Design of Hydraulic Biomass Briquette Machine

By

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DEPARTMENT OF MECHANICAL ENGINEERING

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NIRMA UNIVERSITY

AHMEDABAD-382481

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Design of Hydraulic Biomass Briquette Machine

Major Project

Submitted in partial fulfillment of the requirements

for the degree of

Master of Technology in Mechanical Engineering

(Design Engineering)

By

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Guided By

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Declaration

This is to certify that

i) The thesis comprises my original work towards the degree of Master of Technology in Mechanical Engineering (Design Engineering) at Nirma University and has not been submitted elsewhere for a degree.

ii) Due acknowledgement has been made in the text to all other material used.

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Undertaking for Originality of the Work

I, **Hetav Kinkhabwala, Roll No. 12MMED22**, give undertaking that the Major Project entitled **"Design of Hydraulic Biomass Briquette Machine"** submitted by me, towards the partial fulfillment of the requirements for the degree of **Master of Technology in Mechanical Engineering (Design Engineering) of Nirma University, Ahmedabad**, is the original work carried out by me and I give assurance that no attempt of plagiarism has been made. I understand that in the event of any similarity found subsequently with any published work or any dissertation work elsewhere; it will result in severe disciplinary action.

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Certificate

This is to certify that the Major Project entitled **"Design of Hydraulic Biomass Briquette Machine "** submitted by **Mr. Hetav Kinkhabwala (Roll No. 12MMED22)** towards the partial fulfillment of the requirements for the degree of **Master of Technology in Mechanical Engineering (Design Engineering) at Institute of Technology, Nirma University, Ahmedabad** is the record of work carried out by him under our supervision and guidance. In our opinion, the submitted work has reached a level required for being accepted for examination. The results embodied in this major project, to the best of my knowledge, haven't been submitted to any other university or institution for award of any degree or diploma.

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Abstract

In many of our developing countries, likely in India we face many problems regarding agro-waste. If these wastes are not managed then there will be increased in the quantity of waste. And in order to manage these wastes, solutions are required and one of the solution is discussed here. The present study discusses about the briquette line which is used to make briquettes.

This briquette line basically consists of three equipment's a shredder machine, a screw conveyor and a hydraulic briquette machine. Because of good characteristics of sugarcane bagasse such as low ash content compared to coal, lignin cells are present which acts as a binder, etc., it has been used for making briquettes. Bagasse having long tissues, it is first cut into small parts with the help of shredding machine. These cut bagasse is conveyed to the hydraulic briquette machine with the help of screw conveyor. This conveyed bagasse is compressed in hydraulic briquette machine with the help of hydraulic cylinders.

This report discusses the detailed design of all three equipment's i.e. a hydraulic briquette machine, a screw conveyor and a shredding machine.

Keywords :- *Bagasse, Hydraulic, Briquette, Shredding, Screw Conveyor.*

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Nomenclature

p_i	Internal Pressure (N/mm^2)
d_i	Bore(Inner) Diameter (mm)
f_s	Factor of Safety
d_o	Outer diameter (mm)
d_b	Diameter of Bolts (mm)
l_s	Stroke Length (mm)
F	Force acting (N/mm^2)
σ_t	Tensile Stress of material (N/mm^2)
l	Length of Column (mm)
k	Least radius of gyration of cross section about its axis (mm^2)
I	Moment of inertia of cross section (mm^4)
A	Area of Cross-Section (mm^2)
σ_{yt}	Yield strength in tension(N/mm^2)
σ_{sy}	Yield strength in shear (N/mm^2)
σ_{ut}	Ultimate tensile strength (N/mm^2)
n	End fixity coefficient
P_r	Retraction Force of Striker Cylinder (N)
t_f	Thickness of Flange (mm)
t_s	Thickness of Sliding Plate (mm)
t_w	Wall thickness (mm)
c	Empirical constant = 0.13
W	Total load on Flange
O_c	Oil Capacity of Cylinder (litres)
b	Width (mm)
τ	Permissible shear stress (N/mm^2)
n	Number of Bolts
N	RPM of screw
E_c	Equivalent capacity (m^3/hr)
R_m	(m^3/hr) at 1 revolution per minute
C	Capacity required (kg/hr)
D_s	Diameter of Screw (m)
D_p	Core Diameter of hollow shaft (m)
D_i	Inner Diameter of hollow shaft (m)
p_s	Pitch of screw (m)
k_s	Trough Loading
Q	Mass flow Rate (capacity)
L	Total length of conveyor (m)
D	Weight of material(Density) (kg/m^3)
H	Height (m)
e	Drive effeciency
λ	Progressive resistance co-efficient

BHP	Brake Horse Power (hp)
l_m	Minor Helix Length (m)
L_m	Major Helix Length (m)
R	Disc Outer Radius (m)
r	Disc Inner Radius (m)
F_r	Radial Load (N)
P	Dynamic Load (N)
C_d	Dynamic Load Capacity (N)
L_{10h}	Life Required
L_{10}	Rated Bearing Life (million revolution)
M_t	Torsional Moment (N-mm)
M_b	Bending Moment(N-mm)
F_a	Correction Factor for industrial service
F_c	Correction Factor for Belt-Pitch Length
F_d	Correction Factor for arc of contact
α_p	Contact angle of pulley
θ	Groove Angle for Sheaves
v	Velocity of Belt (m/s)
P_1 P_2	Belt Tensions (N)
k_b	Shock Factor
k_t	Fatigue Factor
τ_{max}	Maximum Permissible Shear Stress (N/mm^2)

Chapter 1

Introduction

This chapter includes objective of project and basics introduction on biomass briquetting, sugar-cane bagasse and different methods to produce briquettes.

1.1 Preliminary Remarks

Biomass solid fuel such as wood, coal, etc are used in boilers, households, etc in almost all developing countries. There is decreased in availability of wood because of deforestation taking place in many parts of our developing country India. So to overcome these problems, solutions are needed and one solution is compaction of waste crop into biomass briquettes which helps in providing an alternative solid fuel.

Large tons of agricultural wastes are generated every year in India. These wastes are burnt in their loose form which causes air pollution. But if these wastes when converted into high density briquettes can provide a renewable source of energy. In order to use these generated wastes, briquette line is used to produce briquettes with the help of three equipments a shredding machine used to cut wastes into pieces of desired sizes, a screw conveyor used to convey wastes and hydraulic briquette machine used to compress waste to make solid briquettes.

1.2 About Biomass Briquetting

When the pressure is applied to the different sizes of loose biomass in order to produce compact solid blocks of different sizes, then this process is called biomass briquetting. In order to produce strong briquettes application of pressure, transformation of heat and binding agents are required. In some biomass, lignin cells are present which acts as binding agent and thus no binding agents are used.

1.2.1 Advantages of Briquette

- Dependency on fuel wood decreases.
- Consumption of wood, coal, etc decreases.
- Easy to handle, store and transport because of its high density.
- Size of briquettes will be uniform and good in quality.
- Waste disposal problems will be solved with this process.
- Deforestation will also decrease with this process.
- Air pollution will also decrease.

1.2.2 Types of Densification Technologies

Two different types of densification technologies are currently in use [1].

- Pyrolyzing technology depends on partial heating of biomass in absence of oxygen. Binder is mixed and then briquettes are produced with the process of casting and pressing at very low pressure. Also known as binding-agent technology.
- Direct extrusion type, in which the biomass is dried in the presence of sunlight and directly compressed with high pressure and high heat. Also known as binder-less technology.

1.2.3 Raw-Materials

The raw materials which can be used for biomass briquetting are:

- Bagasse, Cob, Rice Husks, Leaves, etc i.e different agricultural residues.
- Sawmills, furniture factories, plywood companies, etc producing different wastes.
- Different foreign plants such as Lantana, Euphorbia royalena, etc.

1.2.4 Applications

The application of briquettes are generally recommended for:

Boilers:	Generation of steam
Food processing industries:	Bakeries, restaurants, canteens, etc
Textile process houses:	Bleaching, dyeing, etc.
Agro-products:	Drying of Tea, curing of tobacco, etc.
Clay products:	Brick, making of tile, etc.
Domestic:	To cook food and to heat water
Gasification:	Gasifier's fuel
Charcoal:	Making charcoal in kilns

1.3 About Sugar-Cane Bagasse

1.3.1 The Source and Characteristics of Bagasse

After removing the juice from the sugar-cane, the crushed material left is called bagasse. Bagasse characteristics changes in consistency, composition, and values depends on the type of soil, amount of washing, climate, varieties of cane, efficiency of milling plant and harvesting methods. Bagasse is having a high calorific value of 4400 kcal/kg. Moisture content of most bagasse is also very high percent by weight.

1.3.2 The benefits of using Briquetted Bagasse as a fuel

The main benefits of using briquetted bagasse as a fuel are:

- When bagasse is burnt, the sulphur dioxide and other gases emitted are lesser than conventional fuels.
- The greenhouse gases also reduces.
- Compared to coal's 20-40% ash content, it has low ash content of 2-10%.
- Calorific value is between 3,500-5,000 kcal/kg.
- Elimination of the disposal cost/fees.
- Future power generation can take place as bagasse is a renewable resource.
- From loose biomass of low bulk density, briquettes can be manufactured with a high density.
- Size is uniform thus ease in storing and handling.
- Quality maintained is constant.

1.4 Types of Briquetting Presses

The briquetting press technologies are divided into:

1. High pressure compaction
2. Low pressure compaction

1.4.1 High Pressure Compaction

A power-driven press is used to increase the pressure of biomass to about 150 MPa and hence called high pressure briquetting machines. These machines works without using binders. The lignin in the material gets melted when the compression process produces heat around 120 °C. The hot material is forced through die by the press. Binding of the biomass particles into uniform, solid briquettes takes place only when the lignin cools and re-solidifies.

Three types of High Pressure Compaction Presses are shown in Fig 1.1:-

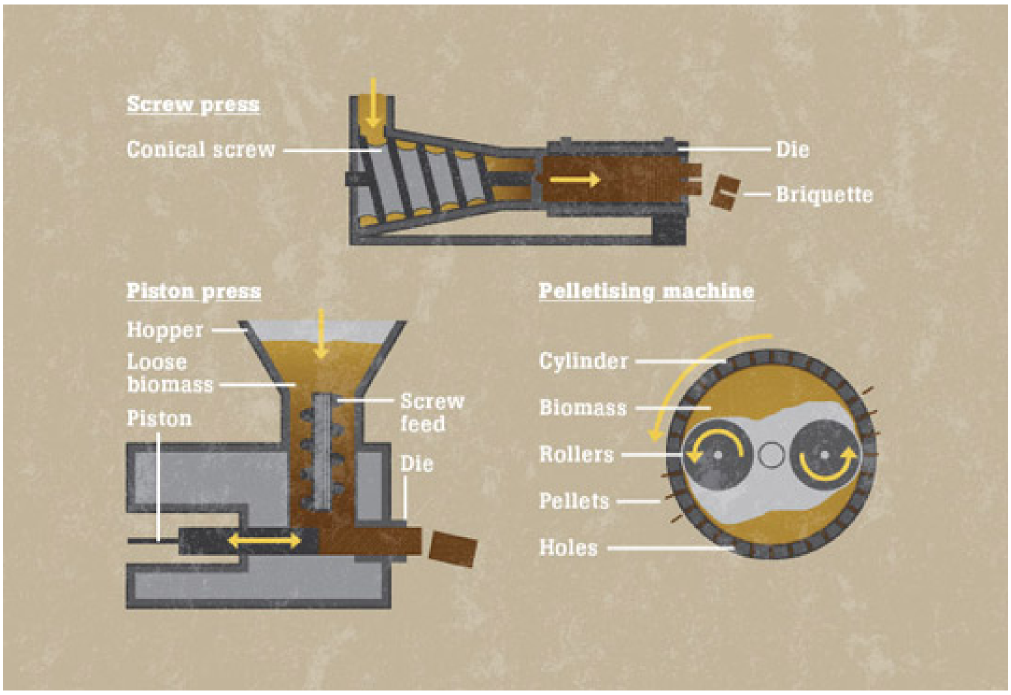

Figure 1.1: High Pressure Compaction Presses [2]

- The Piston Press :- Oscillating piston compresses the biomass which produces cylindrical briquettes which are upto 100 mm in diameter.
- The Conical Screw Press :- Tapered screw is used in the formation of longer and hollow briquettes.
- The Pellet Press :- Rollers are used to compress the biomass and makes pellets which are 6 to 12 mm in diameter.

Hardened steel is used as a material for the dies and moving components in these machines, because of the rubbing action generated by the biomass at the high pressures. Even so, they need to be replaced because of its high wearing processes.

1.4.2 Low Pressure Compaction

As paper and charcoal dust contains low amount of lignin, low pressure compaction machines can be used to produce briquettes of paper and charcoal. In this process, a binders such as starch, clay, and water is mixed together with biomass. A push is exerted by a briquetting press into a mould. Briquettes produced are kept to dry as binder will set and hold the biomass together. As lever is used to drive a piston which compresses the biomass, low pressure briquetting machines are hand operating machines.

Different Types of Low Pressure Presses are:-

- Earth Ram :- Feed stock is poured into the mould keeping the lever arm in open position and then is it quickly pushed down. This will compress the briquettes during the downward stroke. In order to force the briquettes out of mould, the lever is pushed down to remove it as shown in fig 1.2. Then briquettes are dried keeping in the sun. At least two workers are required to complete this process.

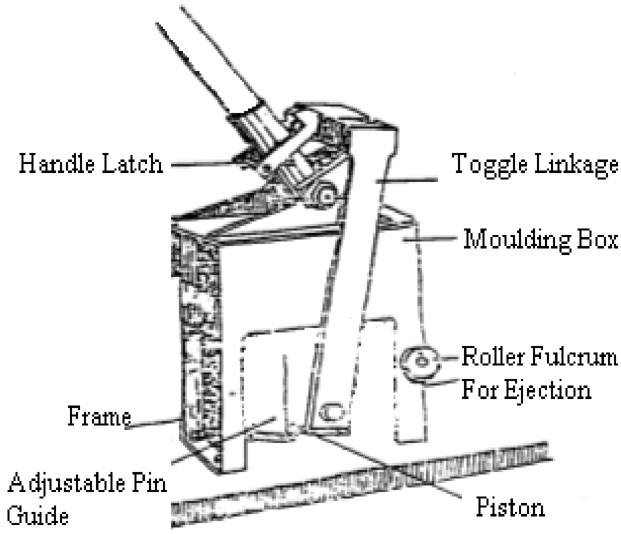

Figure 1.2: Earth Ram [3]

- The Lever Arm Briquette Press :- There are four steps which are used in the production of briquettes described in fig 1.3. The pressure will increase in every steps. Because of its large size and heavy weight two persons are required to produce briquettes.

