Symptoms		**Causes**
Operating	**Inspection**	
Noise	Wear	Misalignment
Jumping	Galling	Slack adjustment
Whipping	Corrosion	Lack of lubrication
Breakage	Link seizure	Material build up
Overheating		Interference
		Vibration Overload Worn sprockets

5.16.5 Preventive maintenance activities and schedule

Table 5:16 Preventive Maintenance Activities

No.	Activities (Detail Of Work)	Frequency	Estimated Time	Comment
1	Check up of chain	1 Week	1hr	
2	Check operation of ultrasonic system	5 Weeks	30 Minutes	
3	Cleaning the filter chamber	3 week	30min	
4	Shaft Check Up	2 Weeks	30min	
5	Lubrication System Check Up For Bearings	1 Weeks	1hrs	
6	Check Up For chain Tension	2weeks	20 Minutes	
7	Check up for sand filter	1 Week	1hr	
8	Check Up For Loosened Bolts And Nuts	1 Week	1hr	
9	Servicing And Lubrication	1 Week	3 Hr	

CHAPTER SIX

COST ANALYSIS

This 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 cloth washing machine and also result and discussion is included.

6.1 Cost Analysis

6.1.1 Elements of cost established selling price

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 Manual Operation washing machine processing analysis should be done in order to be competitive. The way element of cost builds up to establish a selling price is shown on figure below

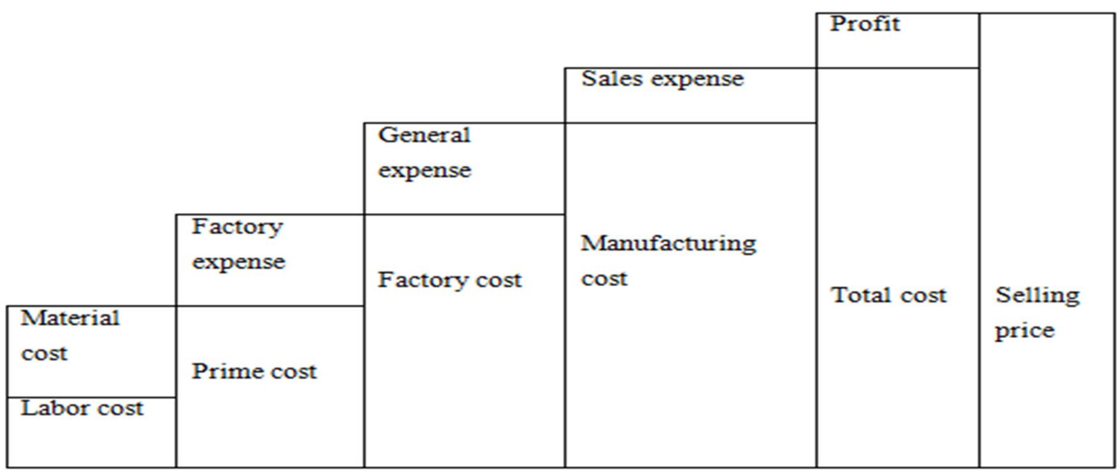


Figure 6: 1 Establishing of selling price **source**:[26]

The chief cost elements of direct material cost and direct labor cost determines prime cost. The factory expense such as light, power, maintenance, supply plus prime cost gives factory cost. The general expense such as marketing and sales cost, legal expense, and security cost, financial, and administrative plus factory cost gives manufacturing cost. The sales expense such as taxes, office stuff, and purchasing plus manufacturing cost gives total cost. (Total cost=manufacturing cost +

sales expense). Finally the selling price established by adding a profit to the total cost for a business.[23]

7.1.2 The costs of raw materials and the cost of standard items

The material costs are refer to those materials which are consumed to produce a real components of our machine and the standard item costs are those costs which is purchased from a local markets/they are a finished product/.

Table 6: 1 The costs of raw materials

No	Material Description	Item	Size Required	Unit	Qty	Unit price		Total price	
						Birr	Cent	Birr	Cent
1	Aluminum ingot	Bearing housings	Ø60x18 mm (0.138kg)(45biir/Kg)	Kg	3	6	21	18	63
2	Aluminum composite panel	Outer drum ,water tanker	1350mmX 1350mm x3mm(105birr/m^2)	m^2	1	191	36	191	36
3	SHS mild steel	Support stand frame	8440mmx30x2.5 mm	Pcs	1.5	330	00	330	00
4	SAE 1045 water quenched	Shaft for gear	Ø 44x80mm (0.956kg) (17.85birr/kg)	Kg	1	17	06	17	06
5	AISI 1020 alloy steel	Pinion	Ø 52x24 mm (0.37kg) (16.80birr/kg)	Kg	1	6	22	6	22
6	AISI 1340 alloy steel	Handle plate	116x14x3 mm (0.038kg) (18.60birr/kg)	Kg	1	00	71	00	71
7	SAE 1045 water quenched	Shaft for pinion	Ø 32x78mm (0.506kg) (17.85birr/kg	Kg	1	9	03	9	03
8	SAE 1045 water quenched	Sprocket shaft	Ø 30x109mm (0.077kg) (17.85birr/kg	Kg	1	1	37	1	37
9	Flat iron	brackets	200mmx50mmx3mm (0.393kg) (13.50birr/kg)	Kg	1	5	31	5	31
10	AISI 1020 alloy steel	Gear	Ø162x24 mm (3.888kg) (16.80birr/kg)	Kg	1	65	32	65	32
11	AISI 1340 alloy steel	Handle bar	Ø24x122 mm (0.434kg) (18.60birr/kg)	Kg	1	8	07	8	07
Total cost								**653**	**08**

Table 6: 2 Standard item cost

No.	Item description	Technical specification	Unit	Qty	Unit price	Total price
1	Bicycle chain	standard	pcs	2	60	120
2	Sprocket & pedal	standard	set	01	160	160
3	Bicycle set	standard	pes	01	60	60
4	Sprocket	standard	pcs	01	50	50
5	Bearing	Inner dia. 15	pcs	02	80	160
6	Electrode	Ø2.5	packet	1	80	80
7	Bearing	Inner dia. 25	pcs	01	90	90
8	Paint (anti rust)	Nefas silk	kg	2	180	360
9	Hinge	standard	pcs	1	10	10
10	Hand hack saw blade	24 teeth	pcs	2	10	20
11	Drill bit	HSS, Ø5,6,10.5,12,16	PCS	5	10	100
12	Lathe cutter	HSS (16 X 16 X 200)	pcs	1	80	80
13	Bolt and nut	M6	pcs	12	2	24
14	Bolt and nut	M12	pcs	4	8	32
15	Pop rivet	Ø4	Pack	1	30	30
16	Rubber seal	standard	pcs	1	80	80
17	Water proof	standard	pcs	1	40	40
18	Ultrasonic Transducer	standard	pcs	4	105	420
19	Water filtration system	standard	kg	59	25	25
					Total cost	**1,941.00**

Total Materials Cost = Cost of raw materials+ Cost of Standard items

=653.08 Birr + 1,941.00 Birr

$\Rightarrow$ Total material Cost = **2,594.08Birr**

7.1.3Labor cost for manufacturing and assembling components

Labor cost for manufacturing

It is the cost of the worker spend and making a product. The cost includes all the labor from the time materials are first handle to the time the product is finished.

