DESIGN AND DEVELOPMENT OF A LOW DENSITY POLYETHYLENE RECYCLING MACHINE

BY

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MATRIC. NO. 2005/21593EA

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BEING A FINAL YEAR PROJECT REPORT SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF BACHELOR OF ENGINEERING (B. ENG.) DEGREE IN AGRICULTURAL AND BIORESOURCES ENGINEERING, FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGER STATE

DECEMBER, 2010

DECLARATION

I hereby declare that this project is a record of a research work that was undertaken and written by me. It has not been presented before for any degree or diploma or certificate at any university or institution. Information derived from personal communications, published and unpublished works of others were duly referenced in the text.

....

Dahunsi, Charles Oluwadare Date

CERTIFICATION

This project entitled "Design and Development of a Low Density Polyethylene Recycling Machine" by DAHUNSI, Charles Oluwadare, meets the regulations governing the award of the degree of Bachelor of Engineering (B. Eng.) of the Federal University of Technology, Minna, and it is approved for its contribution to scientific knowledge and literary presentation.

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Head of Department	
....	8/12/2020 ....
External Examiner	Date

DEDICATION

This project work is solely dedicated to the Author and Finisher of my Soul, Almighty God and to my beloved Parents Mr. and Mrs. Dahunsi.

ACKNOWLEDGEMENTS

My profound gratitude and appreciation go first to the Almighty God, the Author and Finisher of my soul for His love and for sparing my life till this moment. I never knew it would be this possible.

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ABSTRACT

In this work, a low density polyethylene recycling machine was designed, developed and tested. The machine was designed and developed following simple standard engineering principles. The recycling process is aimed at reducing environmental problems caused by improper disposal of used water sachets in Nigeria. The low density polyethylene recycling machine is a simple machine that can conveniently recycle used water sachets by following a series of agglomeration process which consists of heating at a temperature of 115^{0}C by radiation to melt the material into a liquid form, cooling of melted material by convention with the aid of water as a coolant and size reduction of the cooled material to form a pellet. The machine can carry out the whole pre-plasticizing process of heating, rapid cooling and cutting into pellet form in about 1hour 43mints. The machine has an input capacity of 5kg, output capacity of 3.6kg and a power requirement of 2kW. At a machine cutting speed (shaft speed) of 1450rpm, the recycling machine has a melting efficiency of 81%, cooling efficiency of 52% and recovery efficiency of 72%. The machine designed and tested effectively recycled used water sachets. For effective performance, the power requirement for the machine should be above 1.5W at a higher rpm with a tank and pump for a continuous flow of water.

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NOTATIONS

N = Number of revolution per minutes

F = Force acting on the cutting shaft

T_t = Torque of the cutting shaft

n_p = Number of blades

ρ_{ldpe} = Density of the low density polyethylene material

$\dot{\omega}$ = Angular velocity

P_t = Power required to cut the material

y = Deflection of beam

E = Modulus of elasticity

I = Second moment of area

D = Diameter of blade

F_R = Blade resultant force

δ (max) = Maximum stress

α = Arc of contact

θ = Angle of twist

M = Mass per unit length

D_2 = Diameter of the shaft pulley

V_g = Gross volume of pulley

V_h = Volume of hopper

g = Acceleration due to gravity

w = Weight of belt

V_r = Volume taken by V- groove belt

W_p = Weight of pulley

L = Length of belt

ρ = Density of milt steel

D_1 = Diameter of shaft pulley

N_1 = Speed of motor

D_2 = Diameter of shaft

N_2 = Speed of cylinder

C = Center to center distance

T_1 = Tension on tight side

T_2 = Tension on slack side

G = Torsion modulus of rigidity

d = Diameter of shaft

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the study

Plastics have become common materials of our daily living, and many of their properties, such as durability, versatility and light weight, can be a significant factor in achieving sustainable development. However, use of plastics contributes to the growing amount of solid waste generated, since most plastic products are often used only once before disposal. The disposal problem is not simply technical, but it also has social, economic and even political aspects. This is the reason why different methods have been explored and applied for solving the problems associated with polymer waste handling and disposal (Strong, 2000).

Even though external recycling is not the most profitable technique for the treatment of plastic waste, it will have a significant role in the future. In spite of the application of clean technology and waste elimination, it is not expected that the amounts of plastic waste will decline, thus, new recycling method will have to be developed. From the perspective of catalysis, chemical recycling of plastic wastes is the most noteworthy of plastic waste recovery technique (Phillips, 2000).

The world's industrialization and population is growing rapidly and rising sharply. It is estimated to be about 6.5 billion according to the U.S. Census Bureau. The bureau estimated that 249 people are born and 108 people die every minute, meaning that the world's population grew by 141 each minute of 2006. The total is expected to reach 7 billion in 2012. (Microsoft Encarta, 2009). Based on this fact, the demand for an environmental control of the entire world is increasing day by day as it is needed to raise and satisfy the standard of living. Nations with high environmental control always have a better standard of living with good health. In search of developed in stages i.e. from melting of the materials (LDPE) to form a liquid then to cooling were water is use as a coolant. Then a lump is formed inside the mold. The last stage is size reduction were series of blades are welded to a shaft been powered by an electric motor.

1.1 Statement of the Problem

The most critical environmental problems today are those that confront certain countries of the world especially the third world countries, which cover the world's poorest nations and these include countries of Latin America, Africa and Asia. The third world countries are also referred to as developing countries, and Nigeria falls under this category. A growing population and increasing industrialization establish urgent needs to creatively solve the problems of environmental pollution in Nigeria.

The problem usually associated with environmental control particularly in the third world countries may be attributed to the following:-

1. Improper usage of all packaging materials and an effective control of environmental discharges are not properly managed.
2. The cost of mechanical recycling machines i.e. the fabrication and maintenance cost have been a major issue for the individual group.

1.3 Objective of the study

The objective of this study is to design, develop and carry out performance evaluation of a low density polyethylene recycling machine.

improving the standard of living, the world environmental control is seriously increasing at a critical rate when compared to the world population and industry.

Recently, much attention has been directed to the packaging of industrial materials e.g. water sachet, sacks and wraps by a variety of interest groups including: environmentalists, government officials, commercial and retail business men and legislators on the Environmental problems of low density polyethylene (LDPE). Various surveys carried out showed that the percentage of environmental pollution caused by packaging materials wraps and sacks which has been assumed by United State Environmental Protection Agency (USEPA) to be 8.6 percent of the total pollutants in the environment (Phillips, 2000).

Nearly two-thirds of the LDPE found in municipal solid waste originate from packaging. Another sizable fraction comes from non-durable goods, especially trash bags. The two main sources of recycled LDPE are both in the bags, sacks, and wraps category: stretch wrap and merchandise bags. The USEPA calculated that 150 thousand tons of LDPE bags, sacks, and wraps were recovered in 2003, for a recycling rate of 5.7 percent. The overall recycling rate for LDPE in municipal solid waste was 2.4 percent. Also, the overall recycling rate for LDPE in Australia was reported to be 12.2 percent in 2003 above the 2002 rate of 11.2 percent but lower than the 2001 rate of 13.4 percent (Yla-Mella, 2002).

Nigeria has been facing environmental crises over the past ten to fifteen years despite the fact that she is a developing country. The increase in the number of industries and population had led to an increase in environmental pollution which brought about the control measure by recycling LDPE materials to new products.

This research work is aimed to develop a recycling machine of low density polyethylene, which will help to reduce amount of waste materials in the environment. The machines is

1.4 Justification of the Study

Waste materials recycling capability of Nigeria has not been fully exploited due principally to lack of appropriate indigenous processing technology as obtained in other developing Asian countries. Nigeria as a developing country with a growing population and industrialization must ensure a maximum utilization of waste packaging materials of low density polyethylene. To archive this, there is a need to develop an efficient and affordable low density polyethylene recycling technology which can be adopted by people. It is envisaged that manufacturers and research institutions can adopt the developed low density recycling machine for LDPE materials, thus helping to clean up the environment.

1.5 Scope of the Study

The scope of this study is limited to the design, develop and evaluate the performance of a low density polyethylene (LDPE) recycling machine.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Definition of Plastics

Plastics are materials made up of large organic (carbon-containing) molecules that can be formed into a variety of products. The molecules that compose plastics are long carbon-chains that give plastic many of their useful properties. In general, materials that are made up of long, chain-like molecules are called **polymers**. The word plastic is derived from the words *platicus* (Latin for "capable of moulding") and *plastikos* (Greek "to mould," or fit for moulding") (Microsoft Encarta, 2009).