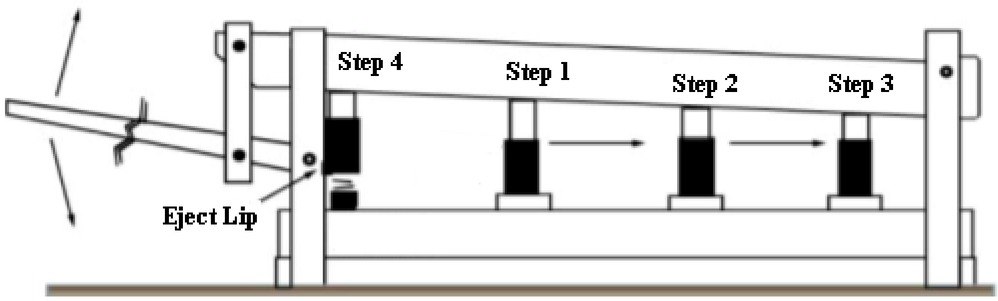

Figure 1.3: Lever arm Briquette Press [4]

Steps involved in forming briquettes are as follows:-

Step 1 :- Handle is raised, insert the filled mould under the handle and the compression begins with lowering the handle with the maximum vertical movement, but the exerted pressure will be very less.

Step 2 :- Handle is raised again, mould is shifted to right and there will be increased in pressure but with less vertical movement.

Step 3 :- Handle is raised again, shift mould to extreme right and maximum compression will be exerted with minimum vertical movement.

Step 4 :- Now to remove briquette invert the cylinder, allow water to drain off and rest cylinder on eject lip and press to eject fuel briquettes.

1.5 Objective of project

The objective of project is

To design a briquette line which includes three different equipments; (1) hydraulic briquette machine (2) screw conveyor and (3) shredding machine; where a hydraulic briquette machine will be use to produce briquettes, a screw conveyor will be use to convey bagasse according to the requirement and a shredding machine will be use to cut bagasse into fine particles.

1.6 Outline of Thesis

The first chapter contains the preliminary remarks and describes basic introduction and objective of project. The second chapter describes various literature reviews which deals with different properties of biomass and various design of different machines used to produce briquettes. It also contains various forces acting on blades. Chapter three contains the layout of briquette line. Complete procedure of briquette formation and design and selection procedure of various parts of hydraulic briquette machine is also included in the same chapter. Chapter four contains basics of hydraulics and hydraulic circuit with different positions prepared in Automation studio 5.6. Chapter five describes the basics of screw conveyors. Design of different parts of screw conveyor is also carried out in the same chapter. Chapter six includes various types of shredding machine and selection and designing procedure of shredding machine has been carried out in the same chapter. And finally conclusion and future scope of work has been discussed in seventh chapter.

Chapter 2

Literature Review

This chapter describes the literatures reviewed for the dissertation work.

Dr. K.T.Chandy [1] has concluded that there are number of options to convert woody biomass and waste feed stocks into different forms of energy for use in various sectors household, agriculture, agro-industries, transport, and public utilities. Very common biomass such as sunflower stalks, sugarcane trash, rice husks and cotton stalks are used in studying the different properties. Also two direct compaction technology, 1) Binder-less technology in which briquettes are prepared at very high pressure without adding water, glue or any type of binder. 2) Binding agent technology in which different binders can be mixed together with biomass and briquettes are prepared at low pressure.

Mac Cosgrove-Davies [3] has discussed various operating principles of briquetting, types of binders, types of machines used to produced briquettes. Series of steps are there in briquetting process which includes collecting material, preparing material, compacting, removing, drying, storing, etc. He has explained three machines, one high compaction screw extruder in which tapered screw is rotated at constant speed and the material is supplied from one end and briquettes are produced from the other end. Other two are low pressure tube-press and earth-ram.

Jason Dahlman and Charlie Forst [4] have described design for manually operating briquette presses which are called as low pressure briquette machines. Working model of manually operating briquette i.e lever arm briquette press has been made with the help of wood. The mould that was used, was prepared from a piece of PVC pipe. In this pipe holes were made so that water can escape when the pistons are pressed. Briquettes were prepared having a center hole and it was found that if this hole is present it helps in drying the briquettes faster.

Beena Patel and Bharat Gami [5]have discussed the biomass characterization which can be useful in understanding various physical and chemical properties. Different biomass samples were collected from ahmedabad of gujarat state and were tested and found that, during firing of these biomass residues, it creates combustion problems. And in order to used these residues as firing agent, understanding of biomass and its composition would help a lot.

Strong and good rice husk briquettes were produced using starch and gum arabic as binders by D.B Yahaya and T.G. Ibrahim [6]. Water boiling tests were carried out by preparing different briquettes adding different binders. These test showed that in order to boil 2 litres of water, 15 minutes were taken by 1 kg of rice husk - starch briquette and rice husk - gum arabic briquette respectively whereas to boil same amount of water 21 minutes were taken by firewood weighing 1.2 kg. Flame test was carried out and found different colors on three materials. Hence they concluded that the briquettes can be used in-place of wood because of its good combustion characteristics.

Peter McKendry[7] has described many types of biomass namely manures, herbaceous plants, aquatic plants and woody plants. Out of these four, woody plants and herbaceous plants are used in producing energy. He concluded that in order to produce steam which can be used in generation of electricity, any biomass can be burned i.e combustion should takes place. Attention has been focused on identifying biomass species of European climate and which can replace conventional fossil fuel.

Yousif A. Abakr and Ahmed E. Abasaeed [8] have designed and manufactured a briquetting machine which works at low pressure. Power screw concept is used in designing this machine, and the briquettes that are produced by agricultural waste can be used as household fuels. This machine was compared with the previous machines and found that the production rate of this machine was better and more i.e eight times the production rate compared to previous machine. Their was also a reduction in total production cost because the binder content was lowered by 65%. Smoke generation was also less because of low binder content and better quality. Drying time of briquettes produced gets lowered as the moisture content was decreased to 35% instead of 50% used in previous machine.

Obi O. F., et al [9] have designed and manufactured a briquette machine which can be used in rural communities. They used sawdust to produce briquettes and performances were calculated at various binder levels. Cassava starch is used as a binder and different physical and combustion properties were identified varying biomass-binder ratios. They concluded that in order to produce heat for household cooking and in small scale industries, optimum ratio of 100:35 can be used to attain good heating value.

Amer Eissa A.H, et al [10] have studied three components cotton, sugar cane bagasse and maize stalks. Physical and mechanical properties of all these components were also studied. Experiments were performed to find out the results of these properties. Samples were taken of different length, different diameters and different moisture levels. Different mechanical tests were performed for all residues. Shear test was performed on sugar cane bagasse by performing an experiment and shear strength obtained at bottom part, middle part, top part of sugar cane bagasse were (2.41 ± 0.095) MPa, (2.23 ± 0.095) MPa and (2.42 ± 0.095) MPa respectively.

Basil Okafor [11] has designed a lawn mower which is easy to operate, durable, portable and easy to maintain. Designed was made such that it works on cordless electric source. Battery powered electric motor was the heart of this lawn mover. Speed multiplication pulleys were used for speed multiplication. These pulleys are connected to a shaft on which cutting blades are mounted. Lift mechanism was also implemented to adjust the height of cut. Collapsible blades were used which in turn reduces the problem of wear. Pulleys were connected with the help of v-belts due to which there is minimum slip. 12V alternator was used which together with collapsible blades make the design unique where no engine is involved.

Segun R. Bello and Musiliu A. Onilude [12] have explained different details on cutting knife and calculated the force relations for wood chipper. Many tool geometries were determined which includes rake angle = 20 °, shear angle = 52.15 ° and frictional angle = 5.71 °. The forces were found out by Merchants circle theory. The forces acting on the knife and the chip were found out. The resultant force acting was calculated as 34.89 N/mm, the specific cutting pressure was 1.79 * 10^6 N/m^2 and the cutting force calculated was 644.84 N. Power required was calculated and the design of shaft was also carried out considering vertical and horizontal loads.

Chapter 3

Design of Briquette Machine

This chapter describes the layout of briquette line, the process of briquette formation & the design & selection procedure of different parts of briquette machine.

3.1 Layout of Briquette Line

The layout of briquette line is shown in fig 3.1 consisting of a shredding machine, a screw conveyor and a hydraulic briquette machine.

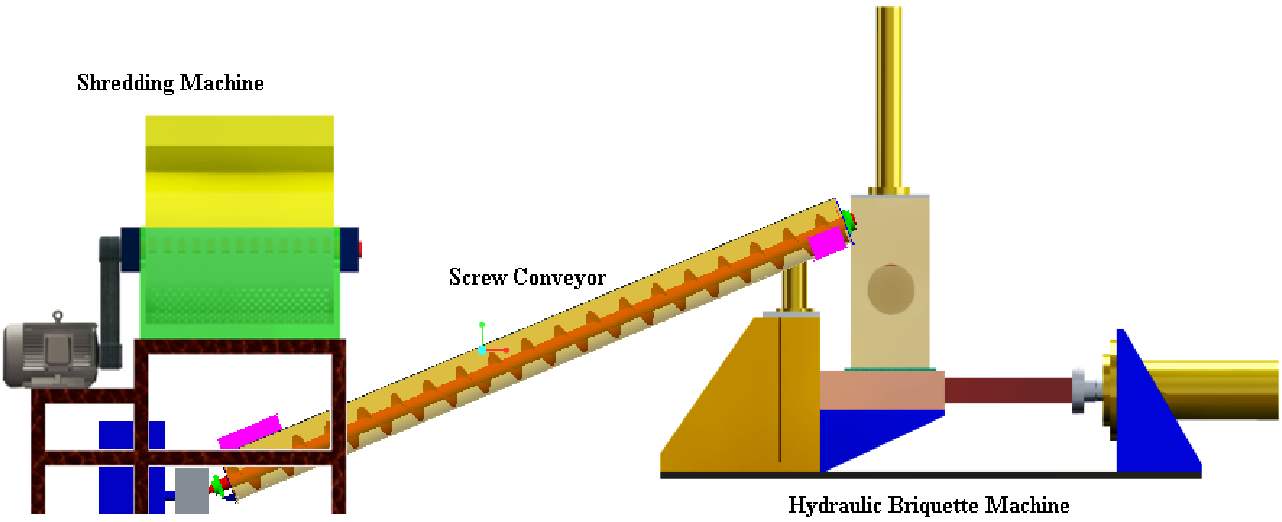

Figure 3.1: Layout of Briquette Line

3.1.1 Procedure of Briquette Formation

The briquette production consists of a shredding stage and a briquetting stage. Figure 3.2 shows the basic process flow.

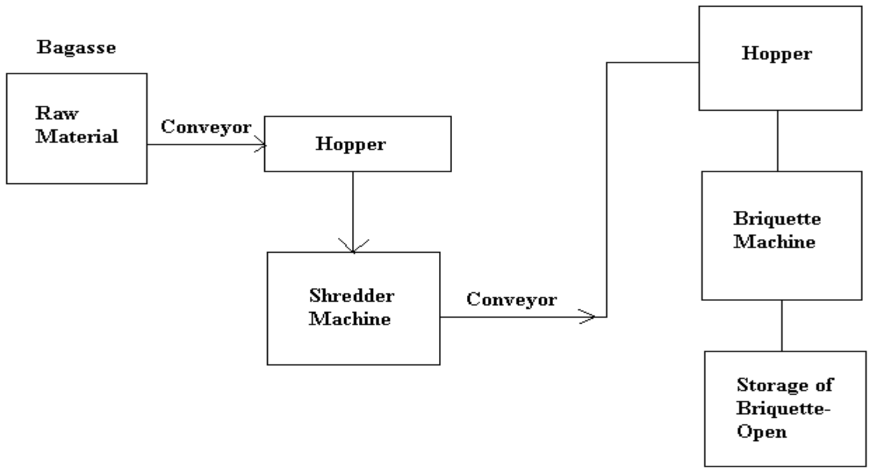

Figure 3.2: Process Flow of Briquette Production

Bagasse is collected from the sugar-cane mills after the removal of juice from sugar-canes. Bagasse having very high moisture content, it has to be stored under sunlight for days until the moisture content reduces to 8%. As bagasse having long tissues it has been pre-shredded i.e cut into small tissues.

After pre-shredding of bagasse is completed, pre-shredded bagasse are allowed to fall in the shredding machine 6.2. Bagasse will fall directly on the stationary blades. These bagasse will get cut into fine particles with the help of the sharp blades which are rotating at 800 rpm.

These cut bagasse will fall down from the strainer into the screw conveyor, where bagasse will be conveyed to the hydraulic briquette machine.

In hydraulic briquette machine, all the three cylinders i.e. stopper cylinder, shutter cylinder and striker cylinder shown in fig. 3.3 will be at home position. Stopper block will move to its final position which is connected to the piston rod of stopper cylinder with the help of connector. When the stopper block comes to its final position, the screw conveyor will convey bagasse in the hopper's inlet chute.

As soon as the material is filled in the hopper upto its limit, with the help of shutter cylinder, the shutter plate which is connected to the piston rod of shutter cylinder will exert the force and levels the fed bagasse. After the bagasse gets levelled, the striker cylinder will act and the striker block will move from its home position to final position compressing the bagasse. The striker cylinder will act upto its required pressure and force will be exerted on the bagasse. The briquette formation takes place and the desired shape of the briquette is achieved. After the formation of a briquette, the back block with the help of back cylinder will move to its home position.

The striker cylinder will give pressure push and thus the briquette formed will fall down directly on the belt conveyor. After the falling of the briquette, the striker block and shutter plate will return to its home position with the help of striker cylinder and shutter cylinder respectively.

And thus the process continues.

3.2 Design of Hydraulic Briquette Machine

Designing of a machine shown in Fig 3.3 involves finding the thickness of plates, selecting cylinder bore diameters, finding thickness of cylinder, determining piston rod diameters, selection of material and determining bolt diameters.