Note:- Labor cost should have paid b/n 10.00birr and 15.00 Birr per hour. For all components,

Table 6:3 Manufacturing Labor cost

No.	Parts to be manufactured	Qty	Working time in minute		Working time in hour	Payment per hour	Labor cost price in Birr	Total cost of part in Birr
1	Bearing House 1	01	Set up time	82.5	3.9	10	39	**39**
			Operation time	147				
2	Bearing housing 2	01	Set up time	90	4	10	40	**40**
			Operation time	150				
3	Outer & inner dram	01	Set up time	30	3	10	30	**25**
			Operation time	150				
4	Support stand frame	O1	Set up time	30	2.5	10	25	**25**
			Operation time	120				
5	Shaft for gear	01	Set up time	70	3.7	10	37	**37**
			Operation time	150				
6	Pinion	01	Set up time	60	3.3	10	33	**33**
			Operation time	140				
7	Handle plat	01	Set up time	20	1.7	10	17	**17**
			Operation time	80				
8	Shaft for pinion	01	Set up time	70	3.7	10	37	**37**
			Operation time	150				
9	Sprocket shaft	01	Set up time	70	3.7	10	37	**37**
			Operation time	150				
10	Gear	01	Set up time	80	3.8	15	57	**57**
			Operation time	150				
11	Waste water filtration tank	01	Set up time	30	2.5	10	25	**25**
			Operation time	120				
							Total	**372**

Labor cost for assembling components

- Detail assembling of manufacturing components is indicated in section manufacturing process.
- To the total cost of labor, it should calculate the time spend for manufacturing & assembling of parts (components).
- The time needed for assembling components of the project is indicated as follows:-

Table 6: 4 Assembling labor cost

Total Labor Cost = Labor cost for manufacturing components + Labor cost for assembling

No.	Assembly	Working time in hour	Payment per hour in Birr	Labor cost price in Birr
1	Sub-assembly 001	0.13	10	1.3
2	Sub-assembly 002	0.10	10	1.0
3	Sub-assembly 003	0.083	10	0.83
4	Sub-assembly 004	0.083	10	0.83
5	Sub-assembly 005	0.183	10	1.83
6	Sub-assembly 006	0.15	10	1.5
7	Sub-assembly 007	0.13	10	1.3
8	Sub-assembly 008	0.183	10	1.83
9	Sub-assembly 009	0.15	10	1.5
10	Sub-assembly 010	0.05	10	.5
11	total-assembly 011	0.33	10	3.3
Total cost				14.19Birr

components.

= **372**Birr + **14.19Birr**$\Rightarrow$ Total Labor Cost =**<u>386.19</u> Birr**

7.1.4 Electrical power consumption cost

It is the cost of electric power needed to machine and weld parts of the project. Electric power is expressed (measured) by a unit watt (w) or kilo watt (Kw).The cost of electric power is expressed in birr per KWH. The electrical machines used and time consumed is indicated below:-

Table 6: 5 Machines & time consumed

No	**Manufactured parts**	**Qty**	**Types of machines & their machining time in hour**						
			Power hack saw	Lathe machine	Milling machine	SW Arc welding machine	Drilling machine	Portable hand grinder	Electric Furnace
1	Bearing House 1	01	-	1:00	1:00	-	1:00	-	1:00
2	Bearing housing 2	01	-	1:00	1:10	-	1:00	-	1:00
3	Outer & inner dram	01	-	-	-	-	0:50	-	-
4	Support stand frame	01	-	-	-	2:00	-	0:30	-
5	Shaft for gear	01	0:20	2:00	0:30	-	-	-	-
6	Pinion	01	0:20	1:30	2:00	-	-	-	-
7	Handle bar	01	0:20	1:00	-	-	-	-	-
8	Shaft for pinion	01	0:20	1:00	1:00	-	-	-	-
9	Gear	01	0:30	1:30	2:30	-	-	-	-
10	Sprocket shaft	01	0:20	1:00	0:30	-	-	-	-
11	Waste water filtration tank	01	-	-	-	1:00	-	0:30	-
Total time			**2:10**	**10:00**	**8:40**	**3:00**	**2:50**	**1:00**	**2:00**

Now let's calculate the energy used for each machine multiplying their power rating with their machining time.

Note: - Power rating of each machine is taken from their life history card

Example-1 Power hack saw

Power rating (p) =0.75KW

Working time (t) =2:10hr

Example-2 Lathe machine

power rating (p) =2.2KW

working time (t) =10:00H

Energy consumed (E) =?

$$E = Pxt = (0.75\times2) + (0.75x\frac{10}{60})$$

Energy consumed (E) =**1.623KWH**

Energy consumed (E) =?

$$E = Pt = (2.2\times10)$$

Energy consumed (E) =**22KWH**

Note: - the energy consumed for each machine is done with the same procedure of the above two examples

Note: - the electrical power cost for 1KWH is 0.70 Birr (source from EELPA)

Table 6:6 Electrical power consumption cost

No	Machine type	Power rating of the machine inKW	Total machining time in hour	Energy consumed in KWH	Payment for 1KWH in Birr	Total payment in birr
1	Power hack saw	0.75kw	2;10	1.623	0.70	1.14
2	Lathe machine	2.2kw	10:00	22	0.70	15.4
3	Milling machine	1.5kw	8:40	13	0.70	9.1
4	SW Arc welding machine	4.9kw	3:00	14.7	0.70	10.29
6	Drilling machine	1.3kw	2:50	3.68	0.70	2.57
7	Electric furnace	5.10kw	2:00	10.2	0.70	7.14
8	Portable hand grinder	2.0kw	1:00	2	0.70	1.4
					Total cost	**47.04**

6.1.5 Machine Depreciation Cost

Depreciation is defined as the reduction in value of the machine over time as it is working at a specific task. 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.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 (T.R.Banga, et.al, 2003).The mathematical formula for the yearly depreciation charge using the straight-line method is:

$$D = \frac{P - S}{N}$$

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 the depreciation cost of **power hacksaw** is calculated as follows and the same is done for other machines.

$D = \frac{P-S}{N}$, Where D = Depreciation charge

P = 40,000 Birr

S = 30% of 40,000 = 12,000 Birr

N = 10 yrs

$D = \frac{40,000-12,000}{10}$ = **2,800 Birr per year**

In one year there are have 12 months

The depreciation cost for a month, 2800/12=**233.33Birr/month**

since there are 4week in a month,

The depreciation cost for a week=233.33/4= **58.33 Birr/week.**

In a week we have 5 working days the depreciation cost per day =58.33/5= **11.67 Birr/day.**

Further we have 8 working hours in a day so

The depreciation cost per hour =11.67/8=**1.46**Birr/hr.

Therefore the time period over which hourly depreciation of the machine that used to manufacture our product is already calculated. Therefore, we can take the depreciation of those machines from the 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 them and the hourly depreciation.

Table 6: 7 Depreciation cost of different machines

No	Machine type	Life span (year)	Machine Price		Depreciation values /hr		Usage time	Total depreciation value	
			Birr	Cents	Birr	Cents		Birr	Cents
1	Power hack saw	10	40,000	00	1	46	2:10	3	16
2	Arc welding machine	5	30,000	00	2	19	3:00	6	57
3	Potable grinder	3	2,000	00	0	24	1:00	0	24
4	Lathe machine	10	150,000	00	5	47	10:00	54	70
5	Drilling machine	10	100,000	00	3	65	2:50	10	34
6	Milling Machine	12	200,000	00	6	08	8:40	52	69
							Total Cost	**127**	**70**

6.1.6 Total cost of *Manual Operation* washing Machine

❖ **Manufacturing cost:-**

- Material cost ---------------------- = 2,594.08Birr
- Labor cost --------------------- = 386.19 Birr
- Electric power consumption cost = 47.04 Birr
- Machine depreciation cost ------- = 127.70Birr

Manufacturing cost =**3,155.01 Birr**

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

- Contingency = 10%×2,594.08Birr

$$= \frac{10}{100} \times 3,148.70 \text{ Birr}$$

Contingency = **314.87 Birr**

❖ ***Total manufacturing cost*** = Manufacturing cost + Contingency

= 3,155.01 **Birr** +314.87 Birr

= **3,469.88 Birr**

❖ ***Profit***: - it is usually taken as20% of the total cost.

$$\text{Profit} = \frac{20}{100} \times \underline{\mathbf{3{,}469.88\ Birr}}$$

⇒ **Profit = 693.98 Birr**

❖ **Selling price** = Profit + Total manufacturing cost

= 693.98 Birr Birr +3,469.88 Birr

=**4,163.86Birr**

6.1.7 Break-Even Analysis

Break even analysis also known as cost-volume-profit-analysis, is concerned with finding the point at which revenues and costs are exactly equal. This point represents the volume of output at which neither a profit is made nor a loss is incurred. Therefore production/sale must not be allowed to fall beyond this point. This analysis can be carried out either algebraically or graphically.[26]

Assumptions in this break even analysis

- The company produces 45 machines per month
- No initial capital investment for this production.
- Assume that cost can be classified in to fixed and variable costs, ignore semi-variable costs.
- Sale price is assumed as constant.
- It assumes no improvement in efficiency.
- Changes in input prices are also constant.
- It consider that production is equal to the sales.

