Project Report On

Production of Green Fiberboard from Pretreated Agro-Industrial Waste

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Preface

Green fibreboard is a composite wood product traditionally formed by breaking down softwood into wood fibers, often in a defibrator, combining it with wax and a synthetic resin binder such as urea formaldehyde resins (UF) or other suitable bonding system, and forming panels by applying high temperature and pressure, the increasing utilization of green fibreboard for furniture manufacturing is favorably influencing the market. Furthermore, the rapidly expanding residential sector and a considerable preference for green building construction are significantly contributing to the market growth across the globe. Moreover, the growing eco-consciousness among consumers is projected to strengthen the sales of MDF as it is mainly produced through renewable and sustainably sourced wood. Several market players are also heavily investing in technical innovations and improvements in the production process to manufacture these fiberboards with superior features, including enhanced durability and extended lifespan.

ACKNOWLEDGEMENT

We would like to thank everyone who had contributed to this project. We would like to express our gratitude to our Project supervisor, *Engr. Dr. Naeem Akhtar Qaisrani* for his invaluable advice, guidance, and his enormous patience throughout the completion of project.

In addition, we would also like to express our gratitude to our loving parents and friends who had helped and given us encouragement.

ABSTRACT

The worldwide occurrence of wood chips based lignocellulosic medium density fiber board is still appropriate and almost there is generally no chance of fiber disasters. Due to the good economic growth in Asia has in addition added to build the interest to increased demand of wood-based raw materials.

Manufacturing of fiberboard was done by using pretreated rice husk and urea formaldehyde resin. The fabrication fiberboard was done by using thermal press. The solvent used for this process is glycerol. Cellulose is major constituent for fiberboard synthesis and lignin, hemicellulose are separated as a byproduct may further used for sugar ethanol production.

Most prominent equipment used for the manufacturing of fiberboard are heat exchanger, shredder, helical stirring reactor, decanter centrifuge and centrifugal pump. For 80 m^3/day production of fiberboard required area of heat exchanger 14 m^2 and volume of straining reactor should be 229.17 ft^3

The aim of this thesis is to develop the efficient sustainable and green environmentally friendly medium density fiber board manufactured from the pretreated cellulose rich fibers. Our raw material is based on the rice straw. In this thesis rice straw mixed with urea formaldehyde resin in order to develop the high strength medium density fiber board.

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Chapter 1

INTRODUCTION

1.1. Overview

The worldwide occurrence of wood chips based lignocellulosic medium density fiber board is still appropriate and almost there is generally no chance of fiber disasters. But at this moment we have sectional shortage of wood fibers. On large scale need of proper wood chips raw material is shortage in many Asian states due to deforestation. Due to the good economic growth in Asia has in addition added to build the interest to increased demand of wood-based raw materials. Wood based biomass is getting more restricted and exorbitant for creators of fiberboard and paper, bio-energy, timber, and wood-based composite fiberboards. Also, the expanding natural mindfulness worries of the strength of forest untamed life variety biomass productivity environment and organic sink guides examination to elective fiber recourses.

Annual plant materials are encouraging possibility for lignocellulose fiber composites. Various yearly plant fibers like flax, hemp, jute, kenaf, bagasse, corn, and bamboo have subject of broad research for the production of non-wood molecule and fiberboards. Farming harvest buildups like oat straws, i.e., straw, barley, oats, rye, and rice are essential for the increase of grains and produced in billions of tones around the world.

The agro-straw materials rich, cheap, and easily available sources of lignocellulose fibers. The fundamental test for board makers is to change over the agrarian straw materials into molecule sheets, medium thickness fiberboards, or high-thickness fiberboards, or high- density fiberboards in a sound technical and economical process. change over the agrarian straw materials into molecule sheets, medium thickness fiberboards, or high-thickness fiberboards, or high- density fiberboards in a sound technical and economical process.

In this proposal the assembling of non-wood superior is investigated on rice straw. Various kinds of glues, urea formaldehyde, melamine-adjusted urea-formaldehyde saps, and methylene diisocyanate were assessed in pilot-scale. Moreover, binder less wheat-straw fiberboards have been produced by creation of straw fibers by addition of hydrogen peroxide.

However, various types of fiberboards known as solid board boards are also fabricated. Masonite sheets were one of the principal business fiberboards. In initiation wet-process, wood fibers were created by steam blast of wood chips and pressed to fiberboards in the absence addition of adhesive. During hot pressing process softening of the lignin and self- connection between fibers participate to the final synthesis of the fiberboards. The major disadvantage of this kind of fiberboard processing includes more water needed, dark color of the boards and long hardening times. The improvement of the hardboard cycle has been coordinated into the more current dry interaction technique and manufactured glue is regularly added [1].

1.1.1. How we define fibreboard?

The methods of synthesis of wood-based fiberboard are divided into The wet and dry process.

1. Wet process particle board
2. Dry process fiberboards

Wet interaction sheets are fireboards having fiber dampness substance of something else than 20% at the phase of shaping additionally, classification of wet process depends Wet hardboards use water as the delivery source for the fibers to be pressed into a mat. This method is development of paper production. Dry process fireboards contain a fiber moisture content of lower than 20% at the form of developing, and contain density ≥ 450 kg/m^3. These sheets are basically created under warmth and pressing factor with the expansion of an engineered cement. For promoting purposes, MDF of explicit thickness reach can be given various divisions. For example

HDF: MDF with a density ≥ 805 kg/m^3

Light MDF: MDF having a density ≤ 600 kg/m^3 Ultra-light MDF: MDF having a density ≤ 555 kg/m^3

1.2. Structure of Cellulose

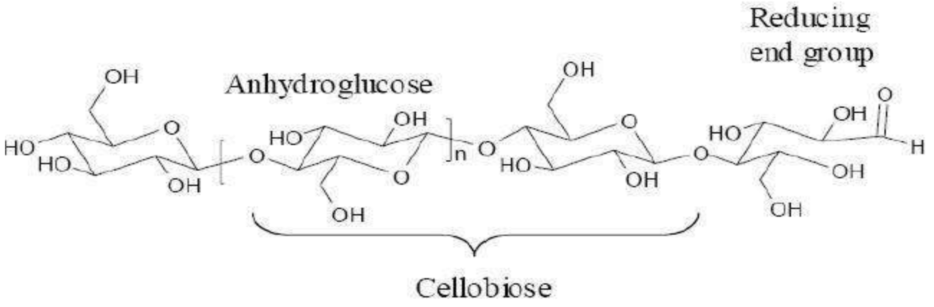

Figure 1.1 Structure of cellulose [1].

1.3. Hemicellulose

Hemicelluloses are plant hetero-polysaccharides whose chemical behavior expands from tissue and from even in various types of cells within the same plant. These polysaccharides are created by a variety of developing blocks consisting pentons, and uranic acids.

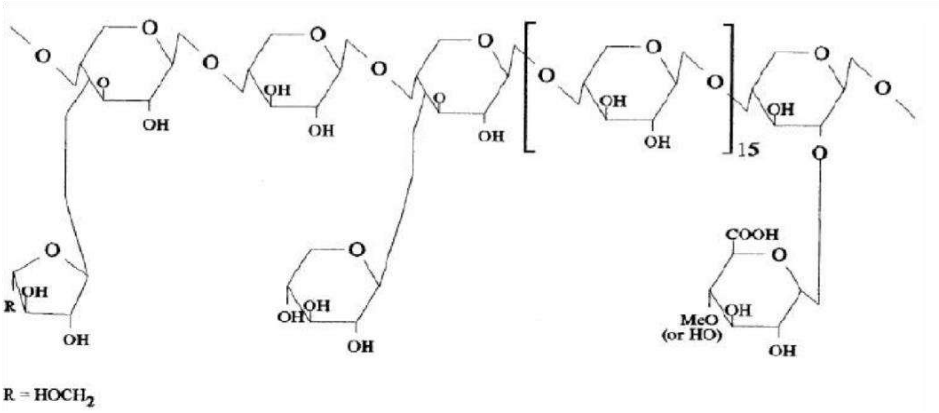

Figure 1.2 Structure of hemicellulose [1]

1.4. Lignin

Lignin is the binder between fibers in wood and yearly plants. As a primary wall component, lignin gives strength, supply of water and constituent's and safety from attack by microorganisms. The respective aromatic constituents of these alcohols in the polymer are called p-hydroxyphenyl, guaiac and moieties. All kinds of plant lignin are comprised of these three phenyl propane cells.

Lignin in softwood is mainly composed of guaiacol.