The modern plastics industry can trace its origin back to a century and a half when, in 1862, Alexander Parkes unveiled Parkesine, the first man-made plastic. In 1891, Rayon was introduced, followed by cellophane in 1900 and Bakelite in 1907. There are in excess of twenty different polymer types in common usage today. These include polyvinyl chloride (PVC), polyethylene (PE), polyamide (PA), polystyrene (PS) and polypropylene (PP), which had been developed by the 1960s.

The term 'Plastics' refers to a range of different polymeric materials. These can be broken down into two distinct groups: thermoplastics and thermosets. Thermoplastics soften and melt on heating and may be mechanically recycled into new products when the original product life is finished. Thermoplastics represent some 95% of plastics in use. Thermosets do not soften or melt on heating once moulded and, therefore, cannot be mechanically recycled in the same way as thermoplastics. They may be ground to a powder and used as filler. Alternatively, they may be feedstock recycled or used in energy recovery processes.

Over the years, many recycling machines have been adopted to recycle low density polyethylene materials. Although the performance of these recycling machines has not been satisfactory, there has been an improvement. The low efficiency of these machines is as a result of not considering certain parameters such as the feeding and melting rate and separation and shredding techniques.

Plastics use has grown significantly in the last 50 years. Globally, consumption has risen from 5 million tonnes to some 100 million tonnes. This growth is attributed to the beneficial properties of plastics. They are relatively strong, lightweight and cost-effective. They can be precisely engineered to perform many different functions as evidenced by range of sectors and applications where plastics are used which can be a major contributor to the economy. The UK used approximately 4.5 million tonnes of plastics productions during 2000 and 4.68 million tonnes during 2001. It is estimated that the plastics sector accounted for approximately 7.5 percent of the UK demand for chemicals in 1988 (BiffawardEnviros, 2002).

2.2 General Properties of Plastics

Plastics possess a wide variety of useful properties and are relatively inexpensive to produce. They are lighter than many materials of comparable strength and unlike metals and wood, plastics do not rust or rot. Most plastics can be produced in any colour. They can also be manufactured as clear as glass, translucent (transmitting small amounts of light), or opaque (impenetrable to light).

Plastics have lower density than metals. Most plastics vary in density from 0.9 to 2.2 g/cm^3 compared to density of steel which 7.85 g/cm^3. plastics can also be reinforced with glass and other fibers to form incredibly strong materials. For example, nylon reinforced with glass can have a tensile strength (resistance of a material to being elongated or pulled apart) of up to 165 MPa (Encarta Premium, 2009). The advantages of plastics are lightness and robustness, resistant to rust and corrosion, transparency and they are freely colourable (Microsoft Encarta, 2009).

Plastics however, have some disadvantages. When burned, some plastics produce poisonous fumes. Although certain plastics are specifically designed to withstand temperature as high as 288°C, in general plastics are not used when high heat resistance is needed. Because of their molecular stability, plastics do not easily break down into simpler components. As a result, disposal of plastics creates a solid waste problem. (Encarta Premium, 2009).

Polymers can be separated into two different groups depending on their behaviour when heated. Polymers with linear molecules are likely to be thermoplastic. These are substances that soften upon heating and can be remoulded and recycled. They can be semi-crystalline or amorphous. The other group of polymers is known as thermosets, These are substances that do not soften under heat and pressure and cannot be remoulded or recycled.(Encarta Premium, 2009).

2.3 Thermoplastics and Thermosetting Plastics

All plastics, whether made by addition or condensation polymerization, can be divided into two groups: thermoplastics and thermosetting plastics. These terms refer to the different ways these types of plastics respond to heat. Thermoplastics can be repeatedly softened by heating and hardened by cooling. Thermosetting plastics, on the other hand, harden permanently after being heated once.

The reason for the difference in response to heat between thermoplastics and thermosetting plastics lies in the chemical structure of the plastics. Thermoplastics molecules, which are linear or slightly branched, do not chemically bond with each other when heated. Instead, thermoplastics chains are held together by weak van der Waal forces (weak attractions between the molecules) that cause the long molecular chains to clump together like piles of entangled spaghetti. Thermoplastics can be heated and cooled, and consequently softened and hardened, repeatedly, like candle wax. For this reason, thermoplastics can be remoulded and reused almost indefinitely.

Thermosetting plastics consist of chain molecules that chemically bond or cross-link with each other when heated. When thermosetting plastics cross-link, the molecules create a permanent, three-dimensional network that can be considered one giant molecule. Once cured, thermosetting plastics cannot be re-melted in the same way that cured concrete cannot be reset; consequently, thermosetting plastics are often used to make heat-resistant products because these plastics can be heated to temperature of 260°C without melting. (Encarta Premium, 2009).

The different molecular structures of thermoplastics and thermosetting plastics allow manufacturers to customize the properties of commercial plastics for specific applications. Because thermoplastic materials consist of individual molecules, properties of thermoplastics are largely influenced by molecular weight. For instance, increasing the molecular weight of a thermoplastic material increases its tensile strength, impact strength, and fatigue strength (ability of a material to withstand constant stress). Conversely, because thermosetting plastics consist of a single molecular network, molecular weight does not significantly influence the properties of these plastics. Instead, many properties of thermosetting plastics are determined by adding different types and amounts of fillers and reinforcement, such as glass fibres (Encarta Premium 2009).

2.4 Amorphous and Crystalline Materials

Amorphous materials are those in which molecular chain structure is random and becomes mobile over a wide temperature range. It means these materials do not literally melt but rather soften and they begin to soften as soon as heat is applied to them. They get softer and as heat is absorbed until they degrade as a result of absorbing excessive heat. Examples of amorphous materials are , acrylic, polyaryluate and polystyrene.

In crystalline materials, the molecular chain structure is well ordered and become mobile only after the material is heated to its melting point. That means such materials do not go through a softening stage but stay rigid until they are heated to the specific point at which they immediately melt. They will degrade if excessive heat is absorbed. Examples of crystalline materials are acetal, nylon, polyester, polyethylene and PVC (Encarta Premium 2009).

2.5 Forms of Recycling

As a result of many years of technology development, plastic waste is now recycled by different methods. These methods may be grouped into three main categories as explained below.

Mechanical Recycling

Plastics can also be recovered from waste via mechanical recycling. The mechanical recycling process involves a number of operational steps: separation of plastics by resin type, washing to remove dirt and contaminants, grinding and crushing to reduce the plastics particle size, infusion by heat and reprocessing into new plastic goods. This type of recycling is mainly restricted to thermoplastics because thermosetting cannot be remoulded by the effect of heat (Aguado and Serrano, 1999).

Mechanical recycling of plastics is limited by the compatibility between the different types of polymer. Presence of a polymer dispersed in a matrix of a second polymer may dramatically change the properties and hinder the possibility of its use in the conventional application. A good example of this is the impact of polyvinyl chloride (PVC) during polyethylene terephthalate (PET) processing. Only a small amount of PVC in the recycling PET strongly reduces the commercial value of the lather (Aguado and Serrano, 1999). Another problem with mechanical recycling is the presence in plastics waste of products made of the same resin but with different colours, which usually impact an undesirable grey colour to the recycling plastic (Aguado and Serrano, 1999).

In addition, most polymers suffer certain degradation during their use to effects of temperature, ultraviolet radiation oxygen and ozone. Therefore, recycled polymer exhibits lower properties and performance than the virgin polymers, and are useful only for undemanding and lesser value applications. Recycling of plastics without prior separation by resin produces a material with mechanical properties similar to timber. Hence, it is often used for the replacement of timber in certain applications. A higher quality of recycled plastics is achieved when separation by resin is carried out prior to the re-moulding step (Aguado and Serrano, 1999).

Feedstock Recycling

Feedstock recycling of plastics, also called chemical or tertiary recycling is based on the decomposition of polymers by means of heat, chemical, or catalytic agent to yield a variety of products ranging from the chemical monomers to a mixture of compounds with possible applications as a source of chemicals or fuels (Aguado and Serrano, 1999). The chemical recycling processes can be classified into three main areas (Janssen and van Santen, 1999) as: recycling to fuels (gasoline, liquefied petroleum gas (LPG) and diesel oils); recycling to monomers; and recycling to industrial chemicals.