Break even point in terms of physical units

$$BEP = \frac{Fixed\ costs}{selling\ price - variabel\ costs\ per\ unit} = \frac{(45units\ x\ 2{,}594.08birr)}{4{,}163.86birr - 554.62birr} = \frac{116{,}733.60\ units.birr}{3{,}609.24irr}$$

$$=32.34 \approx 32units$$

The breakeven point is reached when 33machines have been sold, which mst be sold to earn enough revenue just to cover all expenses.

CHAPTER SEVEN

RESULT AND DISCUSSION

The Manual operation clothe washing machine was locally fabricated and assembled. Then a frequent of different testes to various functions of the machine.

The results from those testes discussed as follows:

I. Pre-production

In the design phase additional to conventional way of failure analysis, Finite element analysis with CATIA V5 simulation soft wear executed for the most critical parts of the machine. The results from both methods confirm that those parts are Safe against failure. In all finite element analysis simulation the Von Mises stress induced in the material do not exceeds yield strength of the material.

II. Post-production

The mechanical washing mechanism:

It includes both hand cranking and pedal powered mechanisms to washed, risen and spine drying of clothes. As predetermined in section 4. the machine mechanical washing mechanism capably washed an average of 3Kg of dirt clothes with 15L water/cycle pulse 50 ml/ Kg /cycle of both ordinary liquid or powder detergent in 40 minutes. The cleanse of clothes after wash found excellent compered with both hand washing and electrical machine washing.

- Electric Power consumption
- Table 2.2: Electrical Energy consumption, impeller washing machines with cold water use.

Washing capacity: Small –Medium ≤ 6 kg

Electrical energy (kWh/cycle with cold water): 0.18kWh/cycle

Electrical Energy cost: is 0.70 Birr/ kWh, source from EELPA

Electrical Energy cost (kWh/cycle with cold water) for impeller washing machines: $\frac{0.18\text{kWh/cycle X}0.70\text{ Birr}}{1\text{kWh}} = 0.126$ Birr/ cycle

BAT level: 0.06kWh/cycle

Electrical Energy cost (kWh/cycle with cold water) for BAT level: $\frac{0.06\text{kWh/cycle X0.70 Birr}}{1\text{kWh}}$ = 0.042 Birr/ cycle

Table 2.5: Horizontal axis washing machines, energy consumption for 60 °C hot wash cycle Washing capacity: Small –Medium ≤ 6 kg

Electrical energy consumption (kWh/cycle at 60°C wash cycle): 1.24Wh/cycle

Electrical Energy cost: is 0.70 Birr/ kWh, source from EELPA

Electrical Energy cost (kWh/cycle at 60°C wash cycle) Horizontal axis washing machines: $\frac{1.24\text{kWh/cycle X0.70 Birr}}{1\text{kWh}}$ = 0.868 Birr/ cycle

BAT level: 0.94kWh/cycle

Electrical Energy cost (kWh/cycle with cold water) for BAT level: $\frac{0.94\text{kWh/cycle X0.70 Birr}}{1\text{kWh}}$ = 0.658Birr/ cycle.

Manual Operation clothe washing machine electrical energy consumption, washing machines with cold water use.

Washing capacity: Small –Medium ≤ 6 kg

Electrical energy (kWh/cycle with cold water): 0kWh/cycle (during hand cranking or pedal rotation)

Electrical Energy cost: is 0.70 Birr/ kWh, source from EELPA

Electrical Energy cost (kWh/cycle with cold water) *Manual Operation* clothe washing machine: $\frac{0\text{kWh/cycle X0.70 Birr}}{1\text{kWh}}$ = 0Birr/ cycle

BAT level: (when sing Ultrasonic cleaning): 0.25kWh/cycle

Electrical Energy cost (kWh/cycle with cold water) for BAT level: $\frac{0.25\text{kWh/cycle X0.70 Birr}}{1\text{kWh}}$ = 0.175Birr/ cycle

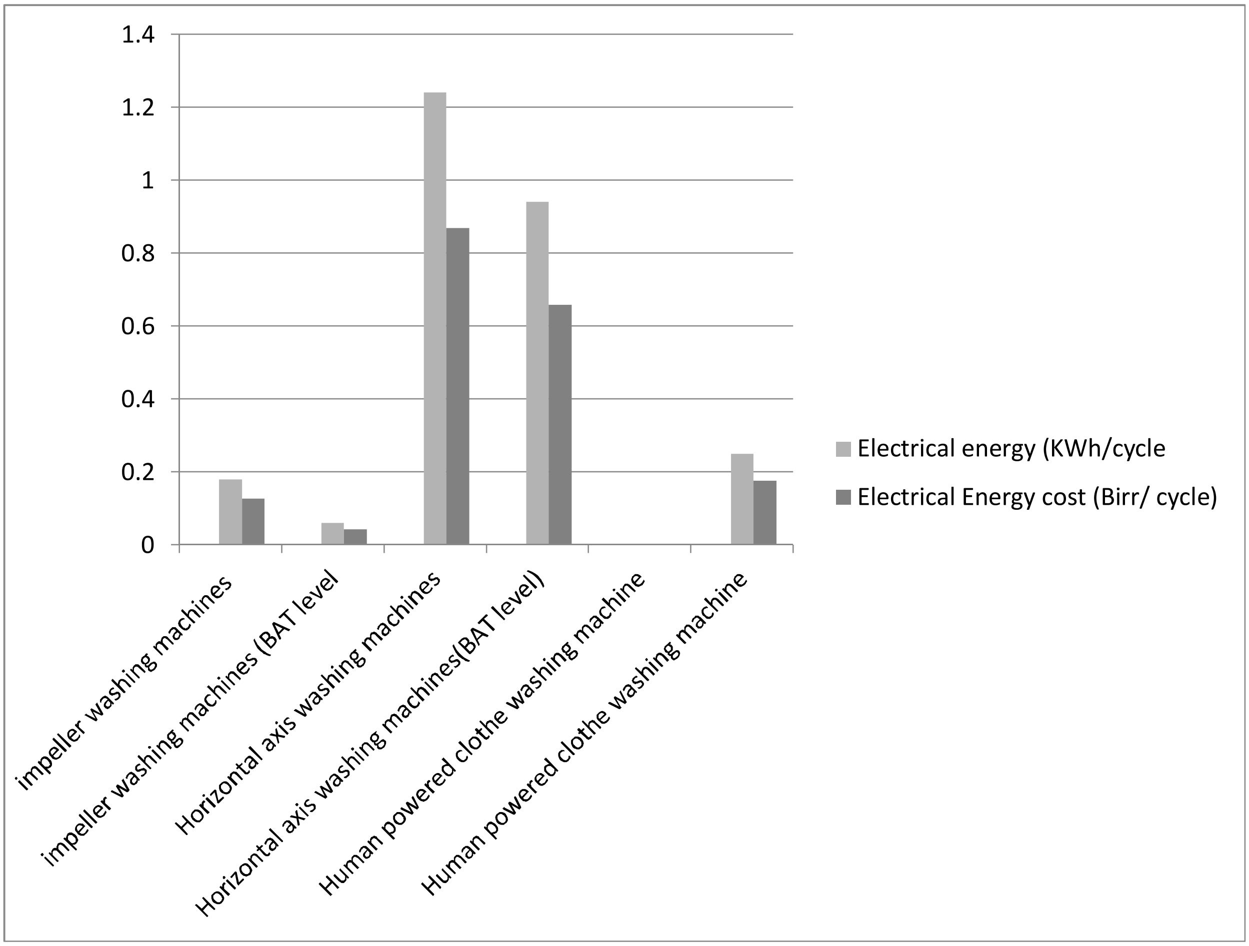


Figure 7: 1 Electric energy consumption, of different washing machines

Water Consumption

Washing capacity: Small < 6kg

Water consumption (L/cycle): 145 L/cycle

Water cost (Birr/L): $30L^3$= 5.85Birr= 30L= 1.80Birr from AAWSA

Water consumption cost of impeller washing machines (Birr) = $\frac{145\frac{L}{cycle}x1.80Birr}{30L}$ = 8.70Birr