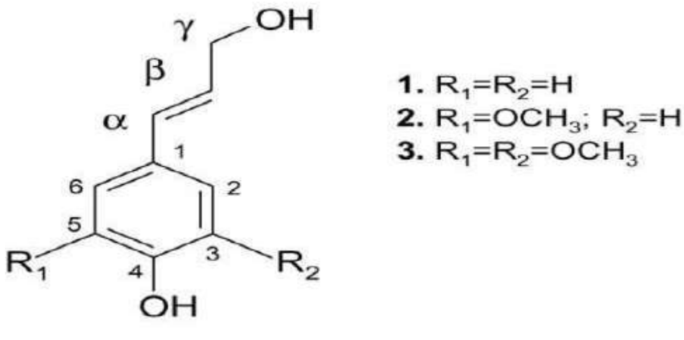

Figure 1.3 Structure of lignin [1]

1.4.1. Structure of Straw

Yearly plants as rice-straw are less homogenous than the perennial softwoods or hardwoods in the morphological building. The straw is the fundamental material that makes the plant to bear and is consist of the stem and leaves;

The amounts of cellulose and lignin are in overall lower in straws than in wood. Therefore, the amount of hemicellulose is higher. A more hydrophilic characteristic of the refined straw fibers is expected compared with wood-based fibers.

1.5. Chemical Composition of Straw

Annual plant materials such as straw, are natural composite lignocellulose materials. In addition, these plants also includes a considerable number of inorganic components such as silicon, potassium, phosphorous, sodium, calcium, iron, aluminum and other elements of low concentration.

Table 1.1 Composition of agro- waste [1]

Some oxides	Rice straw	Wheat straw	Switch grass	Sugar cane	Fire wood
Sio_2	74.31	35.84	65.18	46.61	12.26
Al_2o_3	1.4	2.36	4.51	17.69	2.83
Fe_2o_3	.02	.97	2.03	14.14	4.24
Cao	1.6	4.66	5.60	4.47	37.03
Mgo	1.89	3	3	3.33	5.85
K_2o	11.30	11.40	11.60	4.15	17
So_3	0.84	5.46	0.44	2.08	11.20

1.6. The Fibreboard Production Process

The dry fiberboard mdf process is constructed for wood based components. softwood Species the preferred raw material in the md industry. some examples of hardwood are beech, rubber wood. the differences of wood materials for production of MDF are Probably wider than for the pulp and paper industry.

1.7. Problem Statement

Why we choose biomass for the synthesis of green fiber board panels??

Wood chips, shavings are usually used for the manufacturing of the fiber boar. However due to the environmental crisis wood chips is not a good option to use, that's why biomass (rice wheat peanut shell), wastepaper, corn flicks are used. Due to the deforestation issues wood chips is not a good choice for the synthesis of fiber board on large scale.

1.8. Selection of Project

The annual inhabitants growth rate is about 2.10% Pakistan's population will become twice in less 32 years. Keeping in view the growth rate of Pakistan it is likely that the accommodation requirement will automatically increase in future and the demand of fiber boards/chip boards surely will also increases.

1.8.1. Statistical Analysis

Table 1.2 Statistical analysis of fiberboard

Year	Demand
2004-2005	6.99
2005-2006	7.41
2006-2007	7.85
2007-2008	8.32
2008-2009	8.82

1.8.2. Local Production and Consumption (2001-2002)

Table 1.3 Local production and demand of fiberboard

Year	Domestic	Imports	Exports	Demand
Sheets	6157875	4200	4325	6159350
Kg	246315000	167460	172470	246320010

1.9. Capacity Selection

Generally, capacity of pilot plant is 80-200 m^3/day. But usually, it depends upon

1. Objective

2. Scalability

Objective mean which type of fiber board you want to manufacture biomass fiber board wood chips fiber board etc.

1.9.1. Local Production Based on the Survey

Table 1.4 Local production of fiberboard based on survey

List of manufacturers	Capacity(m^3/day)
Bombay Plywood Industries	120
Compact Particle Board	120
Chenab Particle Board	150
Islamabad Board Mills	150

1.10. Final Capacity

Hence the final capacity is 80 m^3/day.

Chapter 2

EXPERIMENTATION

2.1. Selection of Raw Material

We can synthesize the fiber board from wood as well as non-wood materials. Although the wood base lignocellulosic fiber is extensively used but in future there would be a deficiency. Moreover, the wood-based material is more expensive for the manufacturing of paper pulp and in the fiber board. There is also the issue of the environment problems due to the deforestation activities. Therefore, in our project we have select the non-wood raw material. Different ago-waste are available like wheat straw rice straw. Our raw material is selected according some properties like that the cellulose content hemicellulose lignin and also some properties like that of tensile strength flexural strength and other mechanical properties. Then we have selected the rice straw because of more cellulose content and low hemicellulose and lignin content [2].

Different resin is available like urea formaldehyde resin phenolic resin. The fiber board are recognized as hard boards and medium density fiber boards both are synthesize by dry and the wet process.

Figure 2.1 Rice straw [2]

2.2. Collection of Raw Material

As rice straw is selected for the synthesis of fiber board so their rice husk is collected from the agriculture fields. The raw material is first dried and then crushed according tοour size requirement about 2.5mm. The raw material is then used for the manufacturing of the fiber board [3].

2.3. Pre-Treatment Process

Pretreatment generally connect the problems of carbohydrates lignin shield. The selection of pretreatment technology is so important because the cutting of biomass to very small particle sizes is energy intensive. Different pretreatment processes are used such as alkaline pre-treatment, acidic pretreatment, physical pretreatment, physic-chemical and chemical pretreatment [4]. We use the alkaline pretreatment process for the production of fiberboard with the help of distilled water and glycerol. Glycerol operates the process at low temperature and pressure conditions. The boiling point of glycerol is very high than other materials so it works at low conditions [5].

We choose glycerol because it is cheaper than other acids or alkaline and also improve the cellular production. After the preparation of biomass the alkaline pretreatment process is start where the mixing of biomass rice husk with distilled water and glycerol in helical steering reactor. Helical mixers are good for small diameter laminar as well as turbulent flow applications where mixing process is easy and simple. Distilled water and glycerol are initially present in storage tanks, with the help of centrifugal pump the mixer of glycerol and distilled water inlet in helical steering reactor where biomass already present. For restoring the heat and preheating the mixer of distilled water and glycerol, use heat exchanger at the end a slurry is formed and this stream is reached in regeneration column [6].

Figure 2.2 Pretreatment of agro-waste

2.4. Fabrication Process

Urea formaldehyde also called urea methanol. Selection of urea formaldehyde UF as a resin for blending is important other than resins such as poly epoxy resin, phenol formaldehyde resin etc. [7]. Because urea formaldehyde resin have high tensile strength, less absorption of water, high distortion temperature, and large surface thickness. Through conveyor the cellulose rich stream entered in vacuum dryer, in which moisture content is removed. After pure dryer cellulose rich stream inlet in paddle mixer, which is shaped device and mounted on shaft for the mixing process of liquids, solids, and both. Paddle mixing use for construction products such as paints and slurries [8].

And also for dispersing the solids into liquids. From storage tank one stream of urea formaldehyde UF resin is entered into the paddle mixer where rich cellulose fiber stream already present. The moisture content in small quantity present when the mixing of glue or resin UF and rich cellulose fiber occurred in paddle mixer, for removing the moisture contents we entered the stream of blending. mixture in vacuum dryer [9].

Fabrication is the process in which the formation of something from scratch something. Fabrication of fiberboard in proper way we use the thermal press machine. Basically, thermal or heat press machine important for designing the substance, such as t-shirt. Both mechanical as well as automatic heat press machines are available [10].

Using this machine to ensure the correct time, temperature, and pressure, which are all important to heat transfer process. The blending stream after dryer is pressed in the thermal press unit at 70 °C temperature and 1atm pressure for some time, approximate 5minutes.after pressing time the sample is prepared in required shape, cool it for some time after that the cutting process is start, where the size is reduced according to the given the dimensions. So that the required or final product fiberboard is achieved [11].

Figure 2.3 Sample of fiberboard

Chapter 3

PROCESS DESCRIPTION

3.1. Overview

This section deals with the steps followed to produce fiberboard from agro- waste material (rice husk), its process flow diagram and multiple routes that could have been taken.

3.2. Introduction

Fiberboard is a very important type of the artificial wood which is made up of woody or non woody materials. The process of its manufacturing consists of following steps. In the first step take the rice husk in small pieces and mix with glue through the pretreatment process and formed panels by using high temperature and pressure. Fiberboard has even texture and in every direction the strengths are equal furthermore it is not liable to split and wrap as well as it avoids the wood defects. The fiberboard is used for different purposes as construction. There are two types of fiberboard as hard and soft fiberboard. The hard fiberboard often used as door board, furniture, wall slab, floor and also in decorative purposes. The soft fiberboard can be used as acoustical and heatproof materials [12].

For fiberboard production agro-waste materials such as wheat straw, rice straw, wood chips and rice husk etc. Are used. Selection of rice husk for this process is important because every year its production in large amount from rice milling process. It considered a cellulose fiber, which have un-wanted particles such as silica and dust 20%. The strength and thickness of fiberboard from rice husk is properly good as compared to other waste materials [13].

We have selected supercritical process for the manufacturing of fiberboard from waste material rice husk due to the reasons mentioned above.