Depending on recyclable plastics types, desired composition and molecular weight of products, many different methods of feedstock recycling can be implemented within the areas mentioned above (Yia-Mella, 2002; Janssen and van Santen, 1999). Until now, only a small number of chemical recycling methods have been commercially realized but the interest in more efficient processes is still growing due to the emerging need of polymer waste recycling in the future. At the present, feedstock recycling is more limited by process economy than by technical reasons. The factors which determine the profitability of alternative feedstock recycling methods are degree of separation required in raw wastes, the value of the products obtained, and the capital investments in the processing facilities (Aguado and Serrano, 1999).

According to the separation steps required, the methods can be ordered as follows: gasification, thermal treatment, hydrogenation, catalytic cracking and chemical depolymerization. However, the feedstock methods can be ordered also according to the commercial value of the product. In that case, the order of methods will follow: thermal oils, synthesis gas, hydrogenation oils, catalytic oil and monomers. It is interesting to note that the required pre-treatment and product value follow almost reverse orders (Aguado and Serrano, 1999).

Energy Recovery

Waste incineration, or controlled burning, is typically considered as a disposal method, because it is usually applied as a method of reducing the volume of miscellaneous municipal waste. However, incineration of plastic can also be seen as recovery method, as plastics could replace the application of other oil-based fuels. It can be viewed that the plastics application is the first purpose of oil, and energy production is the secondary task. Indeed incineration with energy reclamation is considered as a recovery method and, due to their high energy content, plastics waste is a valuable fuel. The heat capacity of plastics and some other materials are shown in Table

Table 2.1; Heat Capacities of Plastics and Some Other Materials

Material	Heat Capacity (MJ/Kg)	Material	Heat Capacity (MJ/Kg
PVC	18	Heavy Fuel Oil	41
PE	27	Coal	26
PET	46	Natural Gas	36
PS	41	Milled Peat	10

ABS	35	Paper	17

Unit MJ/m^3 (0^oC)

Source: Yia-Mella (2002)

2.6 Waste Management Hierarchy

This is a framework that ranks waste management in the order of sustainability and in accordance with the environmental impact. The terms are as discussed below (Brown, 2006).

Reduce- means to avoid or reduce the production of waste from source, i.e. waste minimization, thus reducing costs and environmental impacts.

Re-use- some materials and productions can be used again for either the same or different purposes (e.g. milk bottle).

Recycle- materials can be used in production processes or as secondary or raw materials (e.g. aluminum cans). Also composition of green waste does what??

Recovery- where none of the above is possible, the next best thing is to regain as much value as possible through energy recovery.

Disposal- If none of the previous options offers an appropriate solution, only then should waste be disposed of (e.g. landfill).

2.7 Plastics and their Environment

Plastics are used throughout the world for a broad number of reasons. Although plastic is certainly a globally important project, there are many environmental concerns associated with its use. One of the positive characteristics of plastic is the fact that it is durable. Unfortunately, this is not a positive characteristic when it comes to the environment. The fact that a plastic is durable means it degrades slowly. In addition, burning plastics can sometimes result in toxic fumes. Aside from trying to get rid of plastic, creating it can be costly to the environment as well. It takes large amounts of chemical pollutants to create plastic, as well as significant amounts of fossil fuels. On the other hand, some argue that plastics help the environment in several ways. After all, plastic has been used to make cars lighter. As a result, less oil is used to mobilize the car and less CO_2 is emitted. In addition, plastic containers provide safe ways for disposing of toxic wastes products.

The world annual consumption of plastic materials has increased from around 16.8% million tonnes in the 1950s to nearly 100 million tonnes today. In the UK, a total of approximately 4.7 million tonnes of plastic products were used in various economic sectors in 2001 (Aguado and Serrano, 1999).

2.8 Uses of Plastics

Plastics are indispensable to our modern way of life. Many people sleep on pillows and mattresses filled with a type of plastic, either cellular polyurethane or polyester. At night, people sleep under blankets and bedspreads made of acrylic plastics, and in the morning, they step out onto polyester and nylon carpets. The cars we drive, the computers we use, the utensils we cook with, the recreational equipment we play with, and the houses or buildings we live and work in all include important plastic components. The average car contains almost 136kg of plastics nearly 12percent of the vehicle's overall weight. Telephones, textiles, compact disc, paints, plumbing fixture, boats, and furniture are other domestic products made of plastics. In 1979 the volume of the plastics produced in the United States surpassed the volume of domestically produced steel. (Aguado and Serrano, 1999).

Plastics are used extensively by many key industries, including the automobile, aerospace, construction, packaging and electrical industries. The aerospace industry uses plastics to make strategic military parts for missiles, rockets, and aircrafts. Plastics are also used in specialized field and bio-compatible joints. Packaging represents the largest single sector of plastics use in the UK. The sector accounts for 35% of UK plastics consumption and plastics are the material of choice in nearly half of all packaged goods (Aguado and Serrano, 1999).

2.9 Types of Plastics

There are about 50 different groups of plastics, with hundreds of different varieties. All types of plastics are recyclable. To make sorting and thus recycling easier, the American Society of Plastics Industry developed a standard marking code to help consumers identify and sort the main types of plastic. These types and their most common uses are (BiffawardEnviros, 2002):

Polyethylene terephthalate (PET) – Fizzy drink bottles and oven-ready meal trays.

High density polyethylene (HDPE) – Bottles for milk and washing-up liquids.

Polyvinyl chloride (PVC) – Food trays, cling firms, bottles for squash, mineral water and shampoo.

Low density polyethylene (LDPE) – Carrier bags and bin liners.

Polypropylene (PP) – Margarine tubs, microwaveable meal trays.

Polystyrene (PS) – Yoghurt pots, foams meat or fish trays, hamburger boxes, egg cartons, vending cups, plastic cutlery and protective packaging for electronics goods and toys.

OTHERS- Any other plastics that do not fall into any of the above categories – An example is melamine, which is often used in plastic plates and cups.

2.10 Recycling Effect of Contamination

In polymers used for recycling, contamination is present everywhere, resulting in reduction of the quality of recycling. It can be in form of dirt, printing inks, metals, foil, additives, pesticides, partially oxidized polymers; contamination by foreign bodies can be noticed even in PET and HDPE bottles collected from roadsides. In very old scraps of building products, electrical and electronic system, vehicles and furniture which now come for recycling may contain very high concentration of additives in particular, fire retardants, which are now banned. However, accidental or unintentional mixtures and multi-component productions do pose problems (BiffawardEnviros, 2002).

2.11 Common Contaminants in Recycled Polymers

Table 2.2; the common contaminants in recycled polymers

Polymer	Recycled source	Contaminants
PET	Beverage bottles	PVC, green PET, Al, water, glue,
HDPE	Milk/water bottles	PP, milk residue, pigments,
LDPE	Greenhouse films	Insecticides, soil, Ni, oxidation product
LDPE	Shopping bags	Paper receipts, printing ink,
PP	Battery cases	Pb, Cu, acid, grease, dirt
HDPE	Detergent bottles	Paper, glue, surfactants, bleach,
PET	Photographic film	Silver halides, gelatin, caustic residues
Phenol	Circuit boards	Cu, tetrabromobisphenol A
LDPE	Multilayer film	Ethylene vinyl alcohol, polyamide, ionomer
PVC	Beverages bottles	PET, PE, paper, Al foil, PP

ABS retardants	Appliances housings	Polybrominated flame
SBR extender	Automobile tires	Steel wires, fibber, and oil
LDPE	Mulch film	Soil (up to 30%), iron (up to 3% in soil)

Source; BiffawardEnviros, (2002)

2.12 Main Categories of Recycling Plastics

The four main categories of recycling plastics according to (BiffawardEnviros, 2002) are:

Primary Recycling: This is the conversion of waste plastics into products having performance level comparable to that of original products made from virgin plastics.

Secondary Recycling: This entails the conversion of waste plastics into products having less demanding performance requirements than the original material.

Tertiary Recycling: This is the process of producing chemicals/fuels/similar products from waste plastics.

Quaternary Recycling: This is the process of recovering energy from waste plastics by incineration.

2.13 Percentage of Household Dustbin

According to Parfitt (2002), a plastic makes up around 7% of average household dustbin (Figure 2.1).