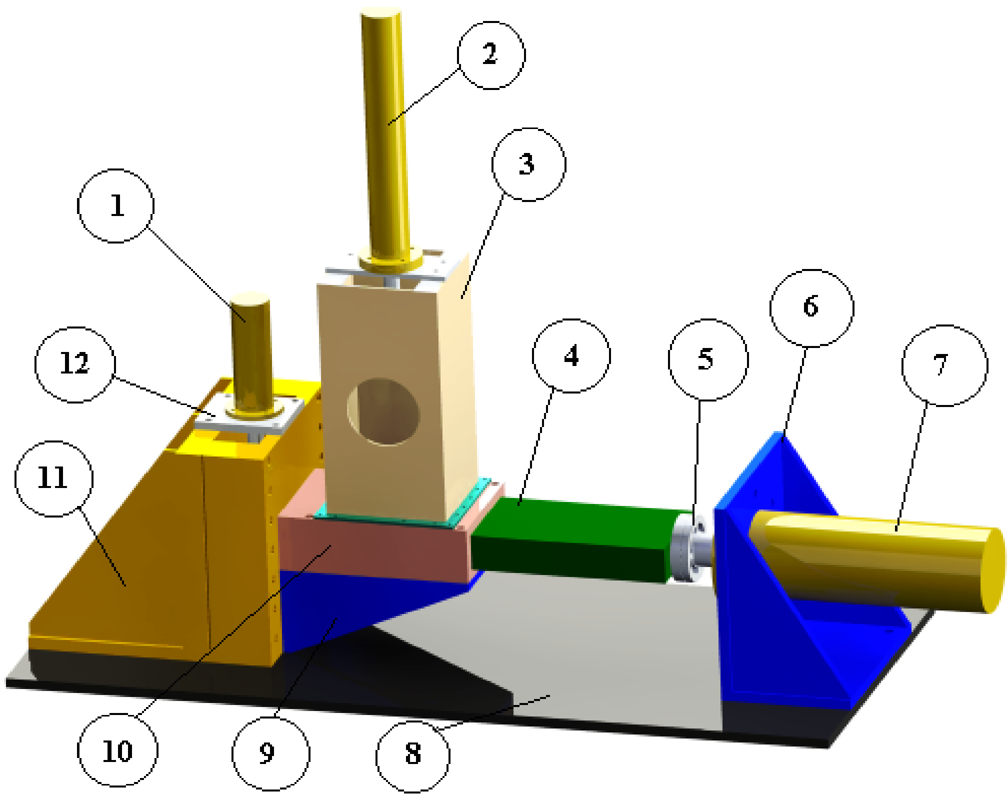

Figure 3.3: Isometric View of a Briquette Machine

Table 3.1: Parts Name of Hydraulic Briquette Machine

Part No.	Name
1	Stopper Cylinder
2	Shutter Cylinder
3	Hopper
4	Striker Block
5	Connection
6	Right Support
7	Striker Cylinder
8	Base
9	Vessel Support
10	Hollow Rectangular Vessel
11	Back Bracket
12	Back Plate
13	Stopper Block
14	Shutter Plate

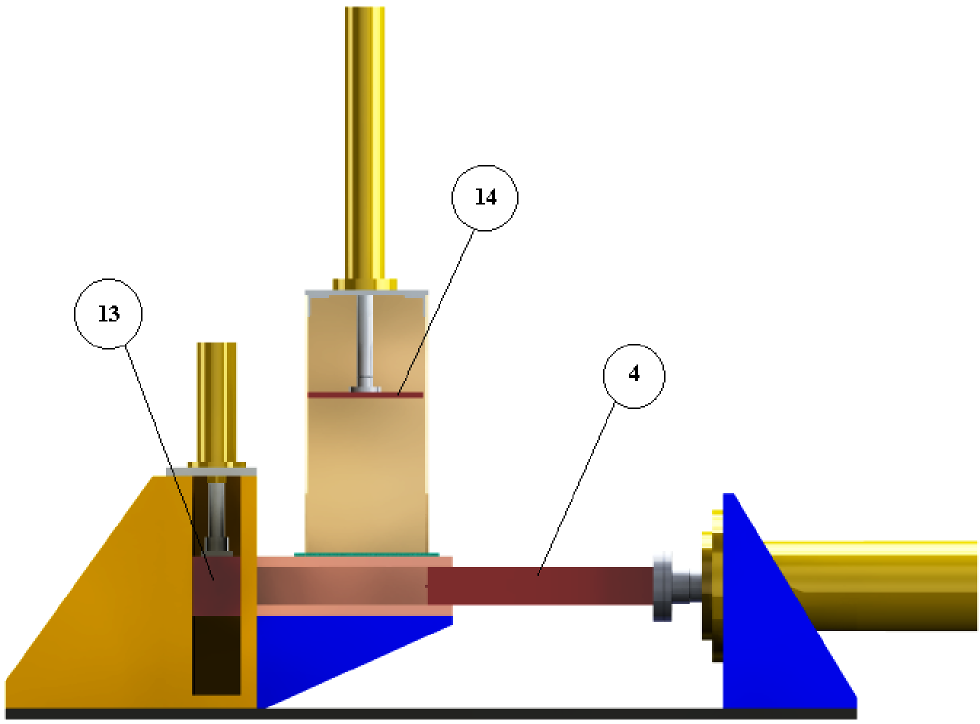

Figure 3.4: Front View of a Briquette Machine

3.3 Hydraulic Cylinder

When hydraulic fluid is passed, a piston slides in the tubular structure and these structures are known as hydraulic cylinders. Thickness of the cylinder, flange thickness and the selection of sizes of bolts are the main design requirements.
There are three hydraulic cylinders: first one striker cylinder it is used to press the bagasse, second one shutter cylinder, it is used to level the fed bagasse, third one stopper cylinder, it is used to stop bagasse until it forms briquette.

3.3.1 Selection

Selection of hydraulic cylinder bore diameter is very important. This selection was done on the basis of the experiment done in order to decrease the volume of the briquette.
In a hollow rectangular box bagasse was filled up-to some level and force was exerted to it until the volume of briquette reduces to one third of its original volume as shown in fig 3.5

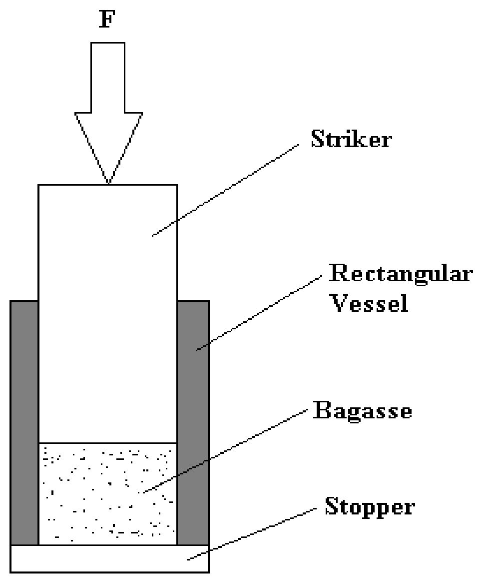

Figure 3.5: Experimental Setup

During experiment maximum pressure noted was 170 bar and the hydraulic cylinder used was having piston bore diameter of 160 mm. This indicates that the maximum force applied was 35 tons.
Therefore the bore diameter of striker cylinder was taken as 160 mm. As the force developed by striker cylinder will be exerted on the sliding plate of the shutter cylinder the bore diameter of shutter cylinder was also selected as 160 mm. Stopper cylinder is only used to stop the bagasse from falling, so the bore diameter of stopper cylinder was selected as 100 mm.
Material selected for hydraulic cylinders is ASTM A106 Grade B [13] . It is similar to plain carbon steel with carbon content of 0.3% and usage of this material is more in hydraulic pressure fields. It's tensile strength = 415 N/mm^2

3.3.2 Wall Thickness

As the pressure applied by the pump is high, the wall thickness of hydraulic cylinders were found considering as thick cylinders. Cylinder wall thickness has been obtained by Barlow's equation as this equation is used for gas pipes and high pressure oil.
According to Barlow's equation,[14]

$$t_w = \frac{p_i \times d_o}{2 \times \sigma_t} \;\; and, \;\; t_w = \frac{d_o - d_i}{2} \tag{3.1}$$

Where,
p_i = 17 N/mm^2
d_i = 160 mm
σ_{ut} = 415 N/mm^2
factor of safety = 2
σ_t = 207.5 N/mm^2
Thickness obtained were 8, 8 and 5 mm for striker, shutter and stopper cylinder respectively excluding corrosion allowance.

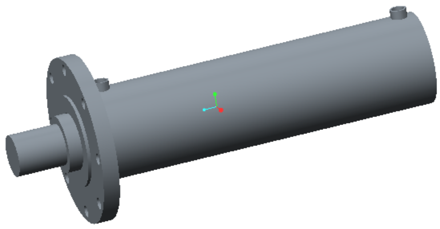

Figure 3.6: Hydraulic Cylinder

3.3.3 Diameter of Piston Rod

Piston rod transfers the force to work piece. Design of piston rod is made such that it transfers forces along its central axis. It is assumed that there is no bending load. The minimum diameter required for the piston rod has been obtained from the fig. 3.7 as 90 mm for both striker and shutter cylinder.

Material selected for piston rod is EN8/C40 [13]. EN8 is a medium strength steel with carbon content of 0.36 - 0.44 % and it is selected because of its high tensile strength.

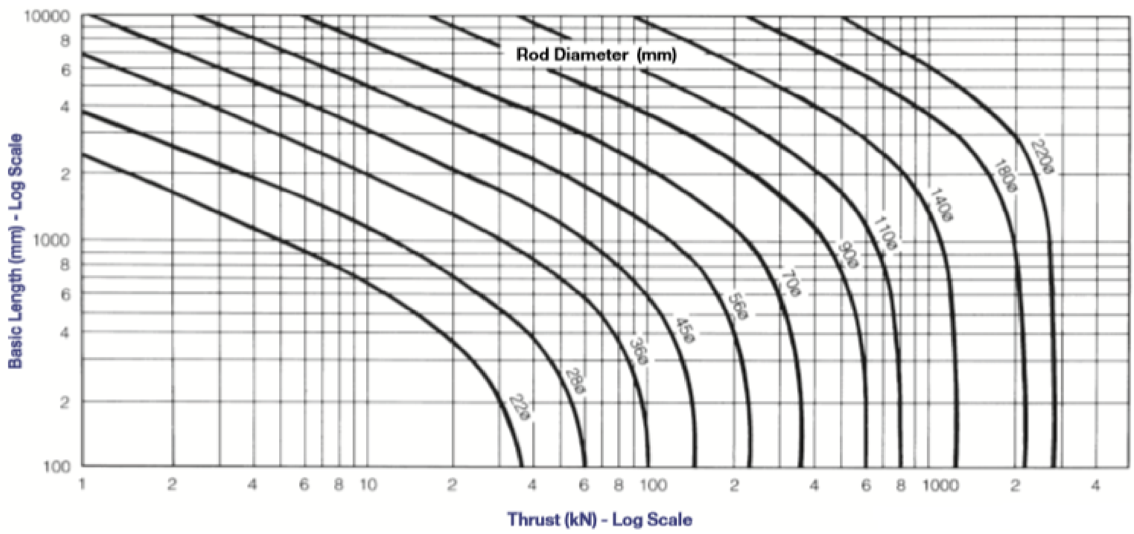

Figure 3.7: Selection of Piston Rod Diameter [15]

3.3.4 Buckling of Piston Rod

Buckling of piston rod [14]happens when the slenderness ratio is greater than 30.

$$Slenderness\ Ratio = \frac{l}{k} \tag{3.2}$$

where l = length of the column;

k = least radius of gyration of the cross section about its axis(mm^2) = $\sqrt{\frac{I}{A}}$

I = least moment of inertia of the cross section (mm^4)

A = area of the cross section (mm^2)

Slenderness ratio has been calculated for shutter and striker cylinders. It has been found that the slenderness ratio for striker and shutter cylinder are 15.55 and 8.88 respectively. As the slenderness ratios are less than 30, there is no effect of buckling.

3.3.5 Flange Thickness Determination

The design of cylinder flange is essentially to obtain the minimum thickness t_f, of the flange, which may be determined from bending consideration [13] .

Thickness of flange :-

$$t_f^2 = \frac{c \times W}{\sigma_t} \tag{3.3}$$

Where t_f = thickness of flange

c = empirical constant = 0.13 from table 3.2

W = total load on flange

Empirical constant c depends upon the ratio of outside diameter of cylinder and inside diameter of support as shown in table 3.2 and in fig 3.8

Thickness obtained was 30 mm for striker and shutter cylinders.

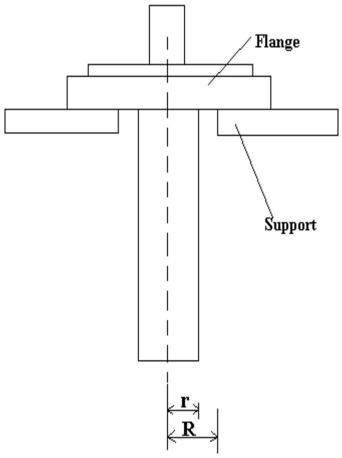

Figure 3.8: Selection of Empirical Constant

Table 3.2: Empirical Constant [13]

R/r	1.25	1.5	2	3	4	5
c	0.13	0.34	0.74	1.22	1.46	1.61

3.4 Design of Hollow Rectangular Vessel

This is a hollow rectangle in which the raw material bagasse is being compressed. The material gets compressed when all the sides are closed, so this is considered as a closed pressure vessel.

The analysis of this block can be approximated by considering circular hollow pressure vessel. The thickness was obtained using the following formula so that the stresses remain within the limit. Material selected is mild steel with 0.2% carbon and allowable stress of 60 N/mm^2.

$$\sigma = \frac{b \times P}{2 \times t} \tag{3.4}$$

Where,

b = width = 70 mm

P = pressure = 17 N/mm^2

$\sigma_{allowable} = 60$ N$/mm^2$

$f_s = 4$

The thickness was taken as 20 mm as the stress obtained was smaller than $\sigma_{allowable}$

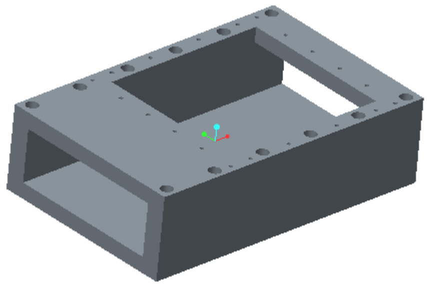

Figure 3.9: Hollow Rectangular Vessel

3.4.1 Design of Bolts

Plates in hollow rectangular vessel are fastened by bolts. So bolts are affected by shear. Size of bolts are determined by the following formulas [14]

Thrust force F = 340 kN ; $\sigma_{yt} = 380$ N$/mm^2$; $f_s = 3$

Permissible Shear Stress

$$\sigma_{sy} = 0.5 \times \sigma_{yt} = 190N/mm^2 \qquad \tau = \frac{\sigma_{sy}}{f_s} = 63.33N/mm^2 \tag{3.5}$$

Size of Bolts :-

Shear Area of 32 Bolts

$$32 \times \frac{\pi \times d_b^2}{4} \tag{3.6}$$

Therefore,

$$F = 32 \times \frac{\pi \times d_b^2}{4} \times \tau \tag{3.7}$$

Diameter obtained is 14.61 mm.

So from IS:4218-3(1999) [16] bolts of M16 are selected.

3.5 Design of Connection between Piston Rod and Strikers

This is connection between piston rod of all three cylinders and their strikers. This holds the piston rod and striker with the help of bolts. This connection plays an important role when the cylinder is retracting.

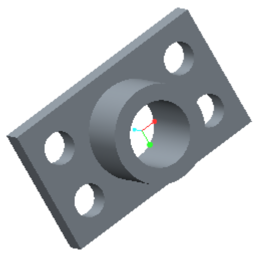

Figure 3.10: Connection between Piston Rod and Strikers

(1) Thickness of Plate :- Thickness of plate is kept 10 mm to make the assembly rigid.

(2) Material of bolts :- Material taken for bolts from IS 1871-2(1987) [17] is 40C8 plain carbon steel with σ_{yt} = 380 N/mm^2

(3) Diameter of Holes :- [14]

P_r = Retraction force

n = no. of bolts = 4

σ_{yt} = 380 N/mm^2

f_s = factor of safety = 2

P'= $\frac{P_r}{n}$ = 11 kN on each Bolt

Permissible Tensile Stress

$$\sigma_t = \frac{\sigma_{yt}}{f_s} = 190\ N/mm^2 \tag{3.8}$$

Size of Bolt

$$\sigma_t = \frac{P' \times 4}{\pi \times d_c^2} \tag{3.9}$$

Diameter obtained $d_c = 8.36$ mm

Now,

$$d_b = \frac{d_c}{0.8} = 10.45\ mm \tag{3.10}$$

So from IS:4218-3(1999) [16] bolts of M12 are selected.