The process involves the following steps as follows:

1. Biomass preparation
2. Pretreatment process
3. Fiber regeneration
4. Mixing process
5. Fabrication of fiberboard

3.2.1. Raw Materials

There are following raw materials used for the manufacturing of fiberboard [14]

1. Rice husk
2. Glycerol
3. Urea formaldehyde (UF)
4. Product

The major product is fiberboard in this process but also by-products that are glycerol, lignin, hemicellulose, and water.

3.3. Block Diagram

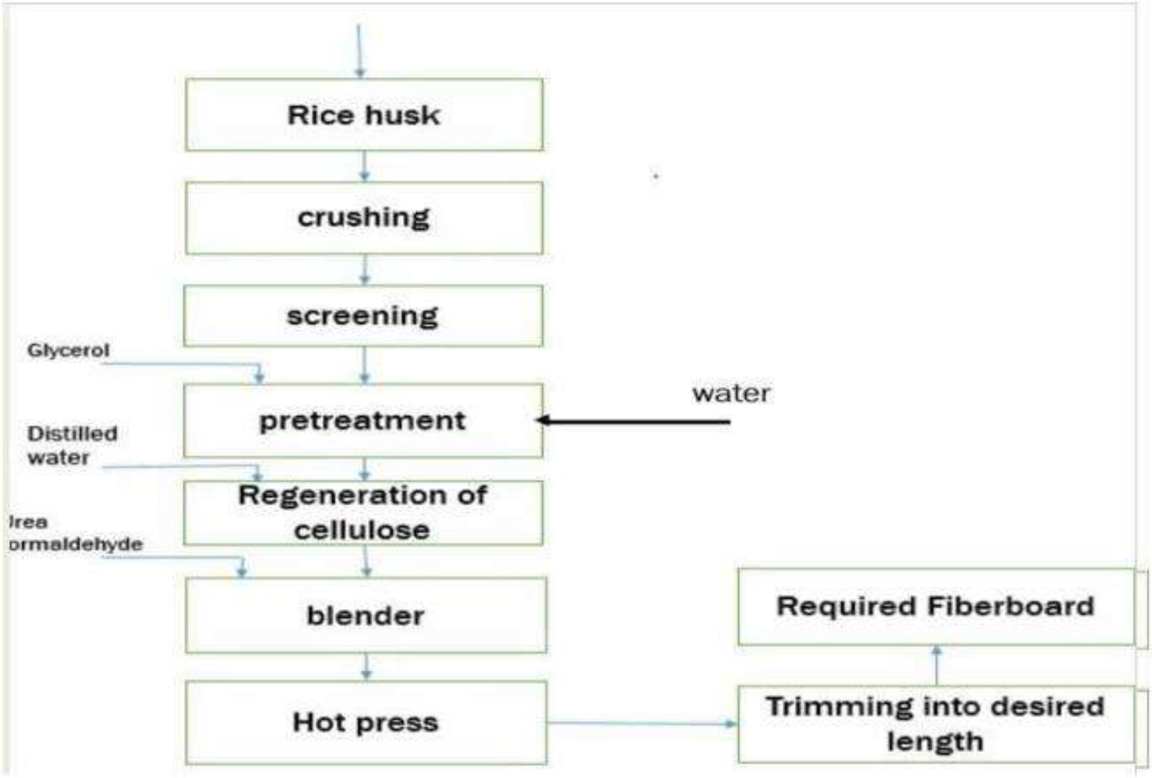

Figure 3.1 Block flow diagram for manufacturing of fiberboard

3.4. Product Stream Description

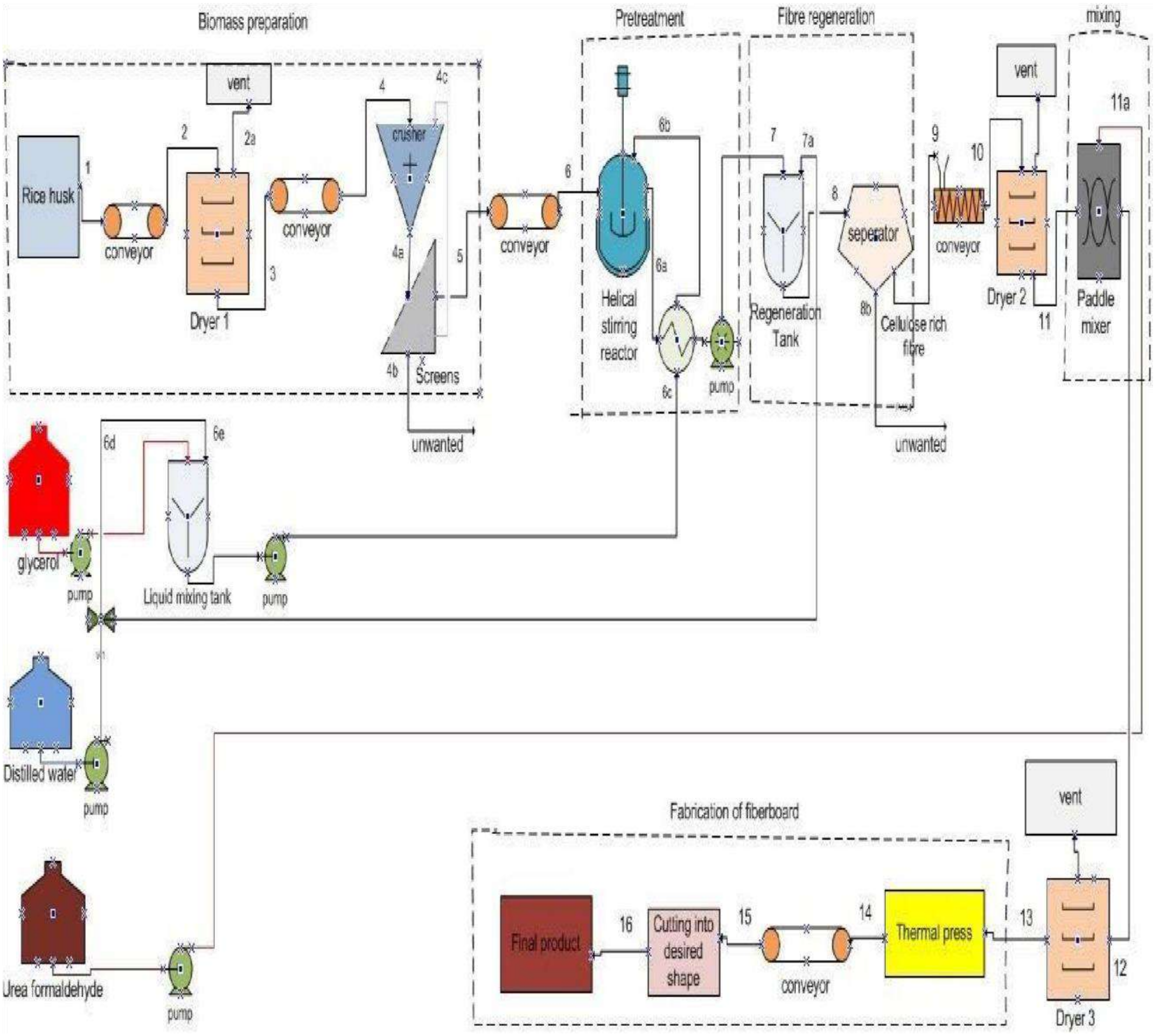

Figure 3.2 Process Flow Diagram

3.4.1. Biomass Preparation

For the preparation of biomass, we use dryer, crusher equipment and screening process. We use vacuum dryer, in which moisture (present in substance) removed by creating the vacuum. In chemical industries such as textiles, agriculture dryer is unit operation for removing the moisture contents [15].

At room temperature, in vacuum dryer the waste material rice husk is dried and the unwanted species i.e. Moisture content is removed at 30 °C. The dried rice husk through conveyor reached in powder crusher machine where rice husk crushed into small pieces. After this sieve analysis processes start where unwanted particles are removed, if the required size is not achieved then recycling process start at the end required size particles of biomass raw material is achieved [16].

3.4.2. Pretreatment Process

Pretreatment generally connect the problems of carbohydrates lignin shield. The selection of pretreatment technology is so important because the cutting of biomass to very small particle sizes is energy intensive. Different pretreatment processes are used such as alkaline pretreatment, acidic pretreatment, physical pretreatment, physic-chemical and chemical pretreatment [17]. We use the alkaline pretreatment process for the production of fiberboard with the help of distilled water and glycerol. Glycerol operates the process at low temperature and pressure conditions. The boiling point of glycerol is very high than other materials so it works at low conditions. We choose glycerol because it is cheaper than other acids or alkaline and also improve the cellular production [18].