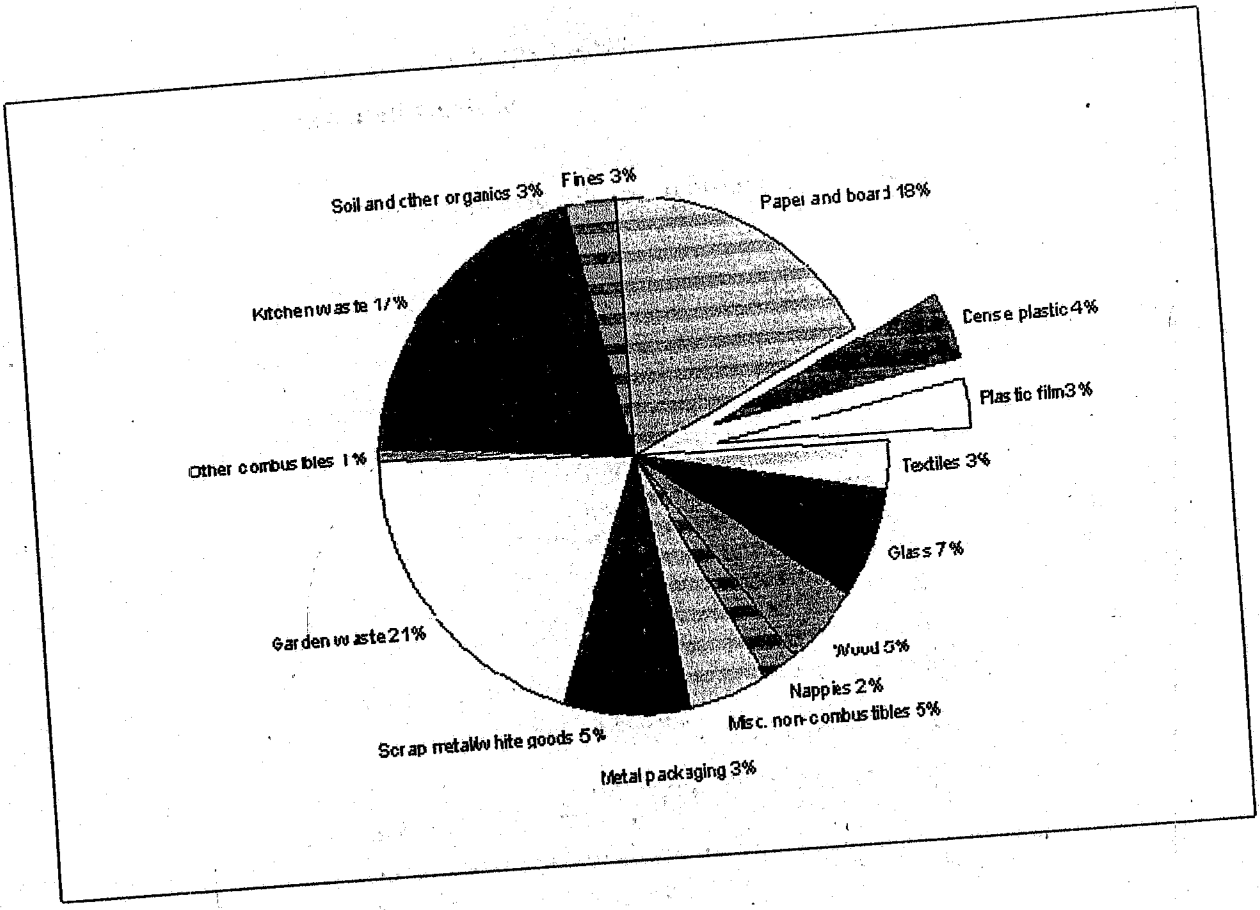


Fig. 2.1: Analysis of Household Waste Compositions

Source: Parfitt (2002)

The amount of plastic waste generated annually in the UK is estimated to be nearly 3million tonnes. An estimated 56% of all plastics waste is used packaging, three-quarters of which are from household. It is estimated that 7% of total plastic waste arising are currently being recycled.

The production and use of plastics has a range of environmental impacts. Firstly, plastics production requires significant quantities of resources, primarily fossil fuel, both as a raw material and to deliver energy for the manufacturing process. It is estimated that 4% of the world's annual oil production is used as a feedstock for plastics production and an additional 3-4% during manufacture (Parfitt, 2002).

2.14 Benefits of Plastics

The considerable growth in the plastic use is due to the beneficial properties of plastics which include among others (Parfitt, 2002):

i. Extreme versatility and ability to be tailored to meet very specific technical needs.
ii. Lighter weight than competing materials, reducing fuel consumption during transportation.
iii. Extreme durability.
iv. Resistance to chemicals, water and impact.
v. Good safety and hygiene properties for food packaging.
vi. Excellent thermal and electrical insulation properties.
vii. Relative inexpensive to produce.

2.15 Plastics for Recycling

Not all plastics are recyclable. There are 4 types of plastics which are commonly recycled. They are high density and low density polyethylene, polypropylene, polystyrene and polyvinyl. A common problem with recycling plastics is that plastics are often made up of more than one kind of polymer or there may be some sort of fiber added to the plastic (a composite) to give added strength. This can make recovery difficult.

2.16 Sources of Waste Plastics

Industrial waste (or primary waste) can often be obtained from the large plastics processing, manufacturing and packaging industries. Rejected or waste materials usually have good characteristics for recycling and will be clean. Although the quality of material available is sometimes small, the quantities tend to be growing as consumption, and therefore production, increases. A commercial waste is often available from workshops, craftsmen, shops, supermarkets and wholesalers. A lot of the plastics available from these sources will be high density and low density polyethylene and often contaminated.

Agricultural wastes can be obtained from farms and nursery gardens outside the urban areas. These are usually in form of packaging (plastic containers or sheets) or construction materials (irrigation or hosepipes). Municipal wastes can be collected from residential areas (domestic or household wastes), street, parks, collection depots and waste dumps. In Asian cities these types of waste are common and can either be collected from the streets or can be collected from households by arrangement with the householders (Lardinois, 1995).

2.17 Identification of Different Types of Plastics

There are several simple tests that can be used to distinguish between the common types of polymers so that they may be separated for processing. These tests are discussed below and possible results presented in Table 2.3 (Vogler, 1984).

Water test: After adding a few drops of liquid detergent to some water, put in a small piece of plastic and see if it floats.

Burning test: Hold a piece of the plastic in a tweezers or on the back of a knife and apply a flame. Dose the plastic burn? If so, what color?

Fingernail: can a sample of the plastics be scratched with a fingernail?

Table 2.3 Identification of Different Types of Plastics

Test	PE	PP	PS	PVC
Water	Floats	Floats	Sinks	Sinks
Burning	Blue flame	yellow flame	yellow sooty smell	yellow sooty smoke
Smell after burning,	like candle wax	like wax	Sweet	hydrochloric acid
Scratch	Yes	No	No	No

To confirm PVC, touch the sample with a red-hot piece of copper wire and then hold to the flame. A green flame from the presence of chlorine confirms that it is PVC. To determine if a plastic is a thermoplastic or a thermoset, take a piece of wire just below red heat and press it into the material, if the wire penetrates the material, it is a thermoplastic; if it does not it is a thermosets.

2.18 Processing of Reclaimed Plastic

Once the plastic has been collected, it will have to be cleaned and sorted. The technique used will depend on the scale of operation and the type of waste collected, but at the simplest level will involve hand washing and sorting of the plastic into the required groups. More sophisticated mechanical washers and solar drying can be used for larger operations. Sorting of plastics can be by polymer type (thermoset or thermoplastics for example), by product (bottles, plastic sheeting) or by colour.

2.19 Research and Development in Polymer Recycling

Recycling of wastes has been practiced for a long time; much impact is bearing seen in the developing countries of Africa and Europe.

ONITIRI and ADENIYI (2002) in their research demonstrated and showed that the compression test on recycled and virgin unplasticized Polyvinylchloride (UPVC) undue transverse loading at different temperature shows that recycled UPVC exhibits better rigidity for all the temperature considered except at 40°c where a stress at yield of 0.5919m*Pa* and 0.6131m*Pa* was recorded for recycled and virgin (UPVC) respectively. The recycled UPVC shows poor dimensional stability at temperature between 25°C and 85°C with great improvement at 100°C and 115°C (16:9760% and 22.8960%, respectively) as compared to strain at fracture of 37.1300% and 42.3910% respectively for virgin UPVC.