Similarly design of bolts can be done for other two connections also.

Check for shear stress in threads

As bolts of M12 are in tension, shear stress in threads are to be checked. Shear stress in threads are checked as,

pitch p = 1.75 from [16]

minor diameter $d_1 = 10.106$

number of teeth z = 28.5714

thickness t = p/2 = 0.875 mm [18]

For permissible shear stress,

$\sigma_t = \dfrac{380}{2} = 190$ N/mm^2

Therefore, $\tau_{allowable} = 0.5 \times 190 = 95$ N/mm^2

Shear Stress in bolt threads are checked as [14]

$$\tau = \frac{P'}{\pi \times z \times d_1 \times t} = 13.8587\ N/mm^2 \tag{3.11}$$

τ obtained is smaller than $\tau_{allowable}$. Therefore the bolt threads are safe in shear.

Chapter 4

Hydraulic Circuit of Briquette Machine

This chapter contains introduction to hydraulics, components of hydraulic system, hydraulic symbols, hydraulic reservoir capacity, selection of pumps and the hydraulic circuit with the different position obtained in simulation.

4.1 Introduction

4.1.1 Components of Hydraulic System And Circuits

All hydraulic circuits contains four basic components; a reservoir which contains the fluid; a pump which is used to force the fluid through whole system; valves which are used to control the flow; and an actuator which is used to convert fluid energy into mechanical energy.
Components of a Hydraulic System are [19]:-

1. Reservoir :-

Reservoir is used to store the working fluid i.e oil. It supplies this oil to the pump. It also reserves the return and drain oil. It also protects the oil from outside dust.

2. Hydraulic Pump :-

Pump is used to transfer oil from one point to another point. Flow is the only thing given by the pump, but the pressure is developed by the flows resistance. Positive displacement pumps are most widely and often used in hydraulic circuit. There are different types of hydraulic pumps:-

Gear Pumps

Vane Pumps

Axial Piston Pumps

Radial Piston Pump

3. Directional Control Valves :-

These valves are used to supply working fluid directly to the cylinder which is supplied by the pump. Hence these valves are provided in between a cylinder and a pump. These valves can be operated with the help of lever, foot, solenoid,etc depending upon the requirement.

4. Actuators :- Cylinders and motors used in any hydraulic circuits are known as actuators. These actuators does the actual job of lifting, pushing, compressing, etc. Hydraulic motors are nearly same as pumps. When oil is supplied to the motor, they will give rotary output.

Generally two types of hydraulic cylinders are commonly used double acting cylinders and single acting cylinders.

4.2 Hydraulic Symbols

- **Lines :-** Lines represents the tube that carries fluid between components. Sometimes arrows are shown to indicate direction of oil flow.

- **Reservoir :-** Reservoirs can be represented as open square stating it is vented reservoir or a closed one stating it is pressurized reservoir.

- **Pumps :-** Pumps can be represented as a circle with a triangle. The triangle indicates the direction of flow towards which it is pointed. If their are two triangles, it indicates that the flow is in both direction. Variable displacement pumps are represented as a circle with an arrow and no arrow is used in constant displacement pump.

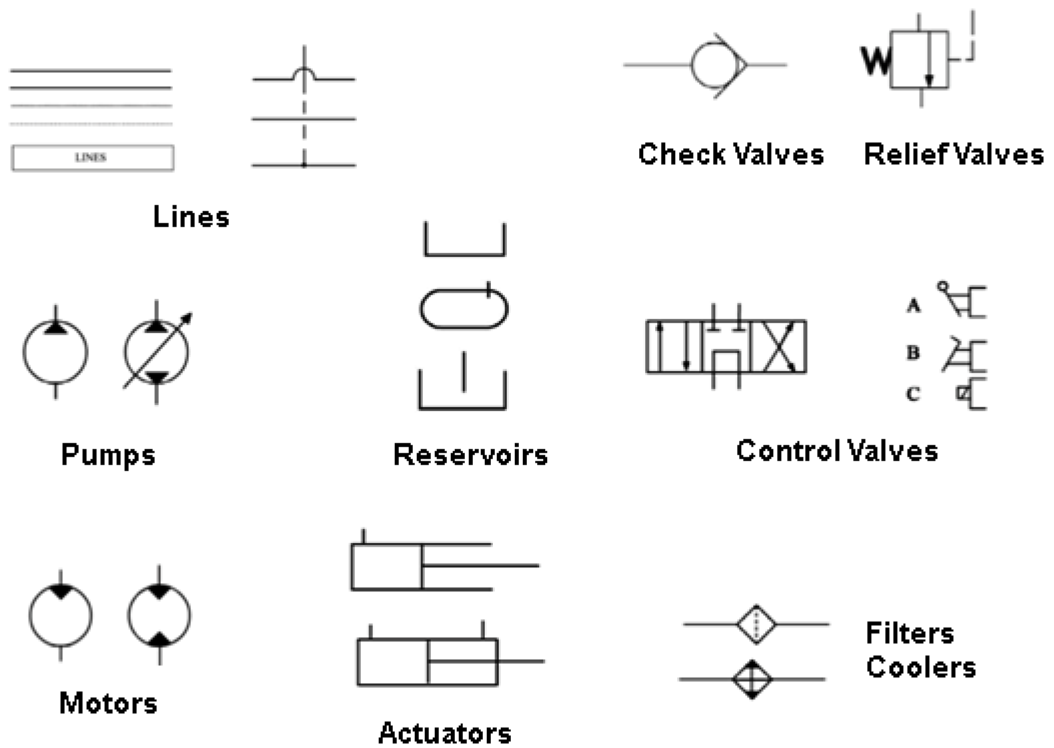

Figure 4.1: Hydraulic Symbols [20]

- **Check Valves :-** A check valve is represented as a circle in a V seat. This circle is nothing but a ball. When oil comes from the left side, the circle will move in V and flow of oil will stop. When oil is applied from the right side of the circle, the circle will move away and oil will flow.

- **Relief Valve :-** Relief valves can be represented as a closed valve in which one line is connected to the pressure line and other connected to the reservoir. Fluid is sent to the reservoir, when the pressure in the system increases than the spring.

- **Control Valves :-** These valves are represented as squares with valve positions. Each valve position has a different squares. Port are connected to the neutral position of the valve.
  The valve can be controlled in different ways. (A) shows it is lever operated, (B) shows it is foot control and (C) shows it is an electric solenoid.

- **Actuators :-** An actuator includes various hydraulic cylinders. Hydraulic cylinders (actuator) are represented as a simple rectangle. The piston and rod are drawn by a T which is drawn into the rectangle.

- **Coolers And Filters :-** The squares that are rotated 45 degrees and are having connections at corners are represented as coolers, filters, etc. A filter or strainer is represented as a dotted line which is perpendicular to the oil flow. A cooler is represented as the solid line perpendicular to the oil flow with 2 triangles pointing out.

4.3 Hydraulic Power Packs

4.3.1 Identification

Hydraulic power packs are having built-in power supply. Some power packs are stationary, large and portable. They have a motor to give power to pump, hydraulic reservoir in which the fluid is filled, and in order to control the pressure, regulators are used.

4.3.2 Function

Hydraulic power packs typically allows various valve connection to control valve or to connect different machines. Hydraulic power is supplied to run another machine with the help of control valve.

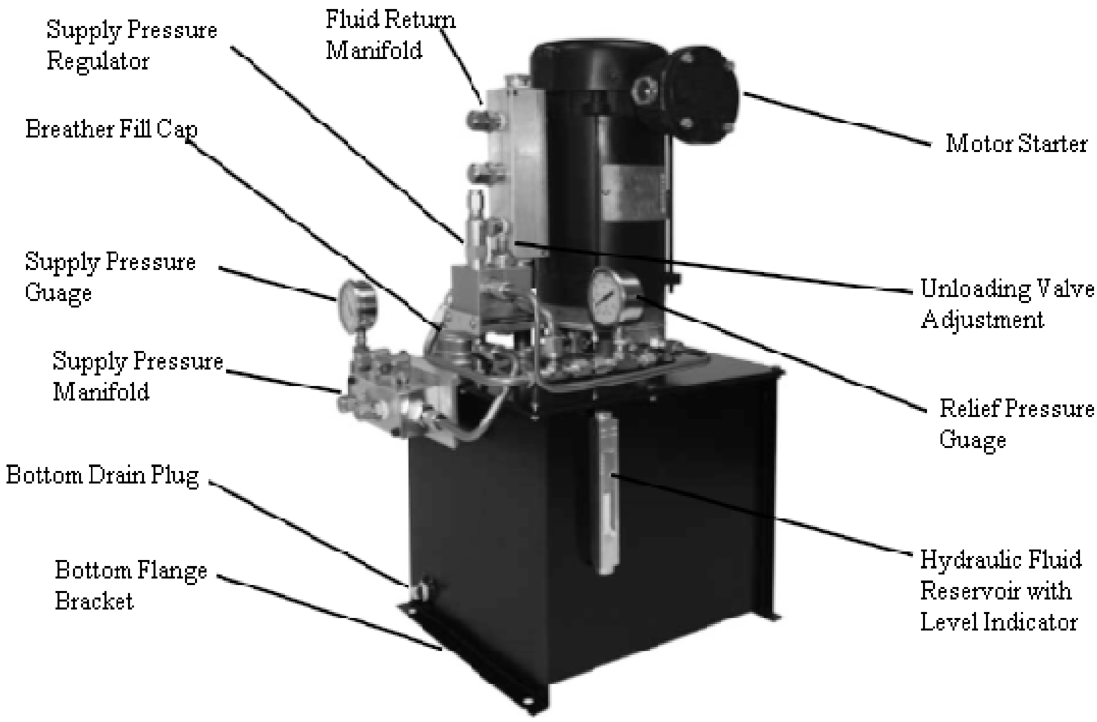

Figure 4.2: Hydraulic Power Pack [21]

4.4 Selection

4.4.1 Hydraulic Reservoir

Hydraulic reservoir stores required quantity of fluid which is supplied to the whole system.

When all cylinders are extended we get minimum fluid indicated in reservoir and maximum when all cylinders are retracted. The capacity of a reservoir is four to five times the volume of the fluid taken by the system every minute. To select total capacity of hydraulic reservoir it is decided according to the strokes/minutes.

Oil capacity of a cylinder is used to decide the capacity of the hydraulic reservoir. Oil Capacity of a cylinder is given as :-

$$O_c = \frac{\pi \times d_i^2}{4} \times l_s \tag{4.1}$$

Oil capacity of cylinders are 8 and 8 litres So the capacity of hydraulic reservoir is selected as 4 times the total oil capacity of cylinders and i.e 70 litres.

4.4.2 Pumps

Two pumps are selected

(1) Gear Pump:-

Gear Pump is normally used for low pressure. When good speed is required, these pumps are used.

Gear pump was selected to make striker block move at high speed.

(2) Radial Piston Pump:-

Radial Piston Pump is normally used when high pressure is required.

Radial Pump was selected because of the capacity to create large amount of pressure.

4.5 Hydraulic Circuit Diagram

The hydraulic circuit diagram is shown in fig. 4.3. Names of components of the hydraulic circuit is given in table 4.1 . The home position of all the 3 cylinders is shown in fig 4.3 and different operating positions has been described in fig. 4.4 to 4.8 Automation studio 5.6 was used to prepare the hydraulic circuit.

Table 4.1: Names of Components of Hydraulic Circuit

Part No.	**Name**	**Quantity**
1	Hydraulic Reservoir	1
2	Filter	5
3	Oil Cooler	1
4	Pressure Relief Valve	2
5	Motor	1
6	Gear Pump	1
7	Radial Piston Pump	1
8	Pressure Guage	2
9	4/3 Solenoid Valve	3
10	Striker Cylinder	1
11	Shutter Cylinder	1
12	Stopper Cylinder	1
13	Non-Return Valve	6

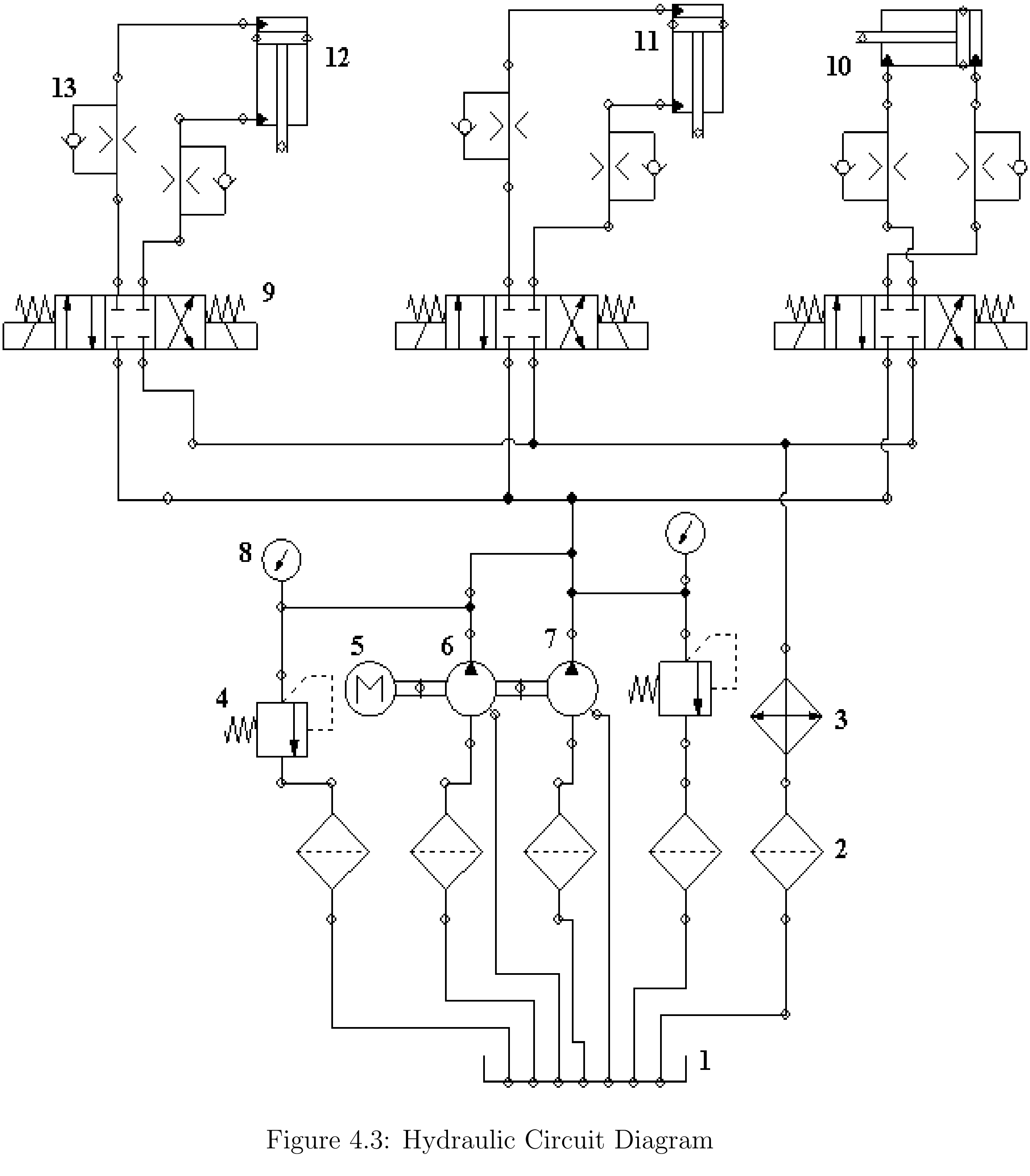

Figure 4.3: Hydraulic Circuit Diagram

Step 1 :- Movement of stopper cylinder

In the first step, the stopper cylinder(12) will act and the other two cylinders will rest at their home position. In this step hydraulic pump pulls the fluid from reservoir via filter and sends it to the solenoid valve. This valve acts, changes its position to parallel connection in which the fluid will enter the cylinder creating extension stroke i.e. brings stopper cylinder from its home to final position.