After the preparation of biomass the alkaline pretreatment process is start where the mixing of biomass rice husk with distilled water and glycerol in helical steering reactor. Helical mixers are good for small diameter laminar as well as turbulent flow applications where mixing process is easy and simple [19]. Distilled water and glycerol are initially present in storage tanks, with the help of centrifugal pump the mixer of glycerol and distilled water inlet in helical steering reactor where biomass already present. For restoring the heat and preheating the mixer of distilled water and glycerol, use heat exchanger at the end a slurry is formed and this stream is reached in regeneration column [20].

3.4.3. Fibre Regeneration

The slurry stream through centrifugal pump from heat exchanger is the inlet of regeneration tank. For the removing impurities use washing process with the help of already present distilled water in storage tank. In regeneration tank the mixing of slurry and distilled water is occurred then cellulose is being regenerated and remaining quantities such as lignin-cellulose and hemi-cellulose are absorbed. After the removal of impurities and unwanted species rich cellulose stream is regenerated [21].

Other equipment in fiber regeneration separator is used, separators are basically used for different separation processes such as for clarifying liquids. Clarifying process in which separation of solid particles from liquid occurred. For product (fiberboard) stream the separation process occurred on the bases of density [22]. For example the separation of water from mineral oil. Solid particles also separate from the mixture at the same time. The rich cellulose stream reached in separator where two streams are distribute, one is product stream and other one is by-product stream. Product stream is rich cellulose stream and by-product stream in which hemi-cellulose, lignin-cellulose, water and glycerol streams are present. The distribution of product stream and by-product stream in mechanical separator unit on the basis of density [23].

3.4.4. Mixing Process

Urea formaldehyde also called urea methanol. Selection of urea formaldehyde UF as a resin for blending is important other than resins such as poly, epoxy resin, phenol formaldehyde resin etc. Because urea formaldehyde resin have high tensile strength, less absorption of water, high distortion temperature, and large surface thickness.

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The moisture content in small quantity present when the mixing of glue or resin UF and rich cellulose fiber occurred in paddle mixer, for removing the moisture contents we entered the stream of blending mixture in vacuum dryer.

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The blending stream after dryer is pressed in the thermal press unit at 70 °C temperature and 1atm pressure for some time, approximate 5 minutes. After pressing time the sample is prepared in required shape, cool it for some time after that the cutting process is start, where the size is reduced according to the given the dimensions. After that the required or final product fiberboard is achieved [25].

3.5. By-Product Description

By product stream contains water glycerol some portion of cellulose hemicellulose lignin, then the given stream is separated with the addition of water stream into liquid and solid streams. The liquid stream containing water and glycerol, while the solid stream contains lignin, hemicellulose and some quantity of cellulose.

Liquid stream separated in an evaporator, which a device used to containing the liquid form of a chemical substance such as water into its vapor form. Liquid is vaporized in the form of gas of the final substance in that process. Both water and glycerol are separated into evaporator on the basis of boiling point at specific temperature. Glycerol recycle to back into the storage tank, on other side water also go back into storage tank after passing through condenser, which condense the water.

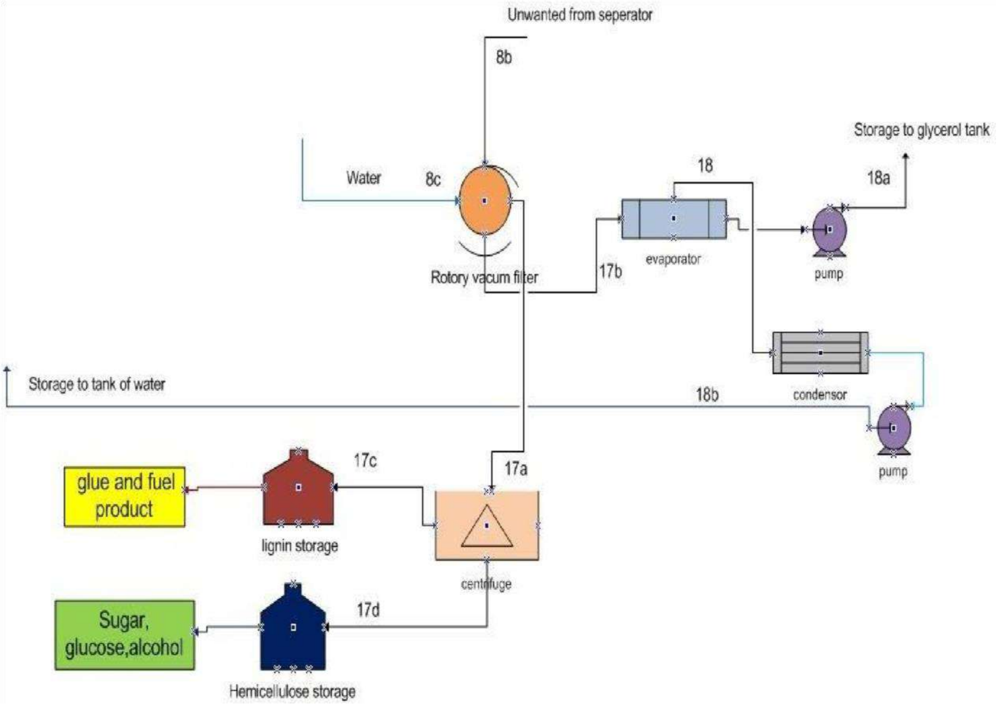


Figure 3.3 Process flow diagram of by product

Solid stream having lignin and hemicellulose are separated into a centrifuge separator, which basically same as a simple separator. At the end the lignin-cellulose and hemicellulose are used into the useful products, such as glue, fuel product and sugar, glucose.

Chapter 4

MATERIAL BALANCE

4.1. Overview

In this chapter there is the discussion about the material balance on the equipment’s. mass balance is the law of conservation of mass.

4.1.1. Principle

Material balance is based on the mass conservation principle which states that the sum of the weight of all inputs must be precisely equal to the sum of all outputs. next, it helps estimation the conversion or yield of methods which serves as a measure of the efficiency of the process in mass terms.

4.1.2. Material Balance in Chemical Engineering

Material balance involves computation the quantities of all materials that enter and leave

System or process which are based on the principle of the "law of conversationof mass". This law states that matter is neither created nor destroyed in the process and the total mass remains unaffected.

4.2. Composition of Rice Husk

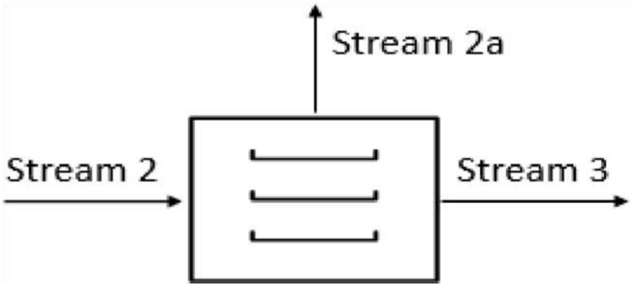
Table 4.1 Composition of rice husk

Component names	Mass % in rice husk
Cellulose.	0.40
Hemicellulose	0.20
Lignin	0.25
Unwanted (silica, dust, etc.)	0.05
Moisture	0.1

4.3. Material Balance on Dryer

Assumptions:

Efficiency of dryer assumed 100%



Feed 1950 kg/h

Stream 2

Stream 2 is the inlet stream of rice husk. The component present in the rice husk are listed in the table below.

Stream 2a

Stream 2a is the out let stream from the dryer. This is actually mass loss due to the heat raised in the dryer in order to remove the water vapor present in the feed.

Stream 3

Stream 3 is the outlet stream from the dryer. Material balance is listed below.

Overall balance

$F_1 = W_1+P_1$ .... (1)

Where

F_1 = Rice husk inlet in the dryer

W_1 = Water evaporated from the dryer

P_1 = Dried outlet

Overall summary of overall balance:

In (kg/hr)	Out (kg/hr)	
F_1 (stream 2)	W_1 (stream 2a)	P_1 (stream 3)
1950	195	1755
1950	1950	

Component balance:

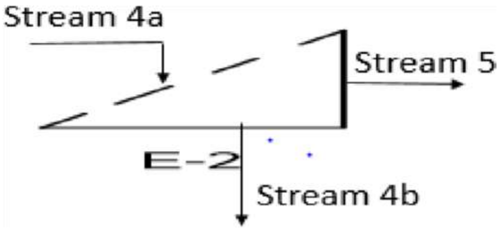
Overall summary of calculation:

Components	**Stream 2 (mole fraction)**	**Stream 2a (mole fraction)**	**Stream 3 (mole fraction)**
Cellulose	0.4	0	0.44
Hemicellulose	0.2	0	0.22
Lignin	0.25	0	0.27
Unwanted	0.05	0	0.05
Moisture	0.1	1	0
Glycerol	0	0	0
Water	0	0	0
UF	0	0	0

4.4. Material Balance on Screen

Assumptions:

Screening removed 100% of unwanted particles.



Stream 4a:

Stream 4 is the inlet stream to the screening process.