Recycled UPVC was found to be a reliable, and in some cases a better alternative to virgin UPVC. Improvement in the mechanical properties of recycled UPVC can be achieved if greater attention is given to purity, homogeneity, and previous history of the UPVC regrind.

Jawad Bhatti (2010) affirmed in is work that a plastic can be made as energy recovery. In south korea, startup named G.R. Technology invented a plastic- fueled burner in 1999 after conducting emissions testing between 2005 – 2007 in conjunction with Penn State University, a subsidiary of G.R technology. These boiler are designed to startup on diesel or kerosene fuel and then run indefinitely on PE or PP

The units are rated to produce 100,000kcal/hr (418.4MJ/hr 19.81b/hr) of feed with 11,500kcal/kg (48.1MJ/kg) plastic fuel pellets. These as emerged to provide plastic fuel of Eco - Clean Burners using the process developed and called "plasto fuel"

Also, at energy conference Jawad.A.Bhatti and J, Col, (2010) recently unveiled a prototype double tank waste graduated combuster for dedicated plastic combustion. The system utilized an upper tank for the pyrolysis of plastic and a lower tank to combust and generates heat and steam.

Al- Salem, lettieri, baeyens (2009) reported in a research work on recycling and recovery routes of plastics solid waste. In is paper, recent progress in the recycling and recovery. A special emphasis was paid on waste generated from polyolefinic source which makes up great percentage of our daily life circle. Plastic product and the four routes of PSW treatment are detailed and discussed covering primary (re-extrusion), secondary (mechanical), tertiary (chemical) and quaternary (energy recovery) scheme and technologies. Although primary and secondary recycling scheme are well established and widely applied. Ii was concluded that many of the PSW tertiary and quaternary treatment scheme appears to be robust and worthy of additional investigation.

Steve Clarke, P. Eng. Kemptville, OMAFRA, and Carl Fletcher, Guelph, OMAFRA. (2002) developed a pilot project plan on polymer to assess the problems and commercial viability associated with the recycling of agricultural plastic. This project has been joint effect of the Ontario soil and crop improvement Association and Food (OMAF). Field research for the project has consisted of a number of pilot collections across Ontario in Alexandria

CHAPTER THREE

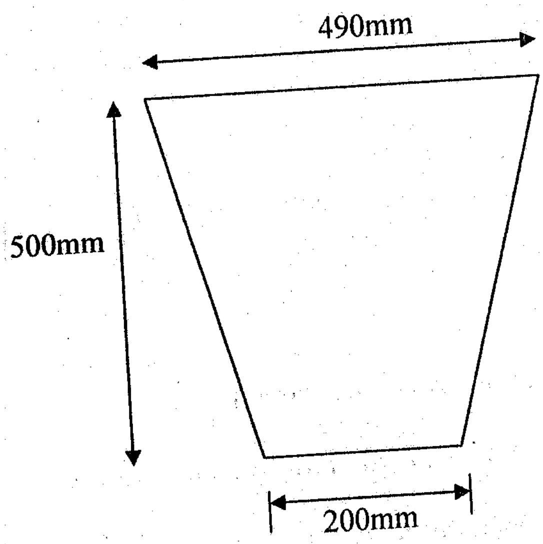
3.0 MATERIALS AND METHODS

3.1 Design Analysis

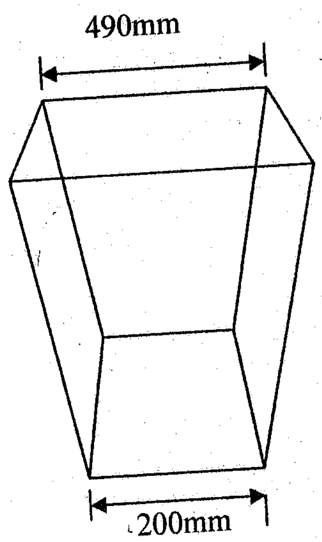
Design analysis is the process aimed at evaluating the necessary design parameters, strength and type of materials for consideration in the selection of the various machine parts in order to avoid failure by excessive yielding and fatigue during the required working life of the machine parts. The results of this analysis will be incorporated in the design calculation to prevent the possibility of under design or over design of parts for the fabrication of the machine.

3.1.1 Design of Hopper

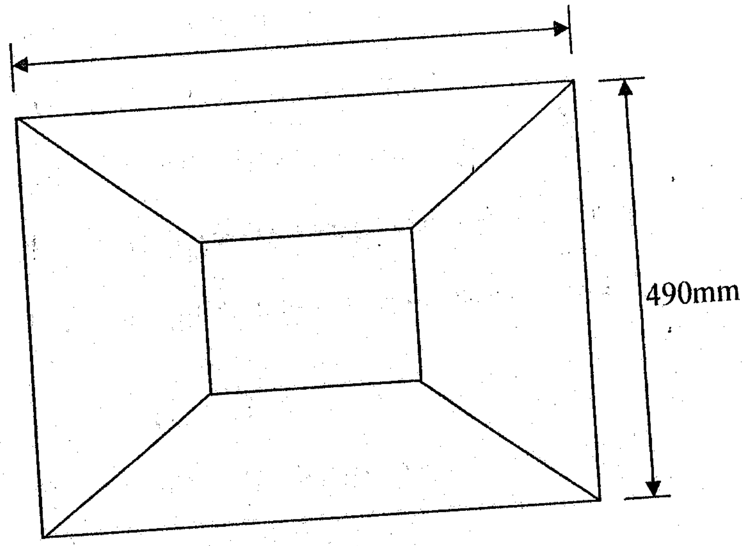
During hopper design, an important consideration is taken to achieve mass out-flow of material out from the hopper thereby minimizing arching (i.e. where no flow occurs) and funneling (i.e. where flow may be reduced). Also the hopper's strength and capacity are taken into consideration. In designing a hopper, it is recommended that the angle of inclination of the sides of the hopper to the horizontal must be greater than the angle of friction between the hopper wall and the material. The cross-section of the hopper is shown in figure 3.1(a, b, c)



(a)



(b)



(c)

Assuming that the hopper is fully loaded with polyethylene, the weight of polyethylene to be fed into the hopper will be:-

$mass\ of\ one\ piece\ of\ polyethlene = 2.32g = 2.32 \times 10^{-3}$kg

$for\ one\ piece = 2.32 \times 10^{-3}$kg

$$Where\ g\ =\ 9.81\text{m/s}$$

$Fg\ =\ 2.32 \times 10^{-3} \times 9.81 = 0.0227592$kg

$Then, the\ weight\ of\ 220\ packs\ =\ 5.0001$kg

= 5kg

3.1.2 Hopper Capacity

In determining the capacity of the hopper, the volume of the hopper is considered by Beyer 1987 using "Cavalien's theorem". Gave an expression for calculating volume of hopper, He stated that the hopper as a Frustum of pyramid shape. Regardless of the shape of the base, whether circular in the case of a cone or square in the case of Egyptian pyramid or any other shape,

Pyramidal frustum is

$$Volume = {}^{1}/_{3}\,h\left(A_1 + A_2 + \sqrt{A_1 A_2}\right) \quad \text{.......(3.1)}$$

Where; A_1 = Area of the top

A_2 = Area of the bottom

h = Height of the hopper

Considering the following dimension;

$Length\ of\ the\ top\ = 0.49m$

$Breadth\ of\ the\ top\ = 0.49m$

$Length\ of\ the\ bottom\ = 0.2m$

$Breadth\ of\ the\ bottom\ = 0.2m$

$Height\ of\ the\ hopper = 0.5m$

$Therefore;$

$Area\ of\ the\ top, A1\ = 0.49 \times 0.49$

$= 0.2401m^2$

Area of the bottom

$A2 = 0.2 \times 0.2$

$= 0.04m2$

Substituting in equation (3.1),

Volume of hopper $= V = {}^1/_3\, h(A_1 + A_2 + \sqrt{A_1 A_2})$

$= {}^1/_3 \times 0.5[(0.2401 + 0.04) + \sqrt{0.2401 \times 0.04}]$

$= {}^1/_3 \times 0.5(0.2801 + 0.098)$

$= {}^1/_3 \times 0.5(0.3781)$

$= {}^1/_3\,(0.18905)$

$= 0.063016666$

$= 0.06302m^3$

Using 20% as a factor of safety for the capacity of the hopper

$= \frac{20}{100} \times 0.06302$

$= 0.012604m^3$

This is the capacity of the hopper= $0.012604 + 0.06302 = 0.075624m^3$

3.1.3 Quantity of Heat Require To Melt the Material

Mass of material to be recycled (m) = 5kg

Expressing the value of (m) in volume

From density $(\rho) = {}^m/_v$.. (3.2)