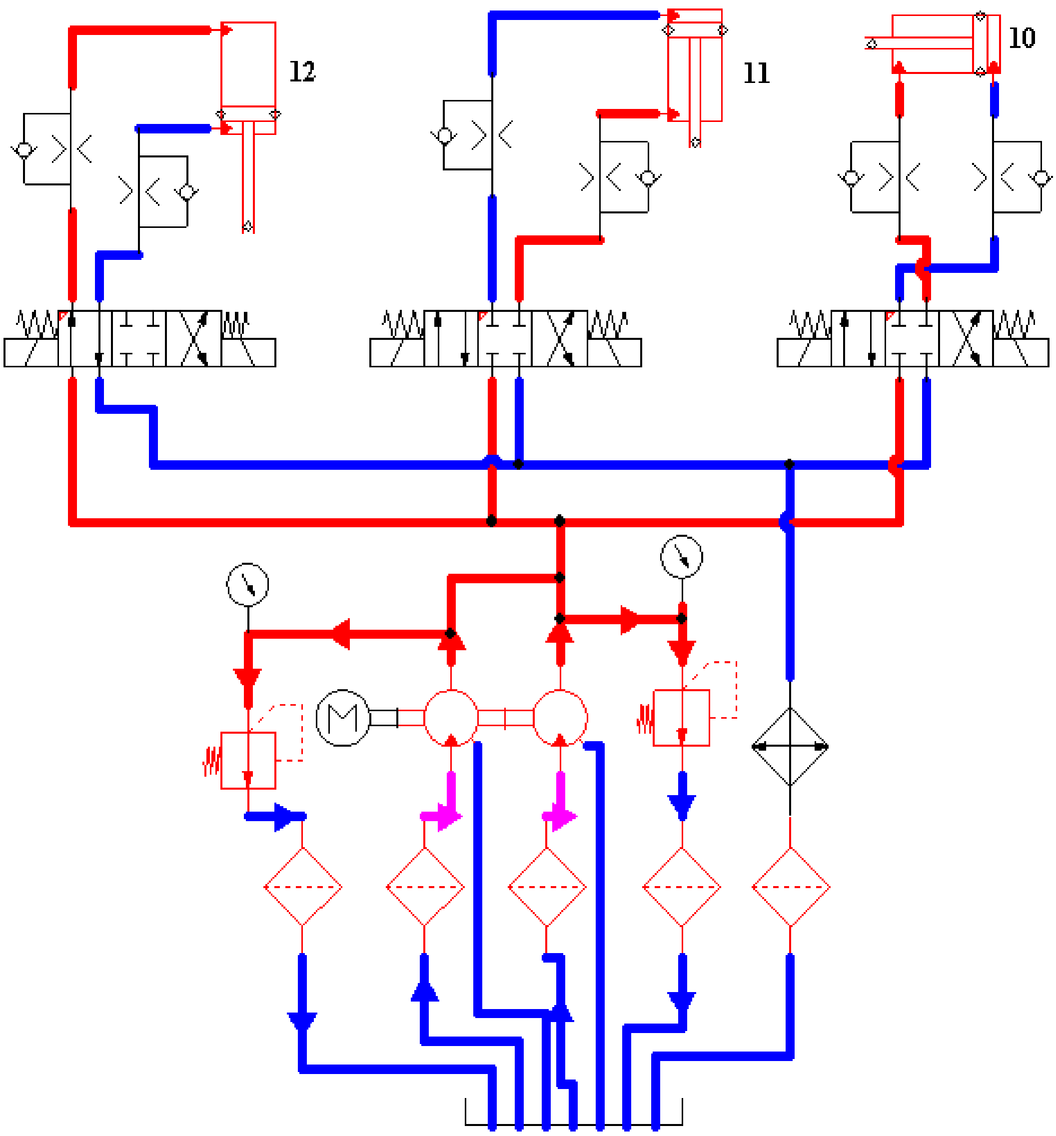

Figure 4.4: Movement of stopper cylinder

Step 2 :- Levelling the fed bagasse with shutter cylinder

In the second step, the stopper cylinder(12) and striker cylinder(10) will stay at its final and home position respectively and the shutter cylinder(11) will act. The valve of stopper cylinder will move to its center position where no fluid is allowed to flow. Hydraulic pump pulls fluid from reservoir via filter and sends it to the solenoid valve. Solenoid valve changes its position to left to bring shutter cylinder from its home to final position. During this step fed bagasse gets levelled.

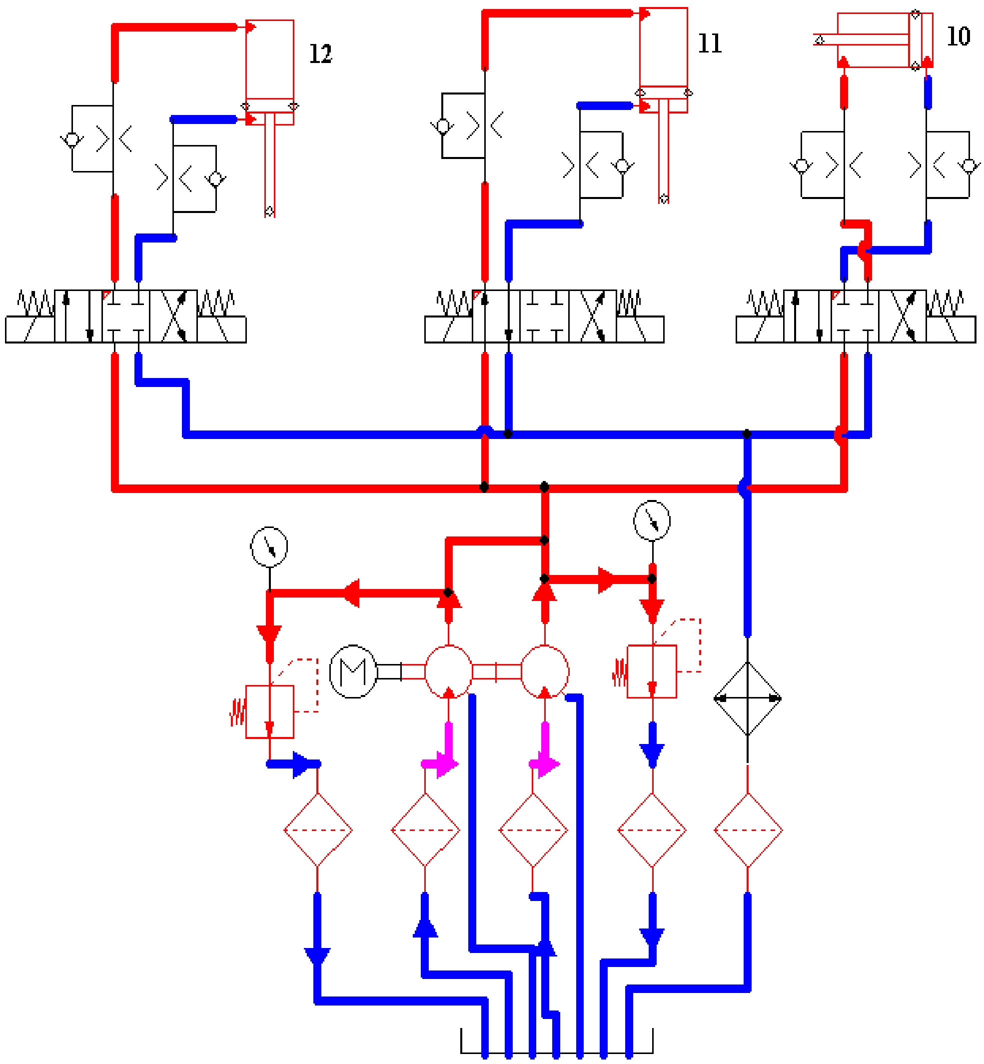

Figure 4.5: Levelling the fed bagasse with shutter cylinder

Step 3 :- Compressing the bagasse with striker cylinder

In the third step, the stopper cylinder(12) and shutter cylinder(11) will stay at its final position and the striker cylinder(10) will act. Solenoid valve of stopper cylinder and shutter cylinder will move to its center position where no fluid is allowed to flow. Hydraulic pump pulls fluid from reservoir via filter and then sends it to the solenoid valve. This valve acts and changes its position to left to bring striker cylinder from its home to final position. During this step, final compression of bagasse takes place.

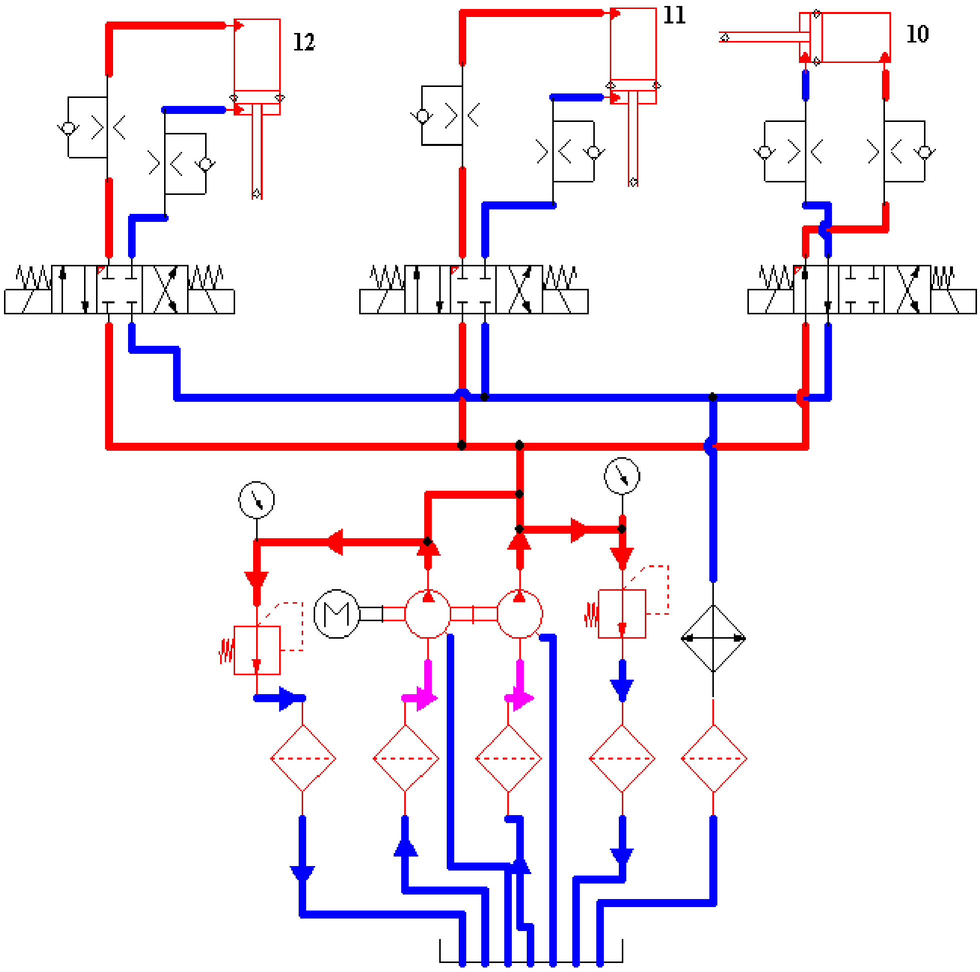

Figure 4.6: Compressing the bagasse with striker cylinder

Step 4 :- Return of the stopper cylinder

In the fourth step, the shutter cylinder(11) and striker cylinder(10) will stay at its final position and the stopper cylinder(12) will act. Hydraulic pump pulls fluid from reservoir via filter and then sends it to the solenoid valve. This valve acts and changes its position to right to bring stopper cylinder from its final to home position. During this step, the briquette formed will fall down.

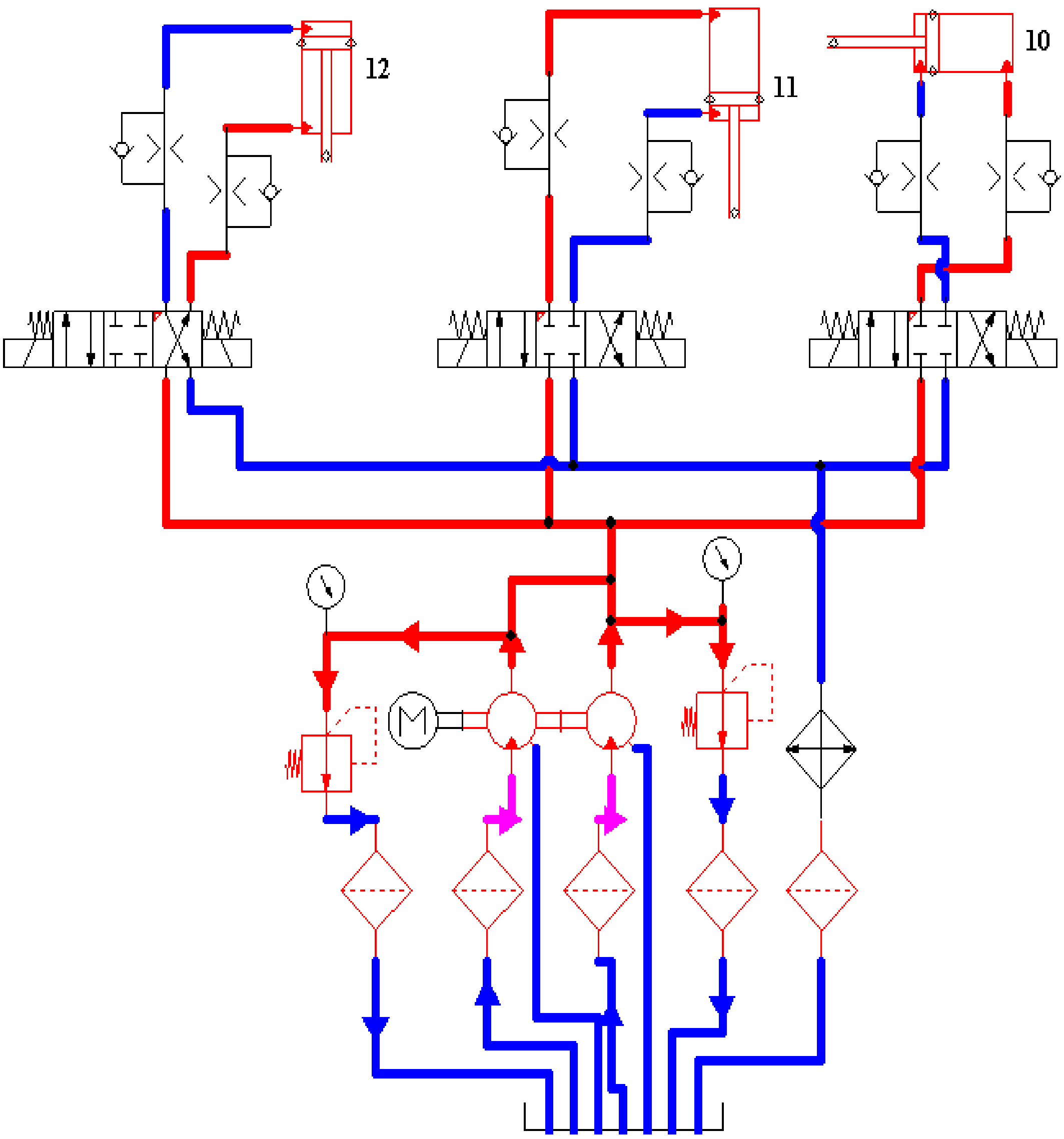

Figure 4.7: Return of the stopper cylinder

Step 5 :- Beginning of new process

In this step the shutter(11) and striker cylinder(10) will move back to its home position with the help of solenoid valves which moves to the right and with the transmission of fluid by pump. Again the stopper cylinder(12) moves to its final position and the process continues.