Stream 4b:

Stream 4b is the unwanted stream like sand dust. It is necessary to remove the impurities to maximum extent. It also prevent the erosion.

Stream 5:

Stream 5 is the outlet stream from screen. Material balance is shown in the given table

Overall balance:

$P_1 = W_2 + P_2$…… (2)

Where

W_2 = undesired particle

P_2 = desired particle stream

In (kg/hr)	Out (kg/hr)	
P_1 (stream 4a)	W_2 (stream 4b)	P_2 (stream 5)
1755	97.5	1657.5
1755	1755	

Component balance:

Overall calculation of component balance

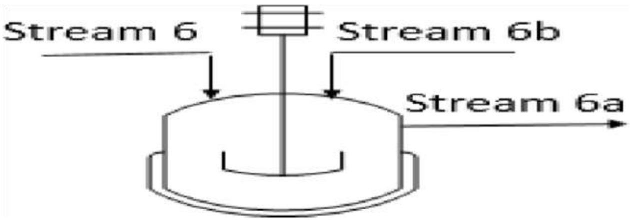
Components	Stream 4a (mol fraction)	Stream 4b (Mole fraction)	Stream 5 (mole fraction)
Cellulose	0.44	0	0.470
Hemicellulose	0.22	0	0.235
Lignin	0.27	0	0.294
Unwanted	0.055	1	0
Moisture	0	0	0
Glycerol	0	0	0
Water	0	0	0
UF	0	0	0

4.5. Material Balance on Pretreatment Reactor

<u>Assumptions:</u>

Solid to liquid feed ratio in pretreatment reactor is 1:10.

Glycerol which introduces in pretreatment reactor containing 25% of water content in it.



Stream 6:

Stream 6 is the inlet stream of the pretreatment reactor. Which contain rice husk (cellulose, hemicellulose and lignin).

Stream 6b:

Stream 6b is the liquid stream consist of glycerol and water. Glycerol is used as pretreatment solvent. Water is added to dilute the solvent. Glycerol to water is used with ratio 75:25.

Stream 6a:

Stream 6a is the outlet stream of the water which contain (water, glycerol, cellulose, hemicellulose, and lignin) in the pretreatment reactor cellulose is absorbed in the solvent.

Overall balance:

$P_2 + F_2 = P_3$……. (3)

Where,

P_2 = Rice husk feed into the Reactor

F_2 = The combination of water and Glycerol

P_3 = slurry containing (water, Glycerol, Rice husk) Overall material balance calculation:

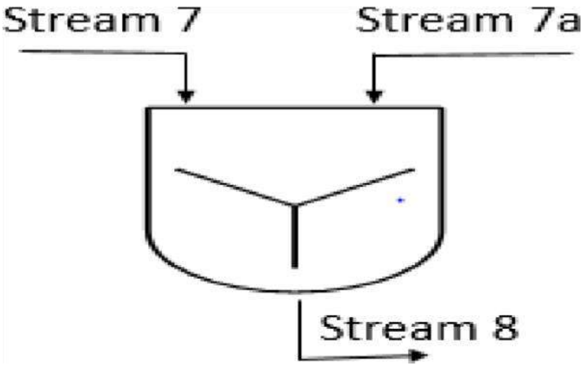
In (kg/hr)		**Out (kg/hr)**
P_2 (Flow rate)	F_2 (Flow rate)	P_3 (Flow rate)
1657.5	16575	18232.5
18232.5		18232.5

Component balance:

Overall component balance

Components	**Stream 6 (Mole fraction)**	**Stream 6b (Mole fraction)**	**Stream 6a (Mole Fraction)**
Cellulose	0.470	0	0.042
Hemicellulose	0.235	0	0.021
Lignin	0.294	0	0.026
Unwanted	0	0	0
Moisture	0	0	0
Glycerol	0	0.75	0.681
Water	0	0.25	0.22
UF	0	0	0

4.6. Material Balance Regeneration Tank



Stream 7:

Stream 7 is the inlet stream of the regeneration tank.

Stream 7a:

Stream 7a is basically the water stream water is used to regenerate the cellulose which is absorbed in the solvent

Stream 8:

Stream 8 is the outlet stream of the regeneration tank. Noticing that the value of cellulose is increased.

Overall balance:

$P_3 + F_3 = P_4$……. (4)

Overall calculation:

	In (kg/hr)		Out (kg/hr)
P_3 (flow rate)		F_3 (flow rate)	P_4 (flow rate)
18232.5		91162.5	109395
	109395		109395

Component balance:

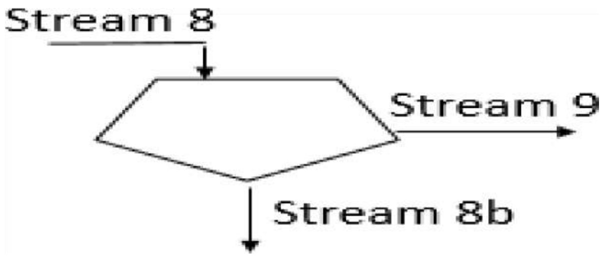
Overall calculation of the component balance:

Components	**Stream 7 (mole Fraction)**	**Stream 7a (mole Fraction)**	**Stream 8 (mole Fraction)**
Cellulose	0.042	0	0.0071
Hemicellulose	0.02	0	0.0035
Lignin	0.026	0	0.0044
Unwanted	0	0	0
Moisture	0	0	0
Glycerol	0.681	0	0.113
Water	0.22	1	0.871
UF	0	0	0

4.7. Material Balance on Seperator

Assumption:

No cellulose went to the unwanted stream.



Stream 8:

Separator is used to separate the desired and undesired component. Stream 8 is the inlet stream of the separator which is the outlet of the regeneration tank.

Stream 8b:

Stream 8b is the undesired stream which consist of the hemicellulose, lignin, water, glycerol and no cellulose separation is done on the basis of the density difference.

Stream 9:

Stream 9 is the outlet stream of the separator which consist of majorly cellulose, means cellulose rich stream and contain minor quantity of other all component.

Overall balance:

P_4= W_3+P_5…… (5)

P_5 = Rich Cellulose stream

W_3 = Stream consisting of hemicellulose and Lignin Overall material balance:

In (kg/hr)	**Out (kg/hr)**	
P_4 (stream 8)	W_3 (stream 8b)	P_5 (stream 9)
109395	108195	1200
109395	109395	

Component balance:

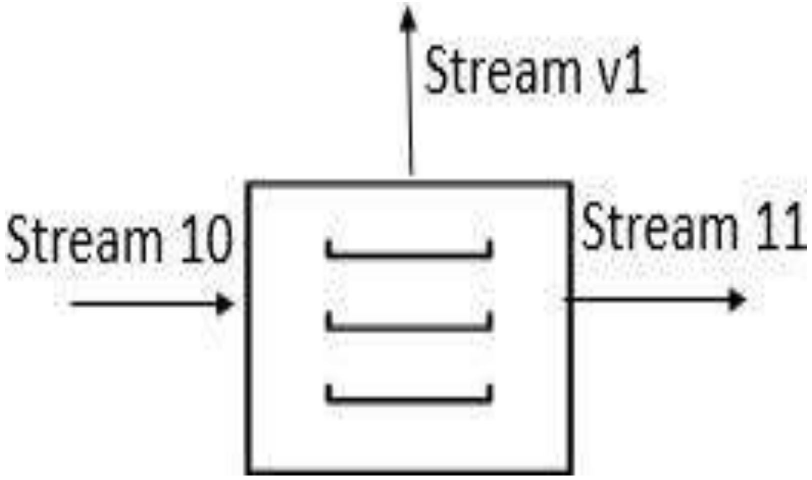
Overall calculation of component:

Components	**Stream 8 (mole Fraction)**	**Stream 8b (mole Fraction)**	**Stream 9 (mole Fraction)**
Cellulose	0.007	0	0.65
Hemicellulose	0.003	0.002	0.1
Lignin	0.0044	0.002	0.15
Unwanted	0	0	0
Moisture	0	0	0
Glycerol	0.113636	0.114	0
Water	0.871212	0.87	0.1
UF	0	0	0

4.8. Material Balance on Vacuum Dryer 2

Assumption:

The efficiency of dryer is assumed to be 100%.



Stream 10:

Stream 10 is the inlet stream which mainly consist of cellulose rich.

Stream V_1:

Stream V_1 is the out let stream from the dryer. This is actually mass loss due to the heat raised in the dryer in order to remove the water vapor present in the feed.

Stream 11:

Stream 11 is the outlet stream from the dryer. Material balance is listed below.