BAT level: 106 L/cycle

Water consumption cost of BAT level (Birr): $\frac{106\frac{L}{cycle}x1.80Birr}{30L}$= 6.36 Birr

Table 2.6: Horizontal axis washing machines, water consumption for 60 °C hot wash cycle

Washing capacity: Small < 6kg

Water consumption (L/cycle): 64 L/cycle

Water cost (Birr/L): $30L^3$= 5.85Birr= 30L= 1.80Birr from AAWSA

Water consumption cost of Horizontal axis washing machines (Birr) = $\frac{64\frac{\mathrm{L}}{\mathrm{cycle}}\mathrm{x}1.80\mathrm{Birr}}{30L}$ = 3.84Birr

BAT level: 55 L/cycle

Water consumption cost of BAT level (Birr): $\frac{55\frac{\mathrm{L}}{\mathrm{cycle}}\mathrm{x}1.80\mathrm{Birr}}{30L}$= 3.30 Birr

Manual Operation clothe washing machine Water consumption

Washing capacity: Small < 6kg

Water consumption (L/cycle): 45 L/cycle

Water cost (Birr/L): $30L^3$= 5.85Birr= 30L= 1.80Birr from AAWSA

Water consumption cost of Horizontal axis washing machines (Birr) = $\frac{45\frac{\mathrm{L}}{\mathrm{cycle}}\mathrm{x}1.80\mathrm{Birr}}{30L}$ = 2.70Birr

BAT level: 60 L/cycle

Water consumption cost of BAT level (Birr): $\frac{60\frac{\mathrm{L}}{\mathrm{cycle}}\mathrm{x}1.80\mathrm{Birr}}{30L}$= 3.60 Birr

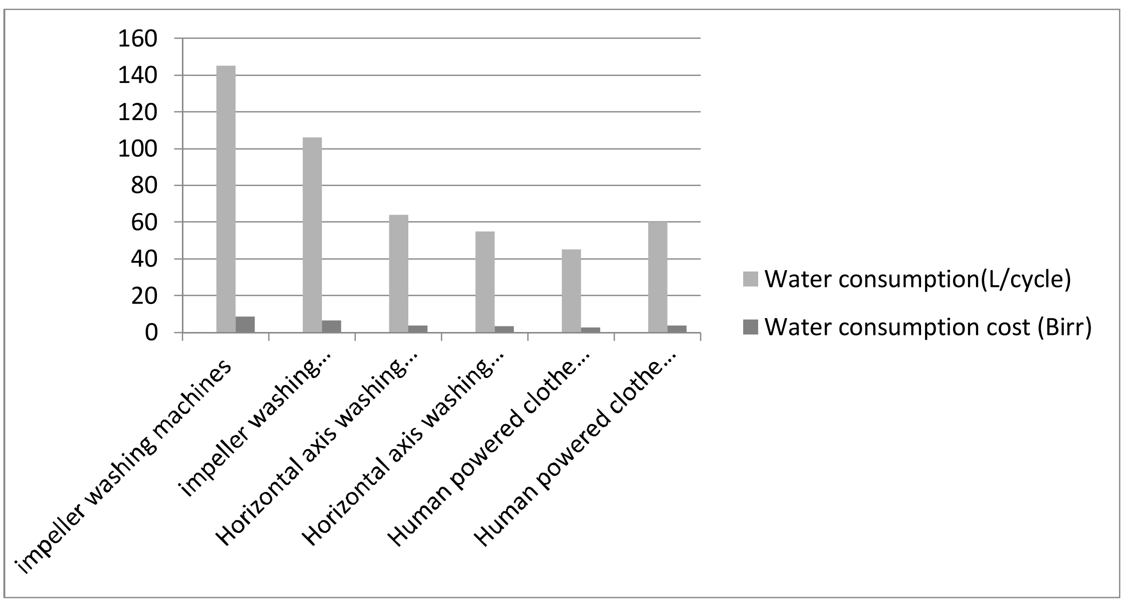


Figure 7: 2 Water consumption, different washing machines

3. Waste water filtration Test

Experiments

The flocculation stage of the water treatment test performed using two chemical experiments:

- Aluminium sulphet
- Calcium carbonate

The test was executed at Awash Melkasa Aluminium Sulphet and Sulphuric Acid S.C quality control laboratory. To determine the purpose of the waste water for reuse first different parameters are checked. Test procedure is according to IS: 3025-Reaffirmed 2002. In addition to Indian standard, the procedures are considered stated in:

- APHA standard method for the examination of water and waste water-20th edition. Method 2340-c.
- Method for chemical analysis of water and wastes, EPA-600/4-79-020,USEPA, method 130-2

The Parameters checked are:

- Water PH: to determine the PH of the given water sample with the stipulation as per IS: 3025(part 11) -Reaffirmed 2002
- Water Turbidity: to determine the turbidity of the given water sample with the stipulation as per IS: 3025(part 10) -Reaffirmed 2002
- Water Hardness: to determine the total hardness of the given water sample with the stipulation as per IS: 3025(part 21) -Reaffirmed 2002
- The test results attached at Appendix B
- From the test results the Calcium carbonate filtration method favored than Aluminium sulphet due to its cost, degree to filter, availability and side effect to humans as well as animals. It is easy to eliminate the byproduct after filtration completed and able to reuse. The flocculation completed in less than 15minuts for 10Lwater. The calcium carbonate causes temporary hardens of water which is removed by secondary slow sand filtration and boiling the water.

- To flocculate waste water with Aluminium sulphet: for 10L=225mg required
- The price of 1Kg Aluminium sulphet = 14 Birr
- To flocculate waste water with Calcium carbonate: for 10L=220mg required
- The price of 1Kg Calcium carbonate = 9 Birr
- Chemical disinfection with other methods (followed by government sector) =2Birr