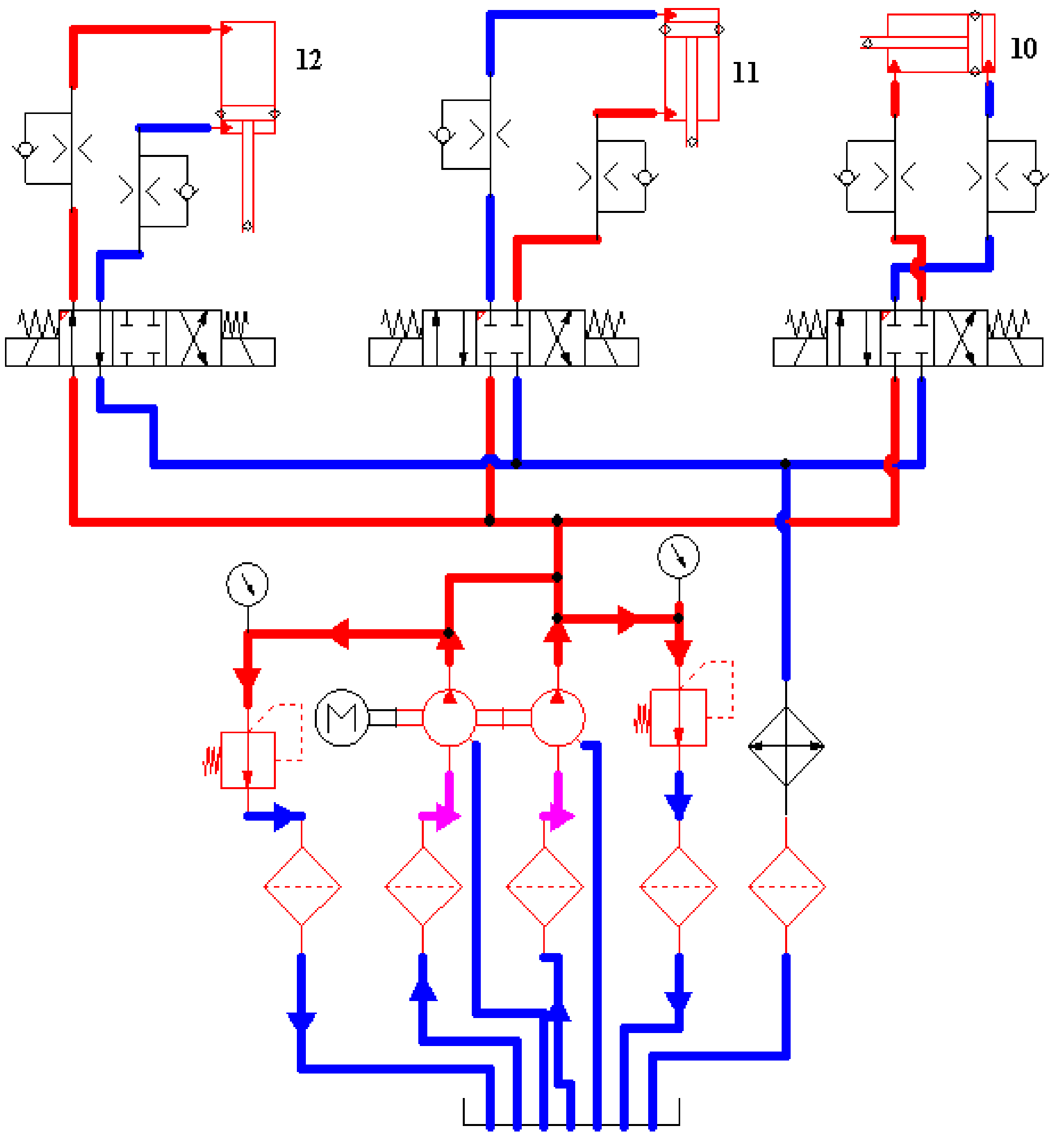

Figure 4.8: Beginning of new process

Chapter 5

Screw Conveyor And Its Design

This chapter contains introduction to screw conveyor, selection of components and design and selection procedure of different parts of screw conveyor.

5.1 Introduction

Different materials are transferred by screw conveyors. In past only grains were handled by screw conveyors but now a days even solids and powders are also conveyed.

5.1.1 Advantages of screw conveyor

- Conveying variety is huge.
- Even material having sluggish properties can be conveyed.
- There can be many inlets and many outlets.
- Controlling the flow can be possible by adding gates.
- Screw conveyor are considered as screw feeders when used as metering device.

5.1.2 Disadvantage of Screw conveyor:

- Capacity of conveyor decreases with the increase in the angle of inclination.

5.2 Components of Screw Conveyor

The isometric view and components of screw conveyor is shown in fig 5.6 .

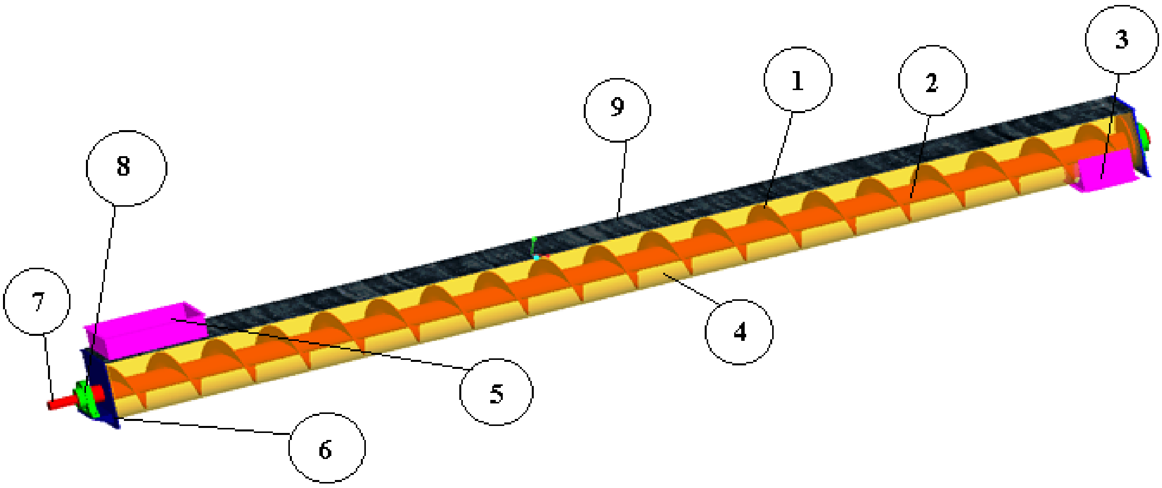

Figure 5.1: Isometric View of Screw-Conveyor

Table 5.1: Components of Screw Conveyor

Part No.	Name
1	Screw
2	Screw Shaft
3	Outlet
4	U Trough
5	Inlet
6	End Cover
7	Drive Shaft
8	Ball Bearing and Housing
9	Top Cover

5.2.1 Different Types of Troughs

Different Types of Troughs are :-

1.Formed Flange U-Trough : This trough is constructed from one piece. Top flange are manufactured from the same sheet. These troughs are widely used.

2.Rectangular Trough : High abrasive materials require rectangular troughs. Wear will be minimum in this trough.

3.Flared Trough : When materials are not able to move on the screw flared, these troughs are used.

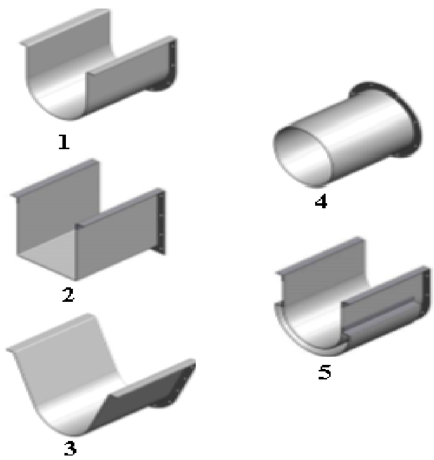

Figure 5.2: Types of Troughs [22]

4.Solid Tube Trough : In solid tube trough, screw had to be removed from trough ends only. Economical than formed flange tube trough.

5.Jacketed Trough : These troughs are used when their is requirement to deliver different temperature materials because jackets will provide cooling or heating to the material.

5.2.2 Hand Screws

A conveyor hand screws can be of two types right handed or left handed shown in fig 5.3. The screw hand is determined by seeing from the screw end.

When the screw is welded around the pipe in a counter-clock wise direction, it is said as left hand screw. When the screw is welded around the pipe in a clock wise direction, it is said as right hand screw.

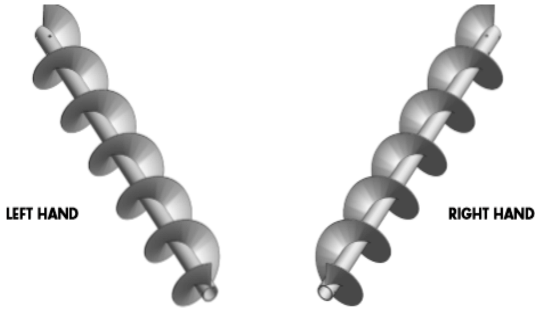

Figure 5.3: Types of Hand Screws [22]

5.2.3 Types of Flights

There are two types of flights :-

Helicoid flights are getting narrower in cross section. The thickness of inner edge is nearly twice the thickness of outer edge. Helicoid flights are shown in fig 5.4 .

Sectional flights are individual flights. Butt welding is done in order to form one loop of a screw conveyor. Sectional flights are as shown in fig 5.4 .

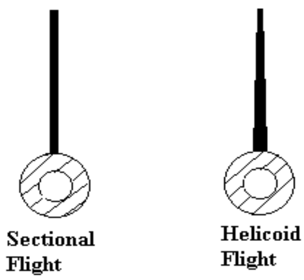

Figure 5.4: Types of Flights

5.2.4 Different types of Screws

Different types of Screws are shown in fig. 5.5 .

1. Standard Flight Screw : These screws are commonly used and can convey wide variety of products.

2. Ribbon Flight Screw : These screws are used where gummy, sticky materials are to be conveyed or when the material sticks on the flight.

3. Cut Flight Screw : These screws can be used for mixing more than two materials while conveying. It is also used for conveying fine, light and granular materials. It is also used for removing dust from the grains, etc.

4. Cut And Folded Flight Screw : These screws are used where the material is not moving properly in slanting position and it is also used to supply air to the material.

5. Sectional Flight Screw with paddles : These screws are used where materials are mixed while conveying them. Paddles used can be made fixed or bolted to the screw shaft.

6. Paddle Screw : These screws are used where materials are to be mixed completely. Even they are used to stir the materials. Paddles used can be made fixed or bolted to the screw shaft.

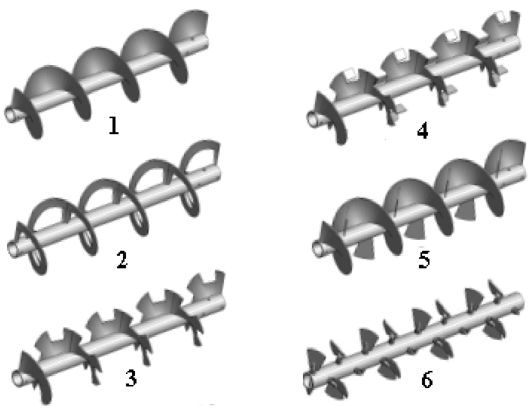

Figure 5.5: Types of Screws [22]

5.3 Design Calculations for Screw Conveyor

This section involves design calculations for different parts of screw conveyor such as core diameter, inner diameter, selection of motor, gearbox, couplings and deep groove ball bearings and development of flights. The exploded view of screw conveyor is shown in fig 5.6 and the parts name are shown in table 5.1.

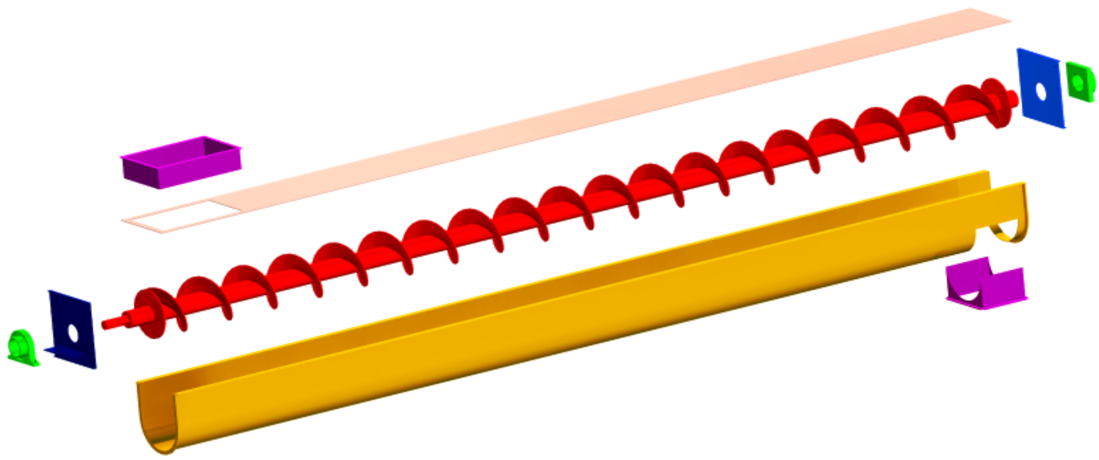

Figure 5.6: Exploded view of Screw-Conveyor

5.3.1 Screw Conveyor Design Procedure

The design procedure for screw conveyor has been explained below. [23] :-

STEP :1 Specifications

Material Handled: Bagasse

Capacity required: 2.83 m^3/hr

Length of conveyor: 3 meter

STEP :2 Properties of Bagasse

1) Bulk Density: 112 - 160 kg/m^3 [22]

2) Material class: E-45RVXY [22]

Where,

E- Irregular stringy, fibrous, cylindrical, slabs, Etc.