Overall balance:

$P_5 = W_4 + P_6$……. (6)

Overall calculation of flow rate:

In (kg/hr)	Out (kg/hr)	
P_5 (Stream 10)	W_4 (Stream v1)	P_6 (Stream 11)
1205.73	120.573	1085.157
1205.73	1205.73	

Component balance:

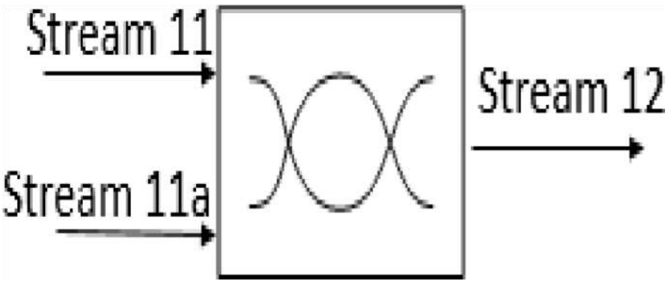
<u>Overall component balance:</u>

Components	**Stream 10 (mole Fraction)**	**Stream V_1 (mole Fraction)**	**Stream 11 (mole Fraction)**
Cellulose	0.65	0	0.722
Hemicellulose	0.1	0	0.11
Lignin	0.15	0	0.166
Unwanted	0	0	0
Moisture	0	0	0
Glycerol	0	0	0
Water	0.1	1	0
UF	0	0	0

4.9. Material Balance on Blender

Assumption:

It assumed that no heat is increased during mixing.



Stream 11:

Stream 11 is the inlet stream of blender which is mainly consist of cellulose i.e. cellulose rich stream.

Stream 11a:

Stream 11a consist of urea formaldehyde (UF). Polymer to fiber ratio is used 40:60.

Stream 12:

Stream 12 is the blended stream.

Overall balance:

$P_6 + F_4 = P_7$……… (7)

Where,

F_4 = Flow Rate of UF

P_7 = Flow Rate of blended stream

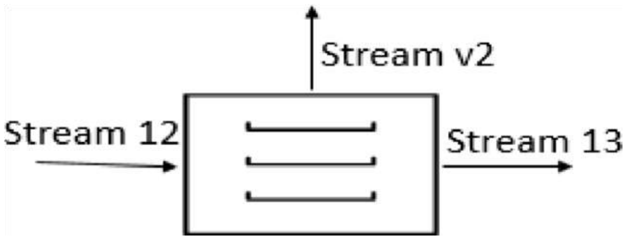
Overall calculation of Flow Rate:

In (kg/hr)		**Out (kg/hr)**
P_6 (stream 11)	F_4 (stream 11a)	P_7 (stream 12)
1080	720	1800
1800		1800

<u>Component balance</u>:

Components	**Stream 11 (mole Fraction)**	**Stream 11a (mole Fraction)**	**Stream 12 (mole Fraction)**
Cellulose	0.722	0	0.433
Hemicellulose	0.111	0	0.06
Lignin	0.166	0	0.1
Unwanted	0	0	0
Moisture	0	0	0
Glycerol	0	0	0
Water	0	0.1	0.04
UF	0	0.9	0.36

4.10. Material Balance on Vacuum Dryer 3



Stream 10:

Stream 12 is the inlet stream which mainly consist of cellulose rich.

Stream V_2:

Stream V_2 is the out let stream from the dryer. This is actually mass loss due to the heat raised in the dryer in order to remove the water vapor present in the feed.

Stream 13:

Stream 13 is the outlet stream from the dryer. Material balance is listed below.

Overall balance:

$P_7 = W_5+P_8$……. (8)

Where,

W_5 = Flow Rate of Removal of final moisture

P_8 = Flow Rate of blended mixture ready for fiberboard production

Overall material balance:

In (kg/hr)	**Out (kg/hr)**	
P_7 (stream 12)	W_5 (stream v2)	P_8 (stream 13)
1800	72	1728
1800	1800	

Component balance:

Component material balance:

Components	**Stream 12 (mole Fraction)**	**Stream v2 (mole Fraction)**	**Stream 13 (mole Fraction)**
Cellulose	0.433	0	0.451
Hemicellulose	0.066	0	0.451
Lignin	0.1	0	0.104
Unwanted	0	0	0
Moisture	0	0	0
Glycerol	0	0	0
Water	0.04	1	0
UF	0.36	0	0.375

4.11. Capacity Calculation

P = 1728 kg/hr

D = 685 g/cm^3 (density of UF)

D = 1260 g/cm^3 (density of cellulose rich fiber)

Weighted average density = (0.40×685) + (0.60×1260)/2 = 515 kg/m^3

Capacity = (1728/1180)×24 = 80 m^3/day

Standard dimensions of fiberboard sheet

Width = 2 ft

Length = 4 ft

Thickness = 0.0625 ft

Volume = (2×4×0.0625) = 0.5 ft^3 = 0.01415 m^3

No of sheet = (80/0.01415) = 5654/day

Chapter 5

ENERGY BALANCE

5.1. Overview

This chapter presents the energy balance on all the possible equipment in the process as well as the overall energy balance of the process. the values of heat capacities are taken from literature at average temperature.

All the calculations for energy balance was done on ms excel using q = mcpΔt.

5.1.1. Forms of Energy

1. Kinetic energy
2. Potential energy
3. Internal energy

5.2. Energy Balance Vacuum Dryer 1

Assumption:

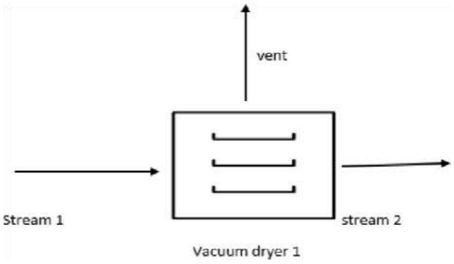
Efficiency of dryer assumed to be 100 %.

Stream 1:

The stream 12 entering in the dryer contain mass 1950 kg/hr. The heat capacity of cellulose rice husk stream and temperature are listed in the table.

Heat is evaluated by using equation.

Q= $mc_p\delta t$ .... (1)



Stream 2:

Outlet heat is evaluated by.

Q_{out}= (heat required to raise the temperature at 60 °C) + (latent heat of vaporization at 20 kPa)

Heat required to raise at 60°C = $mc_p\delta t$……… (2)

Latent heat of vaporization = m×γ

Where

m = mass loss during the moisture removal (kg)

γ = latent heat of vaporization (J/kg)

How to evaluate mass loss:

Initial moisture =10%

Final moisture = 0%

1kg of original matter loss = 100-0/1000 = 0.10 kg

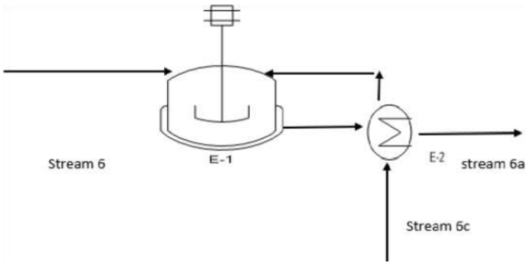
1755 kg/hrOf original mass loss = 1755×0.10 = 175 kg/hr

Latent heat of vaporization at 20 KPa = 175×2358 = 144 kW

Variable	**Stream1 (inlet)**	**Stream 2 (outlet)**	
		Heat raises 60 °C	**latent heats at 20kPa**
M (kg/hr)	1950	1755	175.5
Cp (kJ/kg. °C)	1.779	1.758	2358
ΔT (°C)	30-25	60-25	
Q (kW)	4.82	29	114
Q (kW)	4.82	143	

5.3. Energy Balance on Mixing Reactor

As describe above during vacuum drying temperature was 60 °c, take it as inlet temperature of the reactor.



Assumption:

Some heat is producing and loss during operation so inlet 60 °C and outlet 50 °C Stream 6:

Energy balance:

$Q_{in} = mc_p\delta t$ .... (2)

m = 1657 kg/hr

Cp = 1.80 kJ/kg ℃

$\Delta T = (60-25)$ ℃

By pouting values in equation (2) we get

$Q_{in} = 1657\times1.80\times(60-25) = 28.99$ kW

Where

m is the mass of rice husk in kg/hr

Cp is the heat capacity of rice husk in kJ/kg ℃

Stream 6b:

Stream 2 is the combination of the water and glycerol passing through a heat exchanger in order to exchange the heat. The purpose of the heat exchanger is to save the energy. Inlet temperature of the stream 2 is taken as 30 ℃ while reference temp is kept 25 ℃. Where the heat capacity of the stream 2 is combined 6 KJ/kg ℃

Stream 6a:

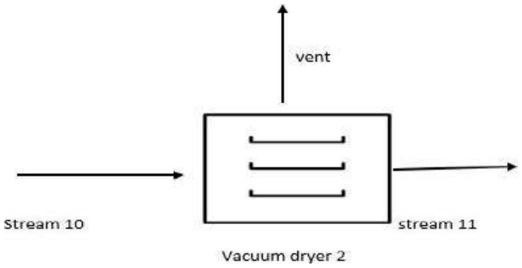
Stream 3 is the combination of the water, glycerol & rice husk. The inlet and outlet temperature are 50 ℃ & 25 ℃ respectively. Combined heat capacity of the three component is 9.80 KJ/kg ℃

Variable	Stream 6 (inlet)	Stream 6b (inlet)	Stream 6a (outlet)
m (kg/hr)	1657		18232
Cp (kJ/kg ℃)	1.80	6	9.80
ΔT (℃)	60-25 = 35	30-25 = 5	50-25 = 25
Q (kW)	28.99	138.125	1240

5.4. Energy Balance on Vacuum Dryer 2

Assumption:

Efficiency of dryer assumed to be 100%.