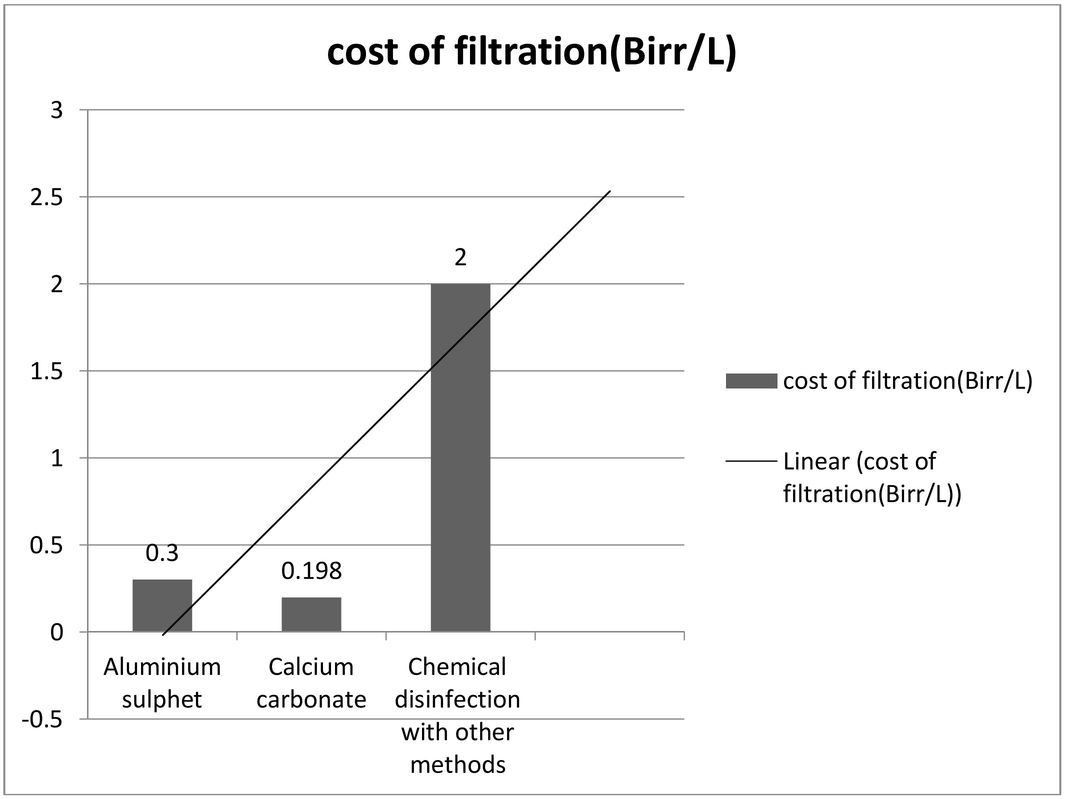


Figure 7: 3 Cost of different water purification methods

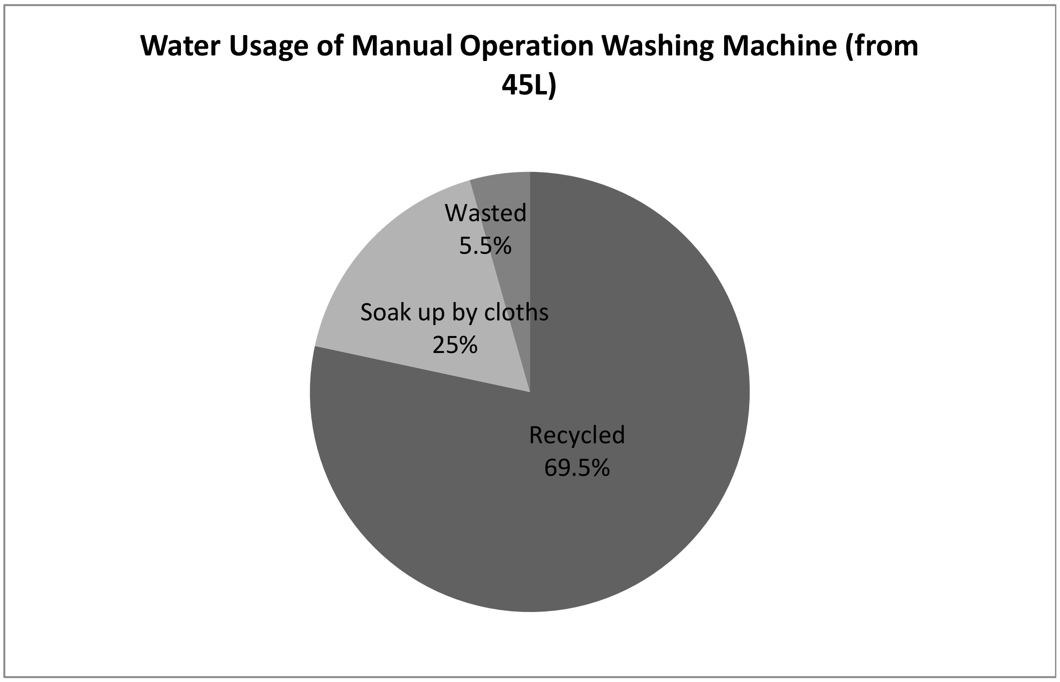


Figure 7: 4 Water usage of Manual Operation washing machine

If 0.01 %(10,000) of the country's population out of 90milion uses *Manual Operation* clothe washing machine. Assume that clothes wash per 2 week interval and the amount of clothe washed is 3kg, average power conception 0.534KWh,.

- There is 26 washes/ individual annually, 260,000 washes by10, 000 people annually.
- If they use the mechanical system only to wash: 0.534KWh X260, 000= 138840Kwh is saved 97,188 Birr annually in terms of cost.

31.25L Water Can Be Recycled From 45LPer Individual Wash

812.5L can be recycled for reuse annually per individual

8,125,000L can be recycled for reuse annually per 10,000 people

If the cost of recycled water is $30L^3$= 1.50birr ,30L= 1.14birr

308,750 birr can be saved annually by recycling and reusing of the waste water

4. Ultrasonic cleaning Test

The ultrasonic cleaning device which built in standalone mode, with single frequency of 25KHz,35 W transducer. It was tested instead of measuring the cavitation implosion intensity as a contributory factor in the ultrasonic cleaning process. Two methods are applied:

1. Aluminum Foil Test

In this test, a piece of aluminum foil is positioned vertically in the ultrasonically activated tank. After exposure under specific conditions for 3min., the foil is examined for pits and/or holes caused by the implosion of cavitation bubbles in proximity to the foil surface. The visible patterns of foil damage shows that there is cavitation implosion field, however those patterns are unevenly distributed.

2. Ceramic Ring Test

It employed ceramic rings contaminated with graphite applied using a pencil as the test object.

The graphite contaminant cannot be effectively removed from the porous ceramic surface by rubbing, brushing or spraying techniques and, being relatively inert, is not easily removed by chemical means.

The coated rings are exposed to the ultrasonic field using a standardized procedure and then evaluated for cleanliness by comparing them to a reference photograph of rings graded on a numerical scale.as the result indicates to rich the cleanliness level 5 it takes10cycles or 30min.

At 25 KHz and lower there will be fewer events than the higher frequencies but these events will store and release considerably more energy when they implode resulting in more aggressive scrubbing. Ultrasonic cleaners operating at these lower frequencies will emit stray frequencies or sub harmonics that will be more noticeable and audible to the personal operating the cleaner and due to the longer wave length one may notice less homogeneous cleaning results.

CHAPTER EIGHT

CONCLUSION AND RECOMMONDATION

8.1 Conclusion

Finally the machine is tested for its functionality and in the first test , all the necessary inputs were loaded while the machine was running and discharged after proper timing and thus we got the machine is ready for the next batches except the integration of the ultrasonic cleaning with the manual operation but the integration is displayed in the design part and the prototype is tested by aluminium foil. However the machine is technically feasible. Thus, the project is functional as per the design.

The machine can perform the following activities:

- Washing, rising and dry spinning by both hand cracking and pedaling.
- Recycling 69.5% of the west water from each cy

This machine has also the following advantages:

- Use no electricity
- Environmental friendly

8.2 Recommendations

From the challenges and short comings that the project team have faced through the design & manufacturing of this project, the project team recommend the following:

- The *Manual Operation Clothe Washing Machine* in this project is strictly design & manufacture to wash an average of 3kg clothe but with some modification of design it could also be used to wash large amount of clothe as you desired.
- In order to drive the inner drum easily, the length of the hand cracking lever (handle plat) should be increased.
- If the machine is fabricated by using other alternative like plastic moulding, the manufacturing cost will be reduced by 40%.

- It is possible to increase the efficiency of the machine by integrating with ultrasonic washing system.