$V = {}^m/_\rho$

Where ρ = density of the material (i.e. LDPE)

$$\rho = \frac{920kg}{m3} \text{ (martienssen and warlimort 2005)}$$

Using the mass, the volume of the material to be recycled

$$(V) = \frac{5kg}{920kg/m^3} = 5.435 \times 10^{-3} m^3$$

Taking 20% as a factor of safety

$$V = \frac{20}{100} \times 5.435 \times 10^{-3} m^3 = 1.0869 \times 10^{-3} m^3$$

$$Total\ Volume\ (V) = (5.435 \times 10^{-3} m^3 + 1.0869 \times 10^{-3}$$

$$= 1086.905435 m^3$$

$$\approx 1086.91 m^3$$

$$Melting\ point\ of\ the\ material\ (low\ density\ polyethylene) = 115°C$$

Therefore quantity of heat required to melt 5kg of the material,

Q=MCΔT...(3.3)

That is $Q = MC\Delta T$

Where $m = 5kg, C = 2.302KJ/KgK, T_1 = 25°C\ or\ 298K,$

$T2 = 115°C\ or\ 388K$ (T_1 = room temperature, T_2 = melting temperature)

$$Q = 5kg \times 2.302 \times (115 - 25)$$

$Q = 1035.9\text{kg}$

Therefore,

Wattage, $W = Q/T$

W = 1035.9kg/5 × 60

W = 3.453kw

3.1.4 Cooling Chamber

A tank of water with the following dimensions as stated below.

L = 49cm

B = 49cm

H = 10cm

Volume of a tank = Length × Breadth × Height

= 49cm × 49cm × 10cm

=24010cm

=0.02401m^3

3.1.5 Mould Design

The shape of mold is a frustum like with the following dimensions.

Diameter of the top = 3.6cm = 0.036m

Diameter of the bottom = 4cm = 0.04m

Height of the frustum = 10cm = 0.1m

3.1.6 Volume of Frustum

The total number of frustum in the cooling chamber is nine (9).

Volume of a frustum V

$$V = \frac{\pi}{3} h \left(R^2 + r^2 + R \times r\right) \quad \text{......(3.4)}$$

$$= \frac{\pi}{3}\, 10\, (0.02^2 + 0.018^2 + 0.02 \times 0.018)$$

$$= \frac{\pi}{3}\, 10\, (0.0004 + 0.000324 + 0.02 + 0.018)$$

$$= \frac{\pi}{3}\, 10\, (0.000724 + 0.00036)$$

$$= \frac{\pi}{3} (0.001084)$$

$$= 0.104719755\, (0.001084)$$

$$= 0.000113516$$

$$V = 1.135 \times 10^{-4} m^3$$

Total Volume = (volume of a frustum × Total number of frustum)

$$V = 1.135 \times 10^{-4} \times 9$$

$$= 0.0010215$$

$$= 1.0215 \times 10^{-3} m^3$$

Therefore; to determine the amount of water in the cooling chamber

Volume of water = (volume of a tank – total volume of the frustum)

Total volume of water = $(0.0240 - 1.0215 \times 10^{-3})\ m^3$

$= 2.2989 \times 10^{-2} m^3$

3.1.7 Heat Loss

$$= MC\Delta T \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.5)$$

$$\text{where } \Delta T = T2 - T1 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.6)$$

$T_1 = 0°C \text{ or } 273K$

$T_2 = 115°C \text{ or } 388K$

$\Delta T = 273 - 388$

$\Delta T = -1550C$

$= 5kg \times 2.302 \times -155°C$

$\text{Heat loss} = 1784.05kg$

3.1.8 Rate of Cooling

$$\text{Rate of cooling} = \frac{\text{heat loss}}{\text{time}}$$

$$= \frac{1784.05kj}{45 \times 60}$$

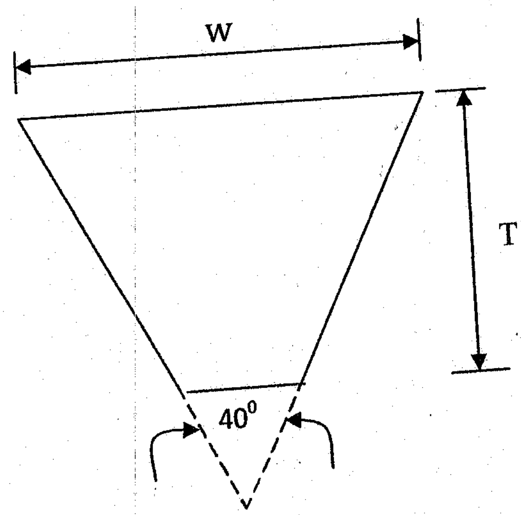
$= 1.3215185kJ/sec$

3.1.9 Belt Selection

V – Belt (based on the usual load of drive 0.75 – 5kw power). The *V*- belt is made of fabric and cords moulded in rubber and normally covered with fabric and rubber. These belts are moulded to a trapezoidal shape and are made endless. These are particularly suitable for short drives. The included angle for *V*-belt is usually from 30^0 to 40^0. The power is transmitted by the wedging action between the belt and the *V*-groove in the pulley or sheave. A cross-section of V-groove belt is shown in figure 3.2

3.1.10 Determination of the Maximum Power of Belt

Calculation of the belt speed



For V – belt A, the following are the data of the sections:-

Figure 3.2; cross section of V- groove belt

Usual load of drive = 0.75 – 5kw

Recommended minimum pulley pitch diameter, dp = 0.09m,

Motor speed N1 = 1450m

Normal thickness, T = 8mm

Weight per metre = 0.100kg

Required shaft speed = 2000rpm (khurmi and Gupta 1979)

Belt speed, $S = \pi dpN_1$ .... (3.7)

$$S = \frac{3.142(0.09 \times 1450)}{60} = 6.833\text{m/s}$$

Required motor speed = 1450 rpm

Speed ratio; $Vs = \frac{n_1}{n_2} = \frac{1450}{2000} = 0.725$

3.1.11 Angular Velocity of Motor-Cylinder Belt

$$W_2 = \frac{2 \times \pi \times 1450}{60} = 151.863\ rad/s$$

$$W_1 = \frac{2 \times \pi \times 2000}{60} = 209.467\ rad/s$$

3.1.12 Power on Motor-Cylinder Belt

Power = torque × angular velocity

=Tw.. (3.8)

Torque on motor-pulley to accelerate the cylinder = $tm = w_2 r_2$ .... (3.9)

r_2 = radius of motor-pulley

Hence,

Power = $tm\ w_2 = w_2^2 r_2$

Therefore, power delivered by the motor

$Pm = (151.863)^3 \times \frac{0.12}{2}$

= 1383.742 *watts*

For efficiency of 95%

$= \frac{95}{100} \times 1383.742$

= 1314.555 *watts*

3.1.13 Cutting Blades on the Rotating Shaft

Ahuja and Shama, 1989 establish spike spacing for his manually operated shredding machine at 30 to 50mm. most existing shredders have one legged spike. In this design, one legged spike of 10cm × 10cm spacing is used.