4 - Sluggish

5 - Mildly abrasive

R - Gives off harmful or toxic gas or fumes

V - Interlocks, mats or agglomerates

X - Packs under pressure

Y - Very light and fluffy,may be windswept

STEP :3 Calculation of Conveyor Speed

The conveyor speed can be calculated by the formula:

$$N = \frac{E_c}{R_m} \; [22] \tag{5.1}$$

Where,

N = RPM of screw

E_c = Equivalent capacity = 2.83 m^3/hr

R_m = m^3/hr at 1 revolution per minute = 0.04247 from table 5.2

Therefore,

N(RPM) = 66.635 RPM = 67 RPM

Table 5.2: Capacity Table

Trough Loading	**Screw Diameter (m)**	**Capacity m^3/hr**	
		At One RPM	**At Max RPM**
30% A	0.1524	0.04247	5.0970
	0.2286	0.1557	15.4320
	0.3048	0.3652	32.8475
	0.3556	0.5889	50.1208
	0.4064	0.8834	70.7921
	0.4572	1.2742	95.7109

STEP :4 CORE DIAMETER :-

From Table 5.2 selected diameter of screw = 153 mm.

Screw diameter according to IS:5563(1985) [24] = 160 mm

Normally for diameter smaller than 400 mm Pitch = 125 mm.

The formula to find the core diameter of the shaft is given below

$$C = \frac{\pi}{4} \times [D_s^2 - D_p^2] \times p_s \times k_s \times B.D \times N \times 60 \;\; [23] \tag{5.2}$$

where,

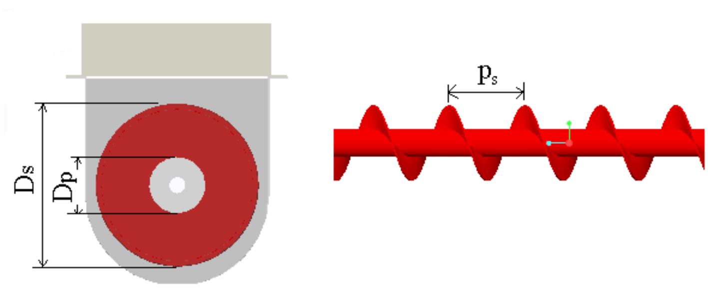

Figure 5.7: Nomenclature

C = Capacity in kg/hr = 450

D_s = Diameter of screw = 0.160 m

D_p = Core diameter of hollow pipe in m

p_s = pitch of screw = 0.125 m

k_s = Trough loading = 30% = 0.3

B.D = Bulk Density = 160 kg/m^3

N = 67 RPM

Therefore outside diameter of screw pipe,

D_p = 0.04123 m = 41.23 mm

According to IS:5563(1985) [24], pipe outer(core) diameter D_p selected is 42.4 mm with 4.0 mm wall thickness. Therefore inner diameter D_i = 42.4 - 2(4) = 35.2 mm.

STEP :5 Calculation of Power Requirement

Power requirement to operate a screw conveyor is calculated as IS:(12960)1990 [25]:-

Power necessary for the progress of the material,

$$P_H = \frac{Q \times L \times \lambda}{367} = 0.01471 \ \ kW \tag{5.3}$$

Drive Power of the screw at no load,

$$P_N = \frac{L \times D_s}{20} = 0.024 \ \ kW \tag{5.4}$$

Power Due to Inclination,

$$P_{st} = \frac{Q \times H}{367} = 0.00186 \ \ kW \tag{5.5}$$

Total Power,

$$P = P_H + P_N + P_{st} \tag{5.6}$$

Where,

Q = mass flow rate (capacity) = 0.45

L = Length of screw = 3 m

D_s = Screw Diameter = 0.160 m

H = Height = 1.524 m

λ = progressive resistance coefficient = 4

Efficiency of gear wheel = 0.85

Therefore, Total Power P = 0.04058 kW = 0.0544 hp

Now,

Brake horse power (B.H.P) [23]

B.H.P. = hp $\times$ p = 0.0544 $\times$ 2 = 0.1088

Actual B.H.P. = 0.1088 / efficiency of gear wheel

= 0.1280 hp.

STEP :6 Selection of Motor

With the horsepower determined in the preceding step, motor has been selected from motor selection table 5.3.

Table 5.3: Motor Selection [26]

Total H.P.	Motor H.P.
upto 0.45	1
0.46 to 0.67	1.5
0.68 to 0.90	2
0.91 to 1.80	3
1.81 to 3.61	5
3.62 to 6.75	7.5
6.76 to 9.00	10

The motor selected is 1 HP motor. From [27], the motor selected is 0.75 kW M2AA 80-B 4 pole with output speed of 1400 rpm and output-shaft diameter is 19 mm.

STEP :7 Selection of Gear-Box

Motor selected in previous step has speed of 1400 rpm and the required speed is 67 rpm, so gear box is selected to reduce the speed.

Ratio required $= \dfrac{InputSpeed}{OutputSpeed} = \dfrac{1400}{67} = 20.89$

Nearest standard ratio available is 20:1

Mechanical service factor $(F_m) = 1.25$ for 12 hr/day operation

Input power = Motor Power x F_m = 0.75 x 1.25 = 0.9375 KW

Output Torque = $(9550 \times 0.9375)/\ 67 = 133.62$ N-m

From [28]- Rating at Input 1500 rpm, Ratio - 20:1

Gear unit size : 2

Input Power = 1.5 kW

Input Shaft Diameter = 18 mm Output Shaft Diameter = 29 mm.

STEP :8 Calculation of Torque

Torque to be transmitted,

$$Design\,Torque = \frac{9550 \times Motor\ kW \times Service\,Factor}{Motor\ RPM} \tag{5.7}$$

where,

Motor power = 0.75 kW

Service Factor = 1.77

RPM of motor = 1400 rpm

Substituting values,

Design Torque = 9.055 N-m

STEP :9 Selection of Coupling

Selection of coupling can be done with the torques that are calculated in the previous steps.

JAW type "LOVEJOY" coupling has been selected. [29].

As calculated torque is less than maximum torque, selected couplings are safe.

Table 5.4: JAW Type Coupling Selection

Properties	**Type-1**	**Type-2**
Connection	Motor Output to GearBox Input	GearBox Output to End-Shaft
Coupling Type	L	L
Coupling Size	075	150
Calculated Torque (N-m)	9.055	133.62
Maximum Torque (N-m)	10.2	140
Min. Bore	9	16
Max. Bore	22	48

STEP :10 Development of Flight [23]

The screw shaft with the profile of the helix of flight and its development is as shown in figures 5.8 and 5.9 respectively. Sectional flights are selected in screw conveyor.

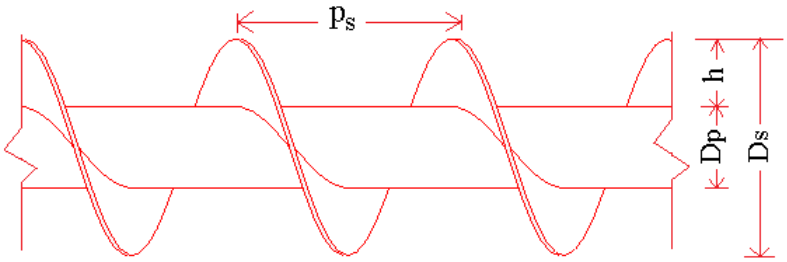

Figure 5.8: Conveyor Screw Flight Helix Profile

Here,

$$h = \frac{D_s - D_p}{2} \tag{5.8}$$

Where,

p_s = pitch = 0.125 m

D_s = Screw Diameter = 0.160 m

D_p = Core Diameter = 0.0424 m

Therefore h = 0.0588 m

Step -1 Calculation of minor helix length

Development of helix flight gives a right-angled triangle. Therefore

$$l_m = \sqrt{(\pi \times D_p)^2 + p_s^2} = 0.1826\, m \tag{5.9}$$

Step -2 Calculation of major helix length

Development of helix flight gives a right-angled triangle. Therefore

$$L_m = \sqrt{(\pi \times D_s)^2 + p_s^2} = 0.5179\, m \tag{5.10}$$

Step -3 Theoretical Development

Theoretical Development is as shown if Fig 5.9 Now,

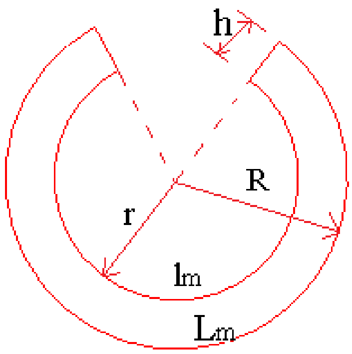

Figure 5.9: Theoretical Development for one Pitch

R = Disc Outer Radius

r = Disc Inner Radius

$$R = \frac{L_m \times h}{L_m - l_m} = 0.0947\, m \tag{5.11}$$

$$r = R - h = 0.0359\, m \tag{5.12}$$

Thus disc internal diameter 0.0718 m and outer diameter 0.1895 m will be cut and then bent in the form of flight over the hollow shaft. This flight section will be butt-welded to form the complete screw.

Now,

No. of flights = 3000/125= 24 flights

23 right handed flights from inlet end of trough to outlet and 1 left handed flight from the end plate of trough at outlet side to discharge.

Thickness of flight selected from IS 5563(1985) Table 1 [24] is 3.15 mm.

STEP :11 Selection of Bearing [14]

Bearing to be selected are deep grove ball bearing, for a shaft of diameter 35 mm and which rotates at 67 rpm. Considering weight of flights and weight of hollow shaft as UDL, radial load calculated was 240 N.

Radial Load F_r = 240 N

Assuming life required L_{10h} = 12000 hrs.

Assuming 90 % probability of survival.

Life in million Revolutions

$$L_{10} = \frac{60 \times n \times L_{10h}}{10^6} = 49 \ million \ rev. \tag{5.13}$$

Dynamic load at one end of screw conveyor is

$$P = F_r = 240 \ N \tag{5.14}$$

Assuming 50 % overloading P = 240 * 1.5 = 360 N

Dynamic Capacity

$$C_d = (L_{10})^{1/3} * P = 1317.35 \ N \tag{5.15}$$

Inner diameter = 35 mm, Therefore from IS:3688 (1990) [30] end shaft with diameter 35 mm is selected.

For Deep Grove Ball Bearing, SKF61807 is selected.

Designation :- 61807

Dynamic Capacity C_d = 4030 N

Inner Diameter = 35 mm

Outer Diameter = 47 mm

Calculated Dynamic Capacity = 1317.35 N.

Hence Bearing selected is safe.

Chapter 6

Design of Shredding Machine

This chapter includes introduction to different types of shredding machine and designing different parts of shredding machine.

6.1 Introduction

Shredding machines are used to cut biomass into small pieces to reduce size, for better handling and for the production of solid fuel. Biomass shredding is used to transform waste to renewable source of energy. It also improves the efficiency of recycling and also helps in lowering waste-filled lands. Biomass shredding equipment is used in the process of untreated biomass.

6.1.1 Types of Shredders

Different types of shredders are as follows [31]:-

1.Chippers :- Chippers are used to reduce the biomass materials into chips at very high speed. There can be multiple stages of machine which cut biomass. Biomass can be fed automatically or manually in these kind of machines. Single or Multiple knives can be used together with multiple or single drums.

2.Hammer-mills :- If biomass is to be crushed or pulverized then hammer-mill shredder machines can be used. Hammers together with rotating drum are most commonly used hammer-mills. This hammer is made of hardened bar or chain. The size output is controlled by output screens and these machines are available with gravity fed mechanism. For different materials, hammer material changes and the rotation speed can also be kept different.

3.Granulators :- These kind of machines are used for plastic cutting. Knives are used instead of abrasive parts. Different sizes of granulators can be made according to the location and requirement of industries.

4.Grinders :- Grinders are used to compress materials by pulverizing and with the help of wear of the materials. Parts used in this type of shredders are drums, wheel and plates. According to the type of material the speed of the grinders can be kept low to high.

5.Shear Shredders :- Rotary cutters are used to cut biomass rather than grinding, pulverising or chipping. Different industries uses different ways of shearing biomass materials. According to the applications, speed, number of knives and feed can be kept.

6.1.2 Number of Shaft Shredders

1.Single Shaft Shredders :- Single shaft shredders are most widely used, very simple in construction, easy to design and are compact. Single shaft shredders can be operated without any extra feeding system. Knives are mounted on a single shaft as shown in fig. 6.1

2.Double shaft shredders :- If the biomass are having very long tissues or if they are large in size, then in order to reduce the size double-shaft shredders are used. Here two shafts are used to mount knives. Double-shaft shredders are also known as pre-shredders. These shredders are suitable for wood and solid municipal waste. Double shaft shredder is as shown in fig. 6.1

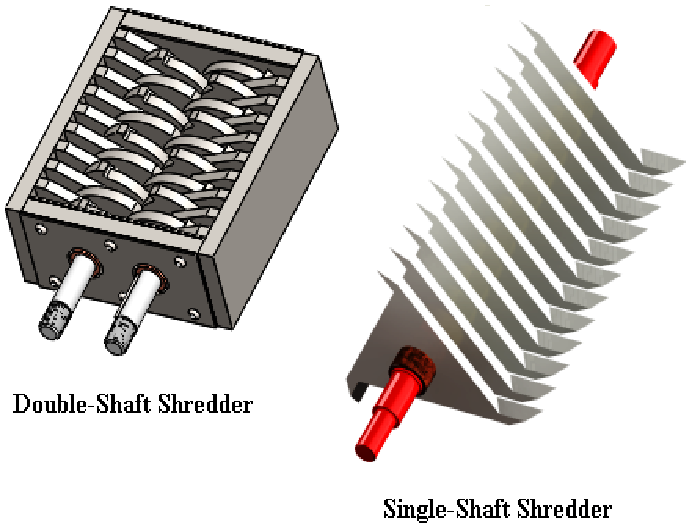

Figure 6.1: Number of Shaft-Shredders

6.1.3 Applications of Shredder

1. Can be used to destroy prototypes and models.
2. Waste of any house can be managed.
3. Any size of waste can be cut.
4. Can be directly used in industries.
5. Can be used to reduce waste filled on land.

6.1.4 Advantages of Shredder

1. Recovery of the produced waste can be done.
2. Recycling costs can be saved.
3. Landfills can be decreased.
4. Landfills can be kept clean.
5. Emitted gases can be reduce.
6. Natural resources can be reserved by cutting them into pieces.