Stream 10:

The stream 1 entering in the dryer contain mass 1200 kg/hr. The heat capacity of cellulose rich stream is 1.80 kJ/kg ℃. The entering temperature of the cellulose rich stream is 30 ℃ while reference temp is 25 ℃. The heat is evaluated by using equation.

$Q= mc_p\delta t$ .... (5)

Stream 11:

Outlet heat is evaluated by.

Q_{out}= (heat required to raise the temperature at 60 ℃) + (latent heat of vaporization at 20 kPa)

Heat required to raise at 60 ℃ = $mc_p\delta t$……… (6)

Latent heat of vaporization=m×γ

Where

m = mass loss during the moisture removal (kg)

γ = latent heat of vaporization (J/kg)

How to evaluate mass loss:

Initial moisture = 10%

Final moisture = 0%

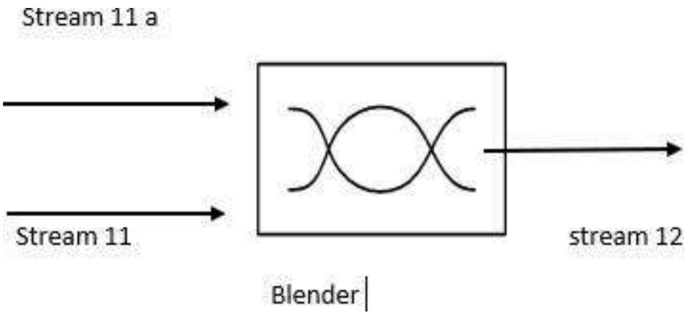
1 kg of original matter loss = 100-0/1000 = 0.10 kg

1080 kg/hr of original mass loss = 1080×0.10 = 108 kg/hr

Latent heat of vaporization at 20 KPa = 108×2358 = 70.84 KW

Variable	**Stream 10 (inlet)**	**Stream 11 (Outlet)** **Heat raise 60 latent heat at 20 kPa**	
m (kg/hr)	1200	1080	108
Cp (kJ/kg °C)	1.80	1.758	2358
ΔT (°C)	30-25	60-25	
Q (kW)	3	18.459	70.84
Q (kW)	3	89	

5.5. Energy Balance on Blender



Assumption:

No heat increased during the mixing process.

Stream 11:

Stream 11 is basically cellulose rich fiber stream. The mass of stream is 1080 kg/hr. Heat capacities and temperature are listed in the table below.

Stream 11a:

This stream consists of urea formaldehyde (UF). The heat capacities and temperature for stream 11a is listed in table below. The UF is used as 40% of total mass.

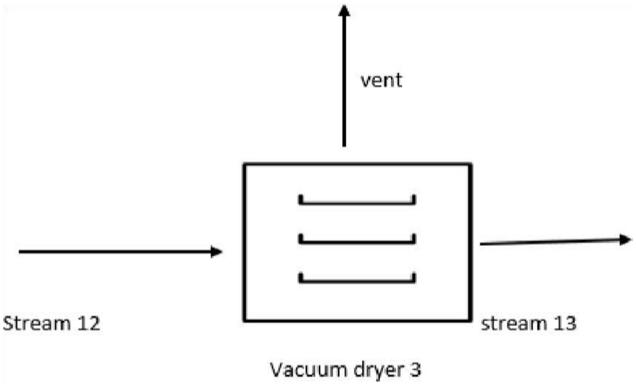
Stream 12:

Stream 12 is the blended stream from the blender. The mass of this stream is 1800 kg/hr.

The heat capacity and temperature difference are listed below.

Variable	Stream 11 (inlet)	Stream 11a (inlet)	Stream 12 (outlet)
m (kg/hr)	1080	720	1800
Cp (kJ/kg °C)	1.80	1.20	1.2+1.8 = 3
ΔT (°C)	55-25	30-25	50-25
Q (kW)	16.12	1.2	20.1

5.6. Energy Balance on Vacuum Dryer 3



Stream 12:

The stream 12 entering in the dryer contain mass 1800 kg/hr. The heat capacity of cellulose rich stream and temperature are listed in the table.

Stream 13:

Outlet heat is evaluated by.

Q_{out}= (heat required to raise the temperature at 60 °C) + (latent heat of vaporization at 20 kPa)

Heat required to raise at 60 °C = $mc_p\delta t$……… (6)

Latent heat of vaporization = $m\times\gamma$ Where,

m = mass loss during the moisture removal (kg)

γ = latent heat of vaporization (J/kg)

How to evaluate mass loss:

Initial moisture = 36%

Final moisture = 0%

1 kg of original matter loss = 360-0/1000 = 0.36 kg

1728 kg/hr of original mass loss = 1728×0.36 = 622 kg/hr

Latent heat of vaporization at 20 KPa = 622×2358 = 407.41 kW

Variable	**Stream (inlet)**	**12**	**Stream 13 (Outlet)**	
			Heat raise 60	**latent heat at 20 KPa**
m (kg/hr)	1800		1728	622
Cp (kJ/kg °c)	3		3	2358 kJ/kg
∆T(℃)	50-25		60-25	
Q (kW)	37.5		50.4	407.41
	37.5		457.81	

Chapter 6

DESIGNING OF EQUIPMENT

Design of Shredder

6.1. Introduction

A shredder is a machinery or equipment used for the size reducing of different materials like agricultural waste. Shredding systems are used to shrink or reduce the size of the size of a given material to required limits. Overall, their major function is to decrease or decrease the size of a given material [26].

6.1.1. Why Shredder used

There are shredders designed to help material reduction across a range of recycling applications, with plastic recycling, scrap metal, e-waste recycling, wood recycling, and agro shredding or recycling. The shredding method produces raw material which is used to be established into manufacturing, as well as finished products such as landscape mulch. Numerous terminology is used to express the size reduction equipment, including grinders, chippers, granulators and hammer mills, impact mill [27].

6.1.2. Material Selection

Material choice for design of shredder is deepened upon the certain factor mostly it should be corrosion resistive and should also be economical.

Material used for shredder are listed below.

Table 6.1 Material used for shredder

Component	Material	Composition
Belt	Leather	Collagen
Hopper	Cast iron	2% c,0.5-1% mn,0.10% s
Cutter	Stainless steel	10.5% cr,1.2 c
Casing	Cast iron	2% c,0.5-1% mn,0.10% s

6.2. Selection Criteria

1. Agro particle size
2. Load size
3. Shredder speed
4. Security levels
5. Advanced features

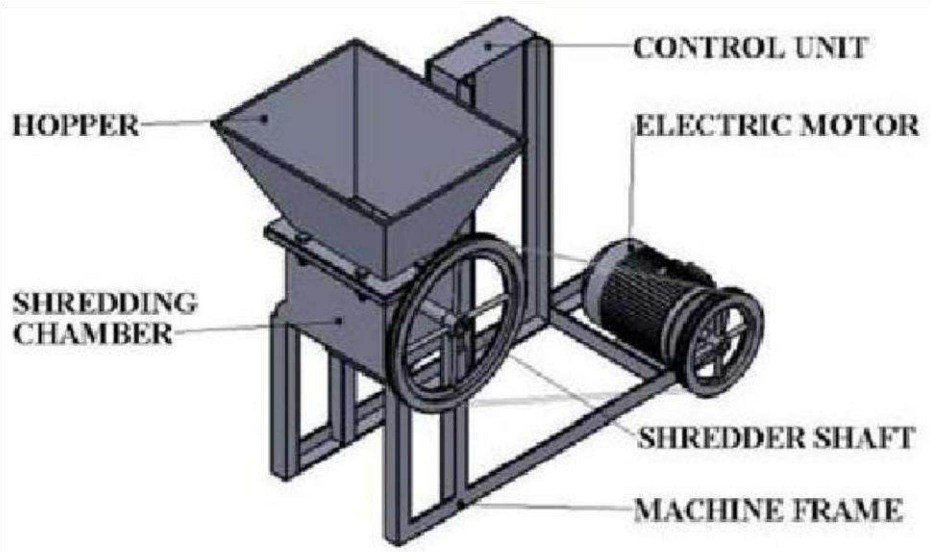


Figure 6.1 Layout of shredder [28]

6.3. Design of Shredder

It involves the design of following parameters [28].

6.3.1. Cutter Specification

Cutter specification are taken from literature.

Outer diameter of cutter	150 mm
Inner diameter of cutter	32 mm
Number of teeth on cutter	6
Thickness of cutter	25 mm

6.4. Design of Hopper

The hopper is the thing where we introduce our feed into the shredder. According to our process, the feed of rice husk at the flow rate of 1950 kg/hr enters into the shredder.