The cutting blade is made of mild steel with height H = 12.5cm sin 60 = 10.8253cm

Diameter = 4cm

Volume of each cutting blade = πr^2 (length)

$= \frac{4^2}{2} \times 12.5$

$= 8 \times 12.5$

$= 100\ cm^3$

Mass of each cutting blade = Volume × Density

$= 100 \times 7850$

$= 785000Kg$

3.1.14 Motor-Cylinder Design Calculation

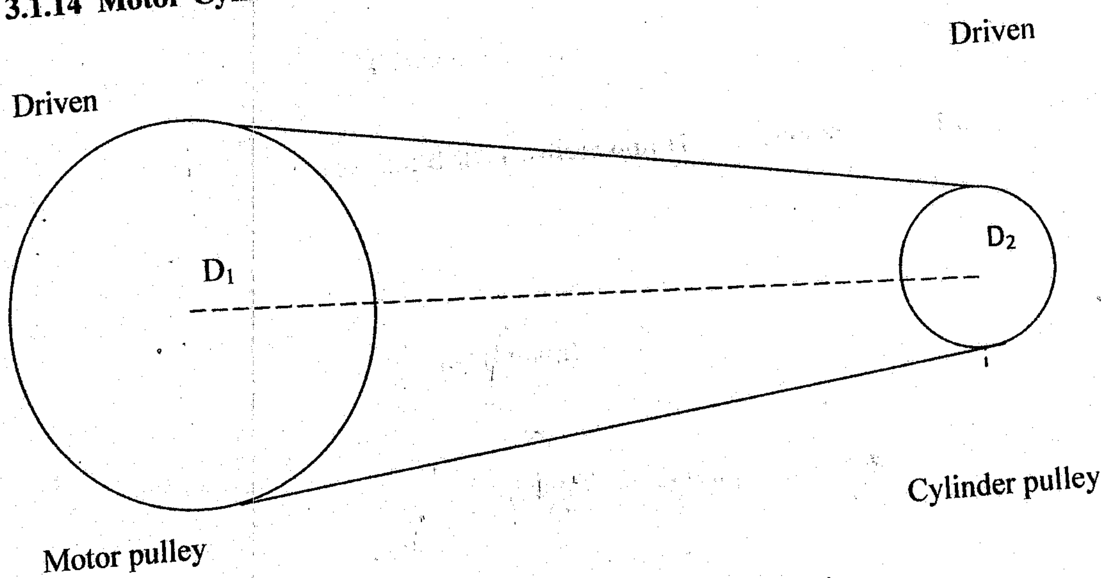


Figure 3.3: Motor-Cylinder Pulley Belt Arrangement

$$\frac{D_1}{D_2} = \frac{N_1}{N_2}$$

Where,

D_1= diameter of motor pulley = 12cm

D_2 = diameter of the shaft driven pulley =?

N_1 = Speed of electric motor = 1450*rpm*

N_2 = Speed of rotating shaft = 2000*rpm*

From the equation;

$$\frac{D_1}{D_2} = \frac{N_1}{N_2} \quad (3.10)$$

$$D_1 N_2 = D_2 N_1 \quad (3.11)$$

$$D_2 = \frac{D_1 N_2}{N_1} \quad (3.12)$$

$$= \frac{12 \times 1450}{2000}$$

$$= \frac{17400}{2000}$$

=8.7cm

= 9.0cm

If the diameter of the shaft driven pulley is 9cm

$$\text{Speed of Shaft} = \frac{\pi \times 0.09 \times 1450}{4}$$

= 410.031*m/s*

3.1.15 Power Required Driving the Shaft,

$$P_S = w_1^2 r_1 \quad (3.13)$$

here,

= radius of shaft of pulley

$_2 = (209.467)^2 \times \frac{9}{2}$

$= 197443.908$ *watts*

3.1.16 Centre-Distance of Motor-Shaft Pulley

The center-distance is obtained from the relation CD = max (2R, 3r + R)...... (3.14)

Where, CD = Center distance

R = Radius of large pulley

R = Radius of small pulley

From the equation above, two center distances will be obtained, but the larger is chosen.

That is $CD = \max\left(\frac{2\times1.12}{2}, \ \frac{3(0.09)}{2} + \frac{0.12}{2}\right)$

CD = max (0.120, 0.195)

CD = 195mm (which is equal to the larger center distance)

Note: the center-distance should not be greater than three times the sum of the sheave diameters or less than the diameter of the larger pulley.

3.1.17 Angle of Contact of Motor-Shaft Pulley

$\emptyset_L$ = Angle of contact of large pulley = $\pi + 2\sin^{-1}\frac{(D-d)}{2CD}$.................................... (3.15)

$= \pi + 2\sin^{-1}\frac{(120-90)}{2(195)}$

$= 11.965°$

$\emptyset_S$ = Angle of contact of small pulley $= \pi - 2\sin^{-1}\frac{(D-d)}{2CD}$

$= \pi - 2\sin^{-1}\frac{(120-90)}{2(195)}$

$= -5.681°$

3.1.18 Length of Motor-Shaft Pulley

Length of belt, $L = \frac{\pi}{2}(D_1 + D_2) + 2CD + \frac{(D_1 - D_2)}{4CD}$ .... (3.16)

According to Khurmi and Gupta (2005)

$= \frac{3.142}{2}(120 + 90) + 2 \times 195 + \frac{(120-90)^2}{4 \times 195}$

$L = 438.28mm$

The length correction factor $K_L = 0.84$ (from tables)

$L = 438.28 \times 0.84$

$L = 368.158mm$

3.1.19 Determination of Weight of Pulley

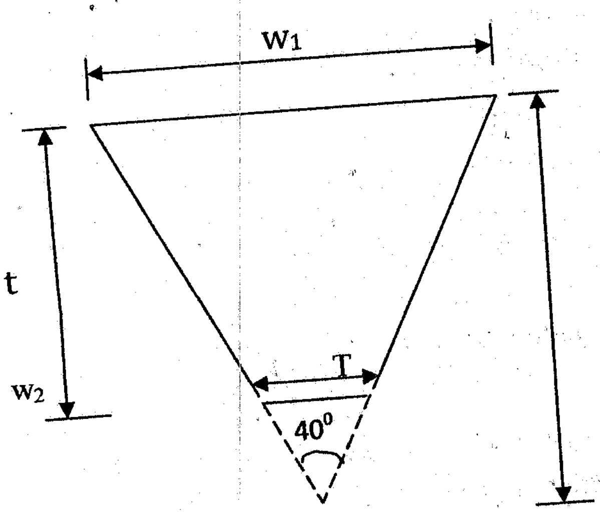


Figure 3.4: Cross-Section of V-groove Belt

Width of the belt; $w_1 = 13mm$

Nominal depth of the belt; $t = 8mm$

Sleeve groove angle $= 40^0$

Density of the leather belt $= \rho = 970Kg/m^3$

(Shaun series)

From the above,

$\beta = \left(\frac{180-40}{2}\right) = 70^0$

Actual depth of the belt, $T = \frac{1}{2} \times 13 \times \tan 70$

$T = 17.859mm$

$w_2 = \frac{t \times w_1}{T}$

$= \frac{8 \times 13}{17.854}$

$w_2 = 5.83mm$

The cross-sectional area of the belt can be calculated as;

$A = \left[\frac{w_1 + w_2}{2}\right]t$

$= \left[\frac{13+5.83}{2}\right]8$

$= 9.415 \times 8$

$= 75.32mm^2$

$= 73.32 \times 10^{-6}$ m

$M = P \times A = 970 \times 75.32 \times 10^{-6} = 73060.4 \times 10^{-6}$

$M = 0.730604Kg/m$

3.1.20 Determination of Length of Belts

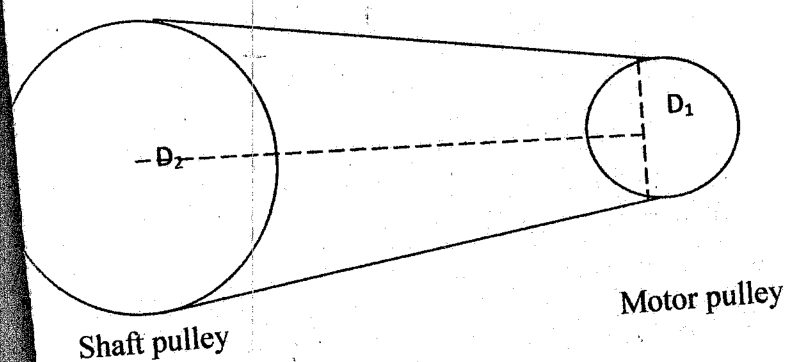


Figure 3.5: Motor- Shaft Belt

D_2 = diameter of the shaft pulley

= 12cm

D_1 = diameter of the motor pulley

= 8cm

Center to center distances, C = minimum

100mm = 0.1m

Nominal Pitch Length,

$$L = 2C + \frac{x}{2}(D_1 + D_2) + \left[\frac{(D1 + D2)^2}{4C}\right] \quad \text{(3.17)}$$

$$L = 2 \times 100 \times \frac{\pi}{2}(120 + 900) + \left[\frac{(120-900)^2}{4\times100}\right]$$

$$= 200 \times \frac{2100\pi}{2} + \frac{90000}{400}$$

= 200 + 3299.1 + 225

= 3724.1mm (max)