6.2 Design of Shredding Machine

This section involves design calculations for different parts of shredding machine such as calculation of shaft diameter using cutting forces, selection of motor, selection of V-Grooved Pulleys, Calculation for number of V-Belts, selection of deep groove ball bearings. Isometric view of shredding machine is shown in fig 6.2 . Bill of material is shown in table 6.1 . Exploded view of shredding machine is shown in fig 6.3

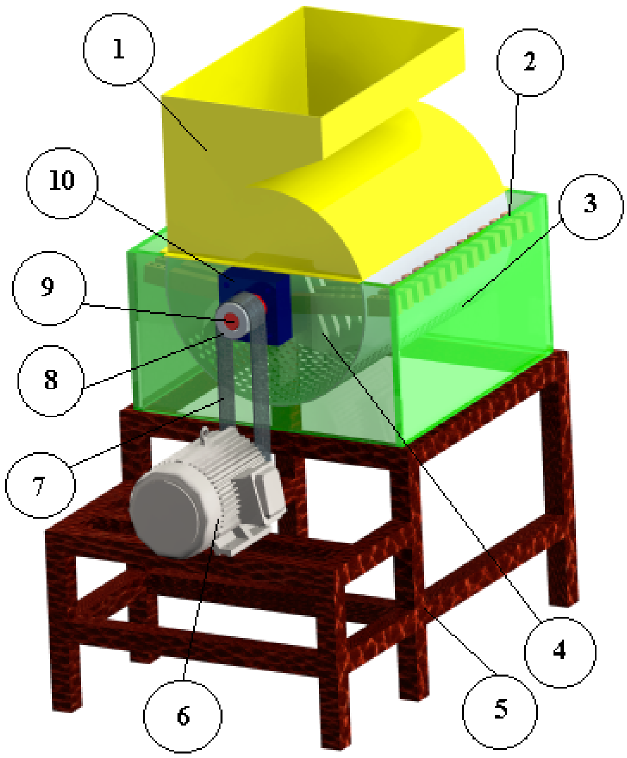

Figure 6.2: Isometric View of a Shredding Machine

Table 6.1: Bill of Material of Shredding Machine

Part No.	**Name**
1	Upper Chute(Hopper)
2	Stationary Blades
3	Strainer
4	Rotating Blades
5	Stand
6	Motor
7	V-Belt
8	V-Grooved Pulley
9	Shaft
10	Bearing and Housing

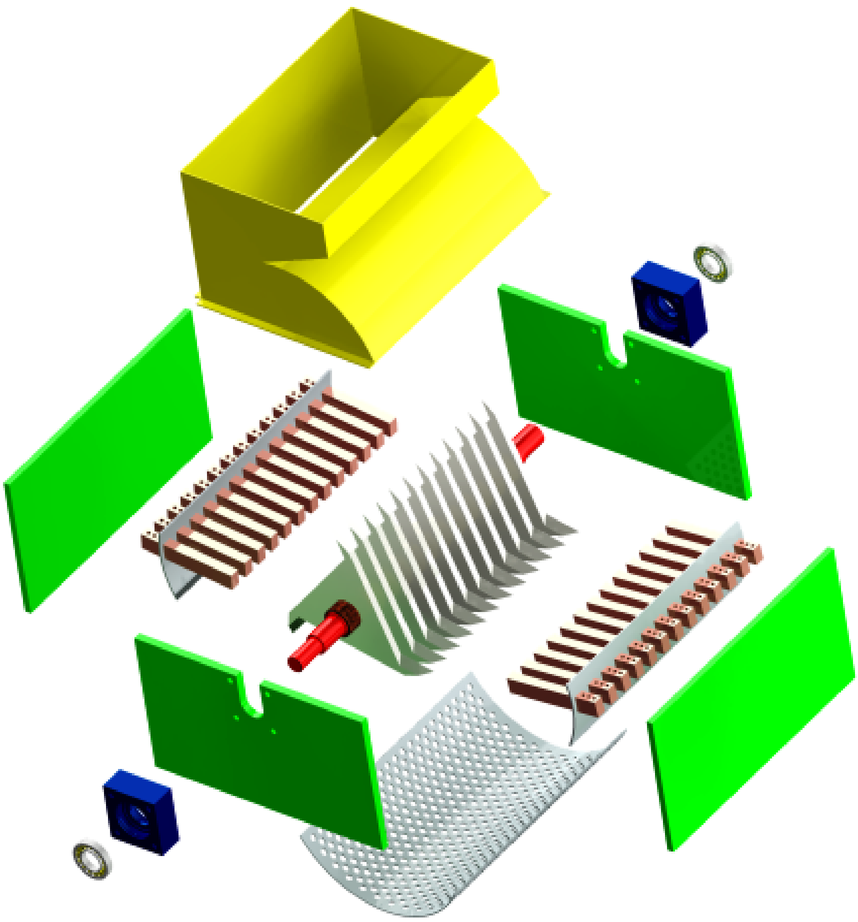

Figure 6.3: Exploded View of a Shredding Machine

6.3 Selection of Motor

6.3.1 Shearing Force

Shear test was performed on sugar cane bagasse by performing an experiment and shear strength obtained at bottom part, middle part, top part of sugar cane bagasse were (2.41 ± 0.095) MPa, (2.23 ± 0.095) MPa and (2.42 ± 0.095) MPa respectively and average shear strength was considered as 2.23 Mpa. [10]

6.3.2 Selection of Motor

Shear force = 2.23 Mpa

Cutting length = 100 mm

Cutting thickness = 2 mm

No. of revolutions per minute = 800 rpm

Cutting force = 2.23 × 100 × 2 = 446 N

Torsional moment (M_t)

$$M_t = CuttingForce \times \frac{P.C.D}{2} = 446 \times 100 = 44600 \ \ Nmm \tag{6.1}$$

Power (kW)

$$kW = \frac{2 \times \pi \times n \times M_t}{60 \times 10^6} = 3.7 \ \ kW \tag{6.2}$$

The motor selected is 4 kW motor. From [27], the motor selected is 4 kW M2AA 112M 4 pole with output speed of 1430 rpm.

6.4 V-Pulley System

The shaft is connected to motor shaft by a speed reduction v-grooved pulley system with belt. [32]

Power (kW) = 4 kW

Motor RPM (n) = 1430 rpm

Required RPM (N) = 800 rpm

Space available centre distance= 450 mm

Service = 12 hr/day

d = Diameter of Smaller Pulley = 90 mm [33]

Step :1 Correction Factor for industrial service F_a

In this application a motor of 4 kW is driving a shaft with blades. From [32], table 8, medium duty and operational hours per day = 12 hr/day, the correction factor selected is

$$F_a = 1.2 \tag{6.3}$$

Step :2 Design Power

$$Design\ Power = F_a \times Transmitted\ Power\ \ = 1.2 \times 4 = 4.8\ \ kW \tag{6.4}$$

Step :3 Type of Cross-Section For Belt

Plotting a point with co-ordinates of 4.8 kW and 1440 rpm speed in [32] Fig 1. It is observed that the point located in the region of the SPZ - Section Belt. Therefore, the selected cross-section of V-belt is SPZ.

Step :4 Pitch Diameter of smaller and bigger pulleys

$$Speed\ Ratio = \frac{1430}{800} = 1.7 \tag{6.5}$$

d = 90 mm and D = d × speed ratio = 153 mm

According to [32] D = 160 mm

Step :5 Pitch Length of Belt

$$L = 2C + \frac{\pi(D+d)}{2} + \frac{(D-d)^2}{4C} = 1295.42\ mm \tag{6.6}$$

Step :6 Preferred Pitch Length

From [32] table 9, the preferred pitch length for Z section belt can be 1250 or 1400 mm. It is assumed that the pitch length of the belt is 1250 mm.

Step :7 Correct Centre Distance

L = 1250 mm

L = 2C + $\dfrac{\pi(D+d)}{2} + \dfrac{(D-d)^2}{4C}$

1250 = 2C + $\dfrac{\pi(160+90)}{2} + \dfrac{(160-90)^2}{4C}$

$2C^2 - 857.31 + 1225 = 0$

C = 427.22 mm

Therefore the corrected centre distance is 427.22 mm

Step :8 Correction Factor for Belt-Pitch Length (F_c)

From [32] table 9, (SPZ - Section and 1250 mm pitch length),

$$F_c = 0.96 \tag{6.7}$$

Step :9 Correction Factor for arc of contact (F_d)

$$\alpha_p = 180 - 2sin^{-1}(\frac{D-d}{2C}) = 170.60^\circ = 171^\circ \tag{6.8}$$

From [32] table 10, F_d is taken as 0.98

Step :10 Power Rating of Single V-belt (P_r)

From [32] table 4 1440 rpm, 90 mm pulley, SPZ-section and Speed Ratio 1.7

$$P_r = 2.01 + 0.20 = 2.21 \ kW \tag{6.9}$$

Step :11 Number of Belts

The number of belts required can be calculated from the following formula:-

$$Number\ of\ Belts = \frac{P \times F_a}{P_r \times F_c \times F_d} = 2.3086 \tag{6.10}$$

Therefore 3 V-Belts are required.

6.5 V-Belt Tensions

Belt Tensions are required to find the diameter of the shaft. Belt tensions can be found out as follows [14]:-

mass of belt m = 0.5 kg/m

co-efficient of friction f = 0.2

Groove angle for sheaves $\theta = 34°$

contact angle of smaller pulley $\alpha_p = 171°$

$$h = \frac{f\alpha_p}{sin\frac{\theta}{2}} = 2.0415 \tag{6.11}$$

Now,

$$e^h = e^{2.0415} = 7.7021 \tag{6.12}$$

Velocity is given as,

$$v = \frac{\pi \times d \times n}{60 \times 10^3} = \frac{\pi \times 90 \times 1430}{60 \times 10^3} \tag{6.13}$$

Therefore v = 6.7387 m/s

Now, mv^2 = 0.5 * $(6.7387)^2$ = 22.70

To find belt tensions following equations are used

$$\frac{P_1 - mv^2}{P_2 - mv^2} = e^h \tag{6.14}$$

$$kW = \frac{(P_1 - P_2)v}{1000} \tag{6.15}$$

Solving equations (6.14) and (6.15),

P_1 = 700 N and P_2 = 111 N

6.6 Design of Shaft

Design of shaft has been carried out considering cutting forces that are acting on rotating blades. [14]

Shear force = 2.23 Mpa [10]

Cutting length = 100 mm

Cutting thickness = 2 mm

Cutting force = 2.23 × 100 × 2 = 446 N

For 12 blades, cutting force = 12 × 446 = 5352 N

Material selected for shaft is 50C4 from IS 1871-2 (1987) [17] .

σ_{ut} = 700 N/mm^2, σ_{yt} = 460 N/mm^2

k_b = 1.5 and k_t = 1.0

Step :1 Permissible Shear Stress

0.30σ_{yt} = 0.30 * (460) = 138 N/mm^2

0.18σ_{ut} = 0.18 * (700) = 126 N/mm^2

The lower of the two values is 126 N/mm^2 and there are keyways on the shaft.

Therefore τ_{max} = 0.75 * (126) = 94.5 N/mm^2

Step :2 Torsional Moment

The torque transmitted by shaft is given by,

$$M_t = Cutting\ Force \times \frac{P.C.D}{2} = 446 \times 100 = 44600\ N\ mm \tag{6.16}$$

Step :3 Bending Moment

The bending moment diagram in the vertical plane is shown in fig 6.4. The bending moment, which is maximum at point D, is given by

M_b = 1072770 N-mm

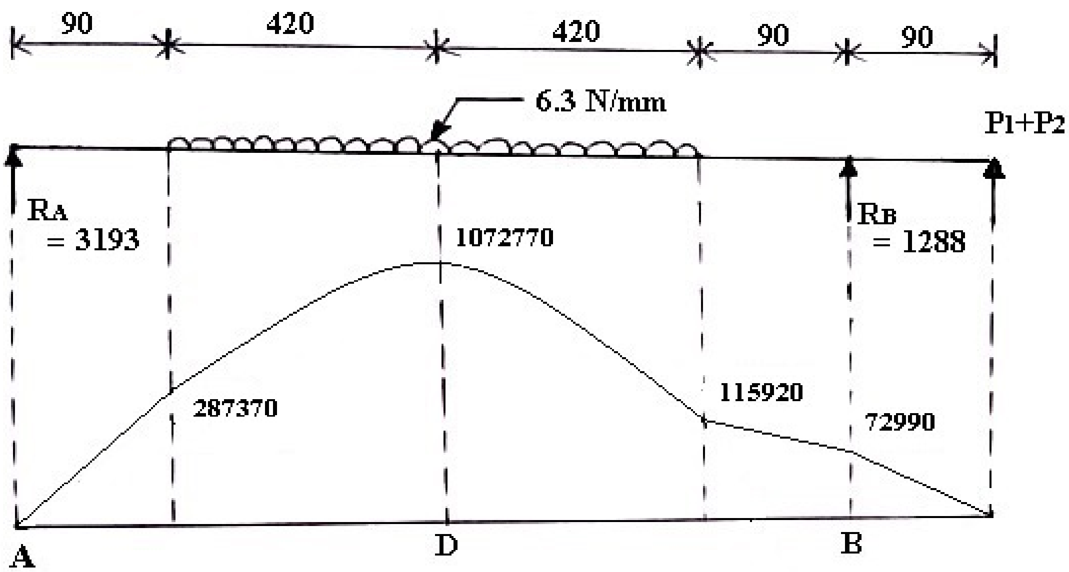

Figure 6.4: Forces And Bending Moment Diagram

Step :4 Shaft Diameter

$$d^3 = \frac{16}{\pi \tau_{max}} \times \sqrt{(k_b M_b)^2 + (k_t M_t)^2} = 86756.68\ mm \tag{6.17}$$

d = 44.26 mm

According to IS:1732(1989) [34] diameter of the shaft selected is 45 mm.

6.7 Selection of Bearings

Bearing to be selected are deep grove ball bearing, for a shaft of diameter 35 mm and which rotates at 800 rpm. The bearing is subjected to only radial load of 3193 N.

Radial Load F_r = 3193 N

Assuming life required = 12000 hrs.

Assuming 90 % probability of survival.

Life in million Revolutions

$$L_{10} = \frac{60 \times n \times L_{l0h}}{10^6} = 576 \ million\, rev. \tag{6.18}$$

Dynamic load at one end is

$$P = F_r = 3193 \ N \tag{6.19}$$

Dynamic Capacity

$$C_d = (L_{10})^{1/3} * P = 26566.83 \ N \tag{6.20}$$

For Deep Grove Ball Bearing, SKF6307 is selected.

Designation :- 6307

Dynamic Capacity C_d = 33200 N

Inner Diameter = 35 mm

Outer Diameter = 80 mm

Calculated Dynamic Capacity = 26566.83 N.

Hence Bearing selected is safe.

Chapter 7

Conclusions and Future Scope

7.1 Conclusions

A fully automated hydraulic briquette machine has been designed that can produce briquettes automatically, with bagasse as a material and without any human effort.
The hydraulic circuit for the briquetting machine has been prepared and various components of the same have been selected. The circuit diagram has been prepared in Automation studio 5.6.
Design of screw conveyor has been carried out which includes different components such as screw shaft, trough, flights, gearbox, couplings and motor.
Design of shredding machine has been carried out which includes different components such as shaft for mounting cutter blades, selection of belt-pulley system and motor.

7.2 Future Scope

As detailed design of briquette line has been carried out which includes three major equipment's hydraulic briquette machine, screw conveyor and shredding machine, these can be manufactured and tested for its purpose.

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