8.3 Scope for Future Work

Although the working model of the drive of Manual Operation washing machine is fabricated and implemented, there is a scope of further work in the project which has not been undertaken. There are a number of ideas where the loss of power can be reutilized and the design can be modified for better performance. Some of them are listed below:

- Energy Storage: The energy being wasted during washing can be stored using flywheel and can be used at the time of spin drying. This would reduce the effort required during drying and would increase the overall capacity of the machine as more energy would be available during spin drying.
- Increasing Washing Capacity: The capacity of washing can be increased so that more clothes can be washed, thus utilizing the wasted energy. It has a disadvantage that all the clothes would not be rinsed and dried simultaneously in the same cycle. The capacity of rinsing and drying is low as compared to washing. Thus, increasing the washing capacity would require the rinsing and drying of the clothes to be done in turns. The machine would then no longer complete the entire laundry process in one cycle.
- Designing a Multipurpose Machine: The energy wasted during washing can be utilized in most fruitful way by using it in another household machine which would work simultaneously as the washing goes on. Load on the new machine would be such that entire energy is consumed and not wasted. The excess energy can be used to generate electricity to charge battery. It can be used to operate pedal powered pumps.

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APPENDIXES

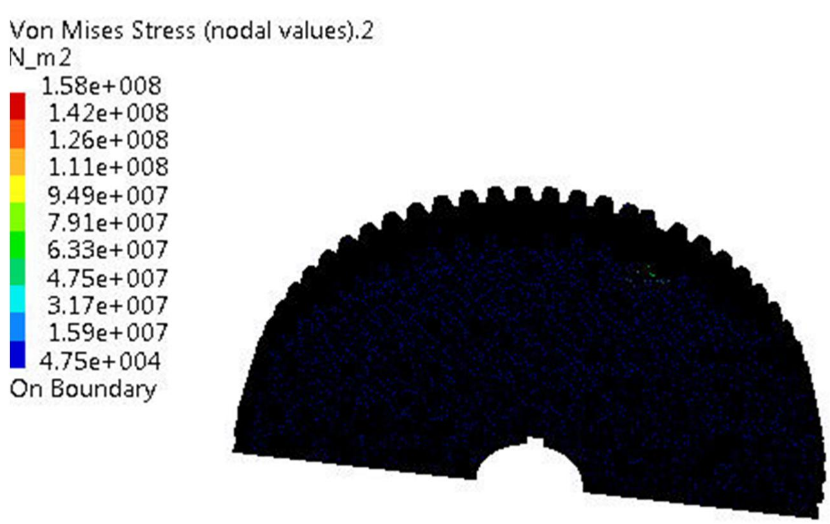
Appendix A-1

Finite Element Analysis of Gear

Materials.1

Material	• AISI 1020 steel
Young Modulus	2e+011N_m2
Poisson Ratio	0.3
Density	7860kg_m3
Thermal Expansion	1.17e-005_Kdeg
Yield Strength	2.95e+008N_m2

Static Case Solution.1 - Von Mises Stress (nodal values)

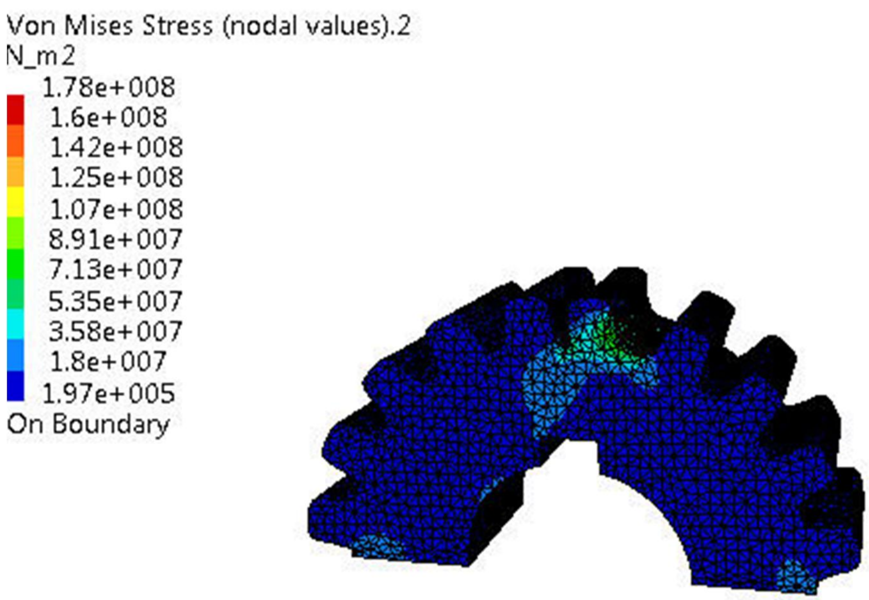


Finite Element Analysis of pinion

Materials.1

Material	AISI 1020 steel
Young Modulus	2e+011N_m2
Poisson Ratio	0.3
Density	7860kg_m3
Thermal Expansion	1.17e-005_Kdeg
Yield Strength	2.95e+008N_m2

Static Case Solution.1 - Von Mises Stress (nodal values)



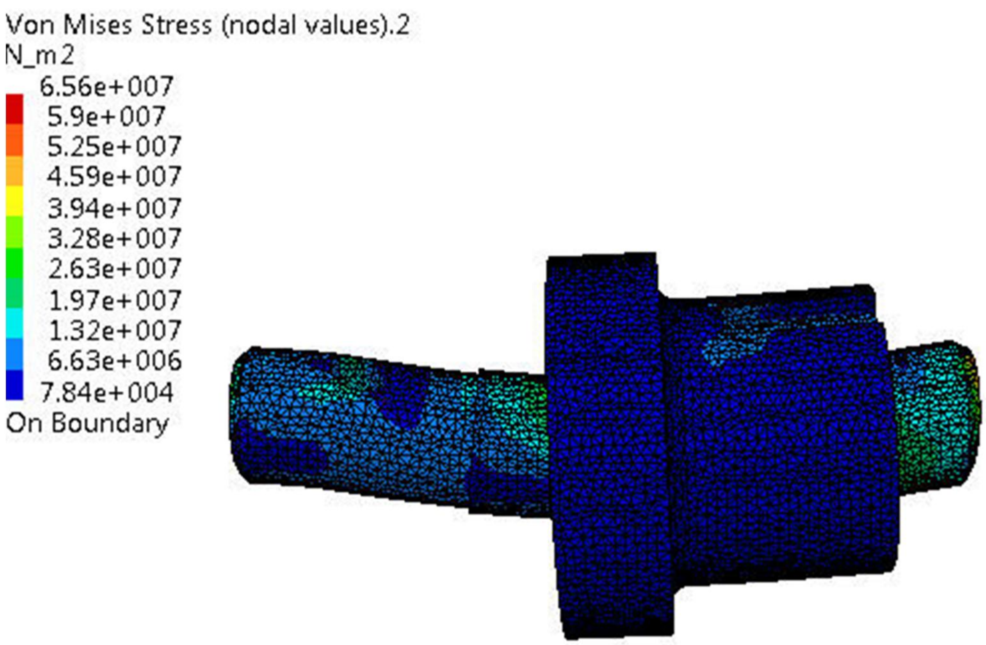
Appendix A-2

Finite Element Analysis of Shaft for Gear (Bending)

Materials.1

Material	Carbon steel SAE 1045
Young Modulus	2e+011N_m2
Poisson Ratio	0.3
Density	7860kg_m3
Thermal Expansion	1.17e-005_Kdeg
Yield Strength	5.18e+008N_m2

Static Case Solution.1 - Von Mises Stress (nodal values)

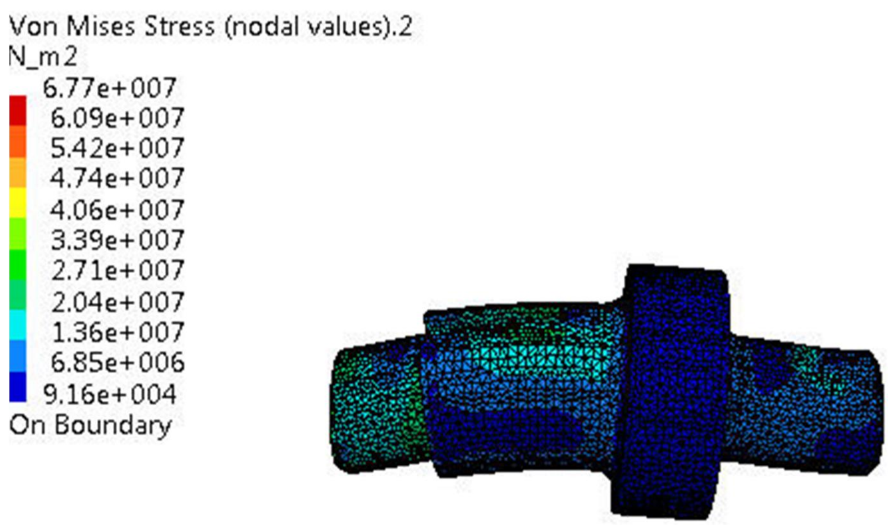


Finite Element Analysis of Shaft for Pinion (Bending)