3.1.21 Design Theory

If the cutting shaft is subjected to twisting moment only,

$$\frac{\tau}{r} = \frac{\tau}{J} \quad \text{(3.18)}$$

$$J = \frac{\pi D^4 - d^4}{64} \quad \text{(3.19)}$$

$$\tau = \frac{\tau r}{J} = \frac{\tau D}{2J} \quad \text{......} \quad (3.20)$$

$$\tau = \frac{16DT}{\pi\left(D^4 - d^4\right)} \quad \text{......} \quad (3.21)$$

$$\frac{M}{J} = \frac{\sigma}{y} \quad \text{......} \quad (3.22)$$

Where,

M = bending moment

σ = bending

J = moment of inertia

y = distance from neutral axis to shaft diameter = $\frac{D}{2}$

$$M = \frac{\pi\sigma(D^4 - d^4)}{32D} \quad \text{......} \quad (3.23)$$

$$\therefore \sigma = \frac{32M}{\pi(D^4 - d^4)}$$

Maximum shear stress = $S_{max} = \frac{1}{2}\sqrt{(\sigma^2 + 4\sigma^2)}$ ...... (3.24)

$$S_{max} = \frac{1}{2}\sqrt{\left\{\left[\frac{32MD}{\pi(D^4 - d^4)}\right]\right\} + 4\left[\frac{16DT}{\pi(D^4 - d^4)}\right]^2} \quad \text{......} \quad (3.25)$$

$$= \frac{16D\sqrt{M^2 + 4T^2}}{\pi(D^4 - d^4)} \quad \text{......} \quad (3.26)$$

For cutting blade,

$$S = \frac{M}{Z}$$

Where,

M = bending moment

Z = section modulus

Maximum stress

$$\sigma_{Max} = \frac{1}{2}\sqrt{S^2 + 4\sigma^2}$$

$$= \frac{1}{2}\sqrt{\left(\frac{M}{Z}\right)^2 + \left(\frac{F}{A}\right)^2}$$

(Oluboji, 2004)

3.1.22 Determination of Weight on Cutting Blade

Area of each rod $= \frac{\pi d^2}{4} = \frac{3.142\ (0.04)^2}{4}$ .... (3.27)

$= 1.2568 \times 10^{-3} m^2$

Length of the blade = 12.5cm = 0.125m

Volume of the blade = $1.2568 \times 10^{-4} m^3$

Weight of blade = (W) = $\rho v g$

$= 7850 \times 1.2568 \times 10^{-4} \times 9.81$

$= 9.678N$

For 18 cutting blade

$W = 18 \times 9.678$

$= 174.212N$

Weight of cylinder

$$\text{Area} = \frac{\pi(D^2-d^2)}{4} \quad \text{...} \quad (3.28)$$

$D = 49.5\text{cm} = 0.495\text{m}$

$d = 44.5\text{cm} = 0.445\text{m}$

$$\text{Area} = A = \frac{3.142(0.495^2-0.445^2)}{4}$$

$= 0.0369185$

$A = 3.692 \times 10^{-2}\text{m}^3$

$V = 49\text{cm} = 0.49\text{m}$

$V = Al = 3.692 \times 10^{-2} \times 0.43$

$V = 1.58756 \times 10^{-2}\text{m}^3$

$\text{Weight (W)} = \rho v g$

$= 1222.56N$

Weight of Low Density Polyethylene (LDPE)

For a feed rate of $5Kg/hr$

Amount broken per second

$= \frac{5}{3600} = 1.388Kg$

Breaking Force $F = 3.9943wgRN$

wg = weight of grain (Kg)

R = panicle radius (m)

N = Breaking speed (rpm)

(Khurmi and Gupta, 2008)

$F = 3.9943 \times 1.388 \times 1.8 \times 10^{-2} \times 1450$

$= 144.70Kg$

Total cutter weight = 174.212 + 1222.56 + 1447.0

F = 2843.772N

3.1.23 Determination of Stress on Cutting Blade

Torque (T) = Fr .... (3.29)

Where,

r = distance to the neutral axis = 0.018

$T = 2843.772 \times 0.018$

$= 51.1879Nm$

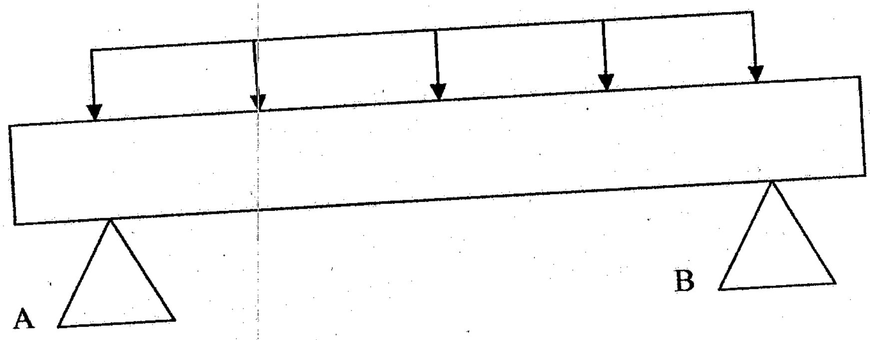


Figure 3.6: Beam diagram of shaft

$R_A = R_B = \frac{2843.772}{2} = 1421.886$

$W = \frac{2843.772}{0.49} = 5803.616 N/m$

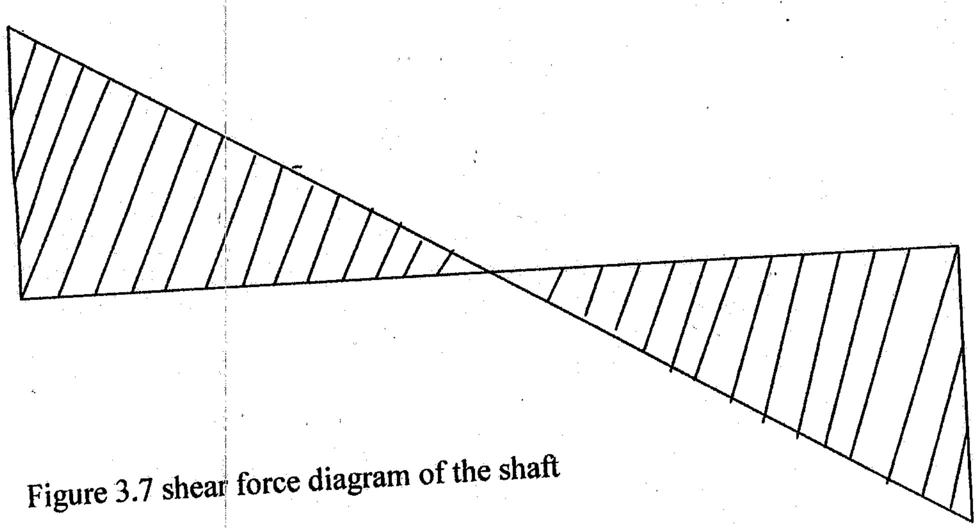


Figure 3.7 shear force diagram of the shaft

-1421.886*Nm*

Shear force diagram of cutting shaft

$$S.F = \frac{wl}{2} - wx \quad (3.29)$$

Maximum shear force at B

$$\frac{wl}{2} = \frac{5.803.616 \times 0.49}{2} = 1421.886Nm$$

Maximum shear force at A

$$-\frac{wl}{2} = \frac{-5.803.616 \times 0.49}{2} = -1421.886Nm$$

3.1.24 Bending Moment of Shaft

174.181Nm

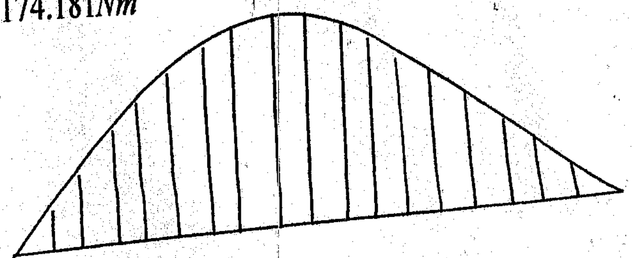


Figure 3.8 bending moment diagram of the cutting shaft

$$M = \frac{wl^2}{8} = \frac{5803.616 \times 0.49^2}{8} \quad (3.30)$$

$M = 174.181Nm$

Maximum shear on shaft

$$S = 16 \times 0.495 \sqrt{\frac{174.181^2 + 4(0.989)^2}{\pi(0.495^2 - 0.445^2)}}$$

$S = 3590.06Nm$

3.1.24 Power Demand at Shaft

$$P = \tau\omega \quad (3.31)$$