Materials.1

Material	Carbon steel SAE 1045
Young Modulus	2e+011N_m2
Poisson Ratio	0.3
Density	7860kg_m3
Thermal Expansion	1.17e-005_Kdeg
Yield Strength	5.18e+008N_m2

Static Case Solution.1 - Von Mises Stress (nodal values)

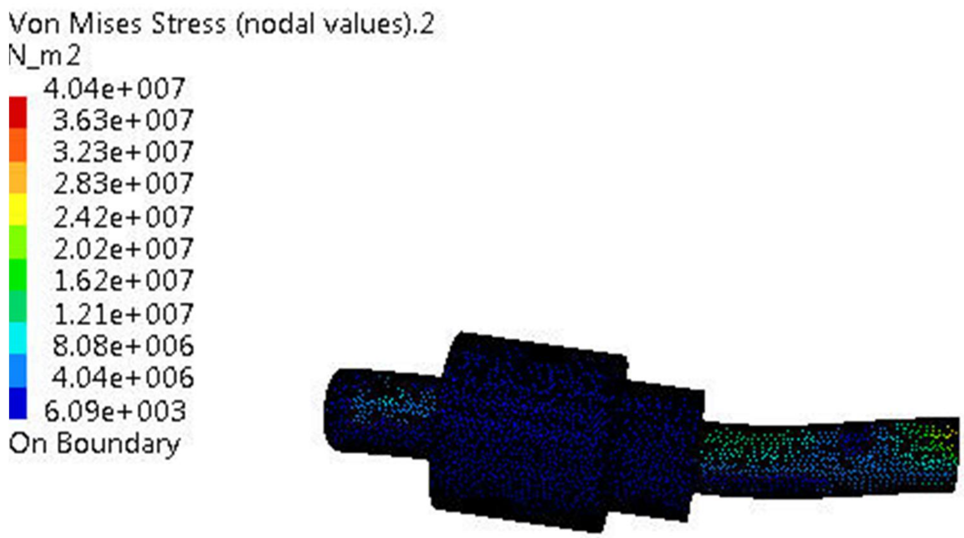


Finite Element Analysis of Shaft for Sprocket (Bending)

Materials.1

Material	Carbon steel SAE 1045
Young Modulus	2e+011N_m2
Poisson Ratio	0.3
Density	7860kg_m3
Thermal Expansion	1.17e-005_Kdeg
Yield Strength	5.18e+008N_m2

Static Case Solution.1 - Von Mises Stress (nodal values)



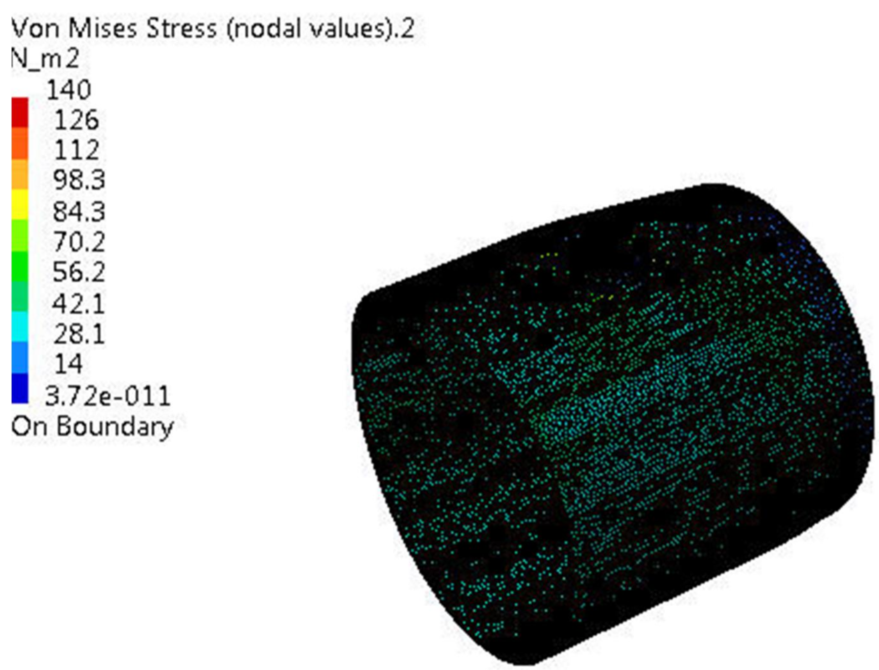
Appendix A-3

Finite Element Analysis of Outer Drum

Materials.1

Material	Aluminium composite 5251 H24
Young Modulus	7e+010N_m2
Poisson Ratio	0.346
Density	2710kg_m3
Thermal Expansion	2.36e-005_Kdeg
Yield Strength	1.5e+008N_m2

Static Case Solution.1 - Von Mises Stress (nodal values)



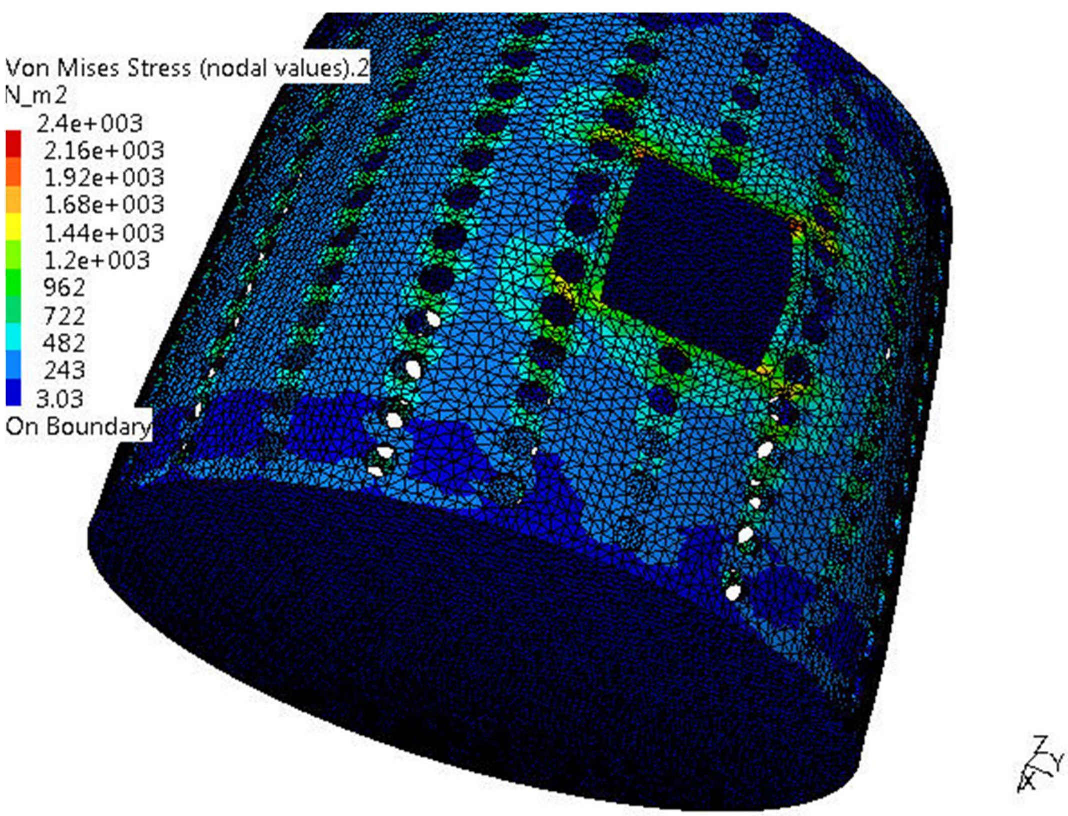
Appendix A-4

Finite Element Analysis of Internal Drum

Materials.1

Material	Aluminium
Young Modulus	7e+010N_m2
Poisson Ratio	0.346
Density	2710kg_m3
Thermal Expansion	2.36e-005_Kdeg
Yield Strength	9.5e+007N_m2

Static Case Solution.1 - Von Mises Stress (nodal values)



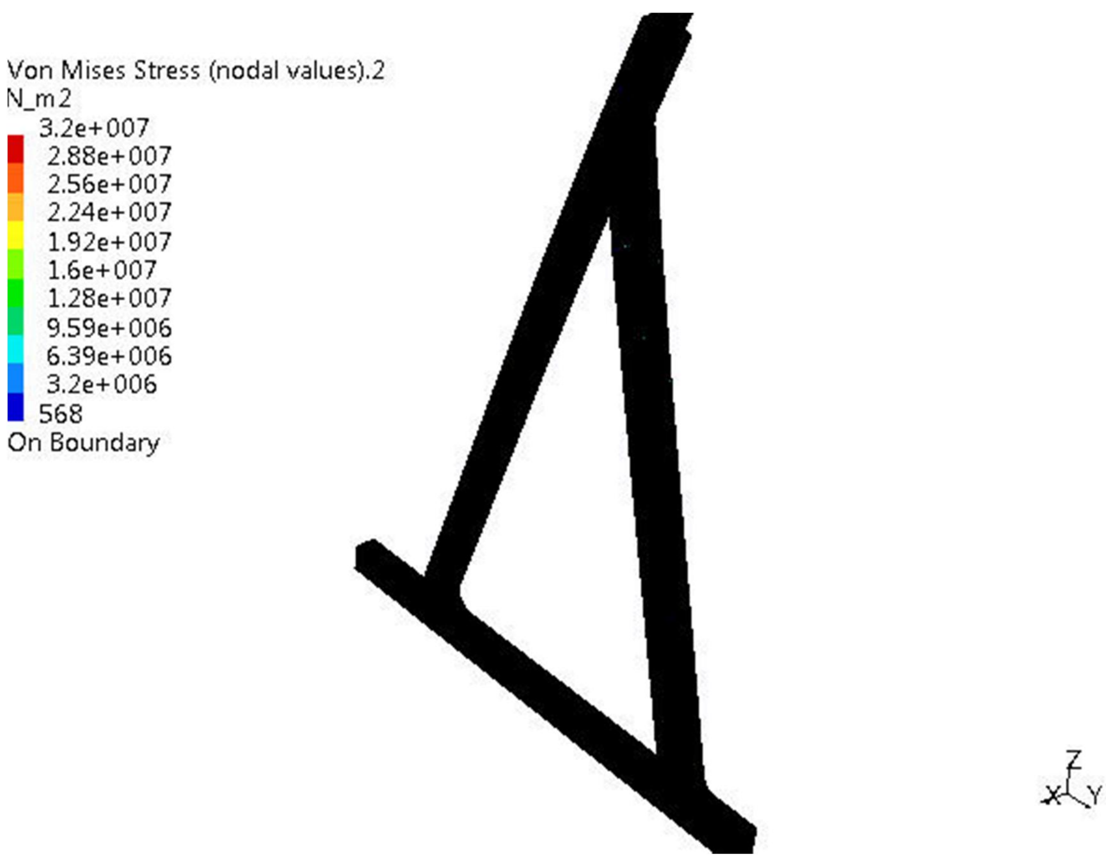
Appendix A-5

Finite Element Analysis of stationery Bic-frame

Materials.1

Material	Carbon steel SAE 1025 annealed
Young Modulus	3e+006N_m2
Poisson Ratio	0.3
Density	7860kg_m3
Thermal Expansion	1.17e-005_Kdeg
Yield Strength	3.7e+008N_m2

Static Case Solution.1 - Von Mises Stress (nodal values)



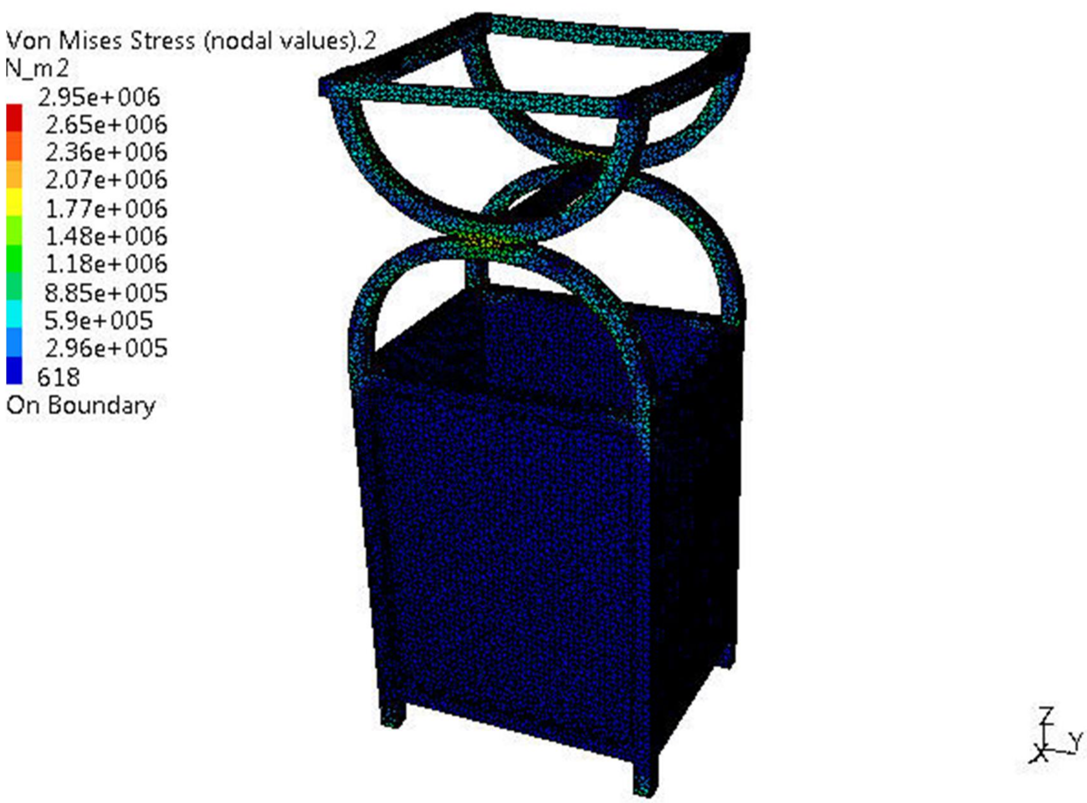
Appendix A-6

Finite Element Analysis of Support Frame

Materials.1

Material	Steel
Young Modulus	3e+006N_m2
Poisson Ratio	0.3
Density	7860kg_m3
Thermal Expansion	1.17e-005_Kdeg
Yield Strength	4.27e+008N_m2

Static Case Solution.1 - Von Mises Stress (nodal values)



Appendix B-2

Calcium Carbonate Method

Source of Water: Adama University

Raw Water PH: 8.30

Raw Water Turbidity: 926 FTU

Raw Water Hardness mg/L as $CaCO_3$: 100.5

Calcium Carbonate to Epsom salt ratio	Calcium Carbonate Dosage	Epsom salt	Residual		
			PH	Turbidity	Hardness
3:1	250mg	83.3 mg	6.87	18.14	142.82