The hopper will be design according to the following dimensions.

Dimensions	**Smaller pyramid**		**Bigger pyramid**	
Length (m)	L	0.425	L	0.848
Width (m)	W	0.425	W	0.85
Height (m)	H	0.65	H	1.3

6.4.1. Volume of Hopper

Volume of hopper = (L*w*h)/3 - (L*w*h)/3

= (0.848*0.85*1.3)/3 - (0.425*0.425*0.65)/3

= $0.2732 m^3$

Volume of rice husk = $\pi \times r^2 \times h$

Where,

Radius of rice husk = 0.003 m

Diameter of rice husk = 0.01 m

Volume of rice husk = 3.14×0.003×0.01

$V = 2.829 \times 10^{-3}\ m^3$

6.4.2. Number of Rice Husk Particles Enter Through Hopper

Numbers of rice husk particles enter through hopper = volume of hopper/volume of rice husk

= 0.2732/(2.829*10-3)

= 965915.92

Mass of one rice husk particle = volume of rice husk × density of rice husk

$= 2.829 \times 10^{-3}\ m^3 \times 119\ kg/m^3$

$= 3.36594 \times 10^{-5}\ kg$

Mas flow rate of rice husk particle through the hopper in one minute = number of rice husk particles × mass of one rice husk particle

$= 965915.92 \times 3.36594 \times 10^{-5}$

$= 32.51214 \frac{Kg}{min}$

Mass of rice husk particles in one hour $= 32.51214 \frac{\text{Kg}}{\text{min}} \times 60 \frac{\text{min}}{\text{hr}}$

$= 1950.728 \frac{\text{Kg}}{\text{hr}}$

6.5. Belt Design

The belt will design according to the following dimensions.

Dimensions	Denote	Value
Speed of driver	N_1	1460 rpm
Diameter of driver	D_1	300 mm
Speed of driven pulley	N_2	730 rpm
Diameter of driven pulley	D_2	600 mm

Speed of driven pulley

$N_2 = \frac{D1 \times n1}{D2}$

$= \frac{300 \times 1460}{600}$

= 730 rpm

Velocity of belt $= \frac{\Pi \times d2 \times n2}{60}$

$= \frac{3.14 \times 600 \times 730}{60}$

$= 22.922 \frac{\text{m}}{\text{Sec}}$

Center distance from pulley $= X = \frac{D1 + d2}{2}$

$= \frac{300 + 600}{2}$

X= 450 mm

6.6. Length of Belt

Length of belt $= \frac{\Pi}{2} \times (D1 + d2) + 2x + \frac{(d2 - d1)2}{4x}$

$= \frac{3.14}{2} \times (300 + 600) + 2(450) + \frac{(600 - 300)2}{4(450)}$

= 2763 mm

Angle of contact $= (180 + 2\alpha) \times \frac{\Pi}{180}$

Where,

$A = \mathrm{Csc}\,\frac{R2-r1}{2x}$

$A = \mathrm{Csc}\,\frac{300-150}{2\times 450}$

$A = 0.3333$

Angle of contact of driver pulley = $\Theta_1 = 180 - 2\alpha$

$\Theta_1 = 180 - 2\times(0.3333)$

$\Theta_1 = 2.4619$ rad

Angle of contact of driver pulley = $\Theta_2 = 180 + 2\alpha$

$\Theta_2 = 180 + 2\times(0.3333)$ $\Theta_2 = 3.8212$ rad

6.6.1. Belt Tension

Maximum permissible belt tension = $T_1\_T_2 = 402$ N

Semi groove angle = $\beta = 35$

Coefficient of friction of cast iron to leather = $\mu = 0.25$

Logarithmic exponent = $e = 2.718$

$T_1/T_2 = e^{\mu\,\theta}$

$T_1/T_2=2.59$

$T_1/T_2 = 2.59$ …… (1)

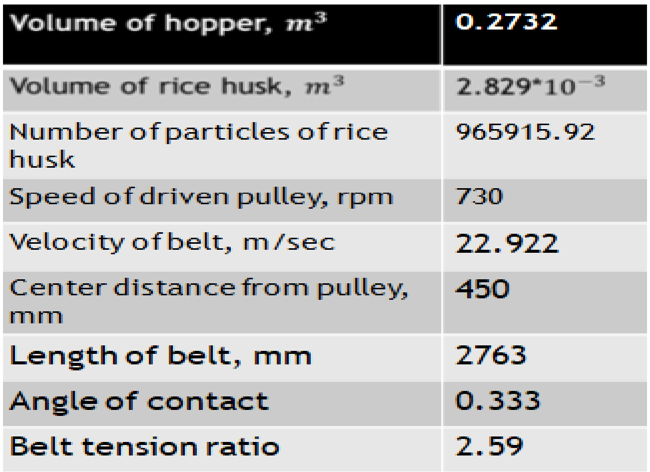
As we also know,

$T_1\_T_2 = 260$ .... (2)

Simultaneously solve both equations. We get,

$T_1 = 611.375$ N

$T_2 = 423$N



Volume of hopper, m^3	0.2732
Volume of rice husk, m^3	$2.829*10^{-3}$
Number of particles of rice husk	965915.92
Speed of driven pulley, rpm	730
Velocity of belt, m/sec	22.922
Center distance from pulley, mm	450
Length of belt, mm	2763
Angle of contact	0.333
Belt tension ratio	2.59

Helical Stirring Reactor

6.1. Introduction

Mixing is the movement of fluids and solids to enhance a process result, which is completed by means of an agitation or may type of mixer source. The process of mixing is concerned with blending of the different phases, of which the most commonly occurring include gases with gases, gases into liquids, and gases with granular solids. The processes including liquids employ the same equipment, namely, tanks in which the liquid is circulated and exposed toa desired level of shear. Different mixing process results can be designed a priori, without resorting to experimental studies, which involve agitator power requirements, heat transfer, liquid-liquid blending, solids suspension, mass transfer to suspended particles, and many solid-solid applications [29].

6.2. Purpose of Agitation

1. Suspending solid particle
2. Mixing miscible liquids
3. Dispersing a gas through liquid in the produce of bubbles
4. Dispersing the second liquid immiscible with the first to form an emulsion
5. Supporting heat transfer between liquid and coil

6.2.1. Types and Applications of Agitator

There are different types of agitator mixers depending upon the agitator type andagitator location [30].

Agitator type	Applications
Paddle	Blending of solids slurry mixing
Turbine Straight bladepitched blade Curved bladedisk blade	Flow in axial, radial and tangential direction vigorous mixing, cheaper than other, speed may exceed from 1000 rpm
Screw blade	Mostly used in food handling
Helical blade Ribbon type Helical screw	Most undoubtedly used in paint industry
Anchor	Mostly used in pharmacy industries for numerous purpose.

6.2.2. Selection of Suitable Impeller

It depends upon following factors:

1. Fluid density
2. Fluid viscosity
3. Degree of agitation
4. Power needs
5. Process requirements
6. We selected turbine for the mixing of slurry with the liquid.

6.2.3. Reason for Selecting Turbine

1. Efficient turbulence flow impeller for blending immiscible liquids
2. Combine axial and radial flows are achieved
3. Low cost
4. Can operate at wide application ran

6.3. Design Parameters

1. Tank diameter
2. Horizontal cross section area of tank
3. Effecting pumping capacity of turbine
4. Turbine design
5. Speed of impeller
6. Impeller power
7. Volume of reactor

6.4. Design Calculation [31]

The design calculations include the following parameters.

6.4.1. Tank

diameter V

=π(DT/2)^2.Z

Where,

V $= 4816 \frac{\text{gal}}{\text{hr}}$

Z $= 7.5 \frac{\text{gal}}{\text{ft3}}$

Also,

V = volumetric flow rate in $\frac{\text{gal}}{\text{hr}}$

D_T = Tank diameter

Z = Liquid depth

4816= 3.14×D_T/2^2×7.5

D_T = 28.60 in

D_T = 2.3833 ft

6.4.2. Horizontal Cross Sectional Area

$A=\pi \times D_T/2$^2

= 4.45 ft

6.4.3. Effecting Pumping Capacity

$Q = V_b \times a$

V_b= Bulk fluid velocity $= 36 \frac{\text{ft}}{\text{min}}$

A = Horizontal cross section area of tank = 4.45ft

Q = 36 × 4.45ft

$Q=160.2\ ft^3/min$

Turbine design

Diameter of turbine=D_t= $D_T \times \frac{D}{T}$

$\frac{D}{T} = 0.3$

$\frac{D}{T} =$ Impeller diameter to tank thickness ratio

D_T = Tank diameter

D_t = diameter of turbine

D_t = 2.3833× 0.3

D_t= 0.7149ft

D_t= 8.5788 in

From the below figure, we find the pumping number n_q using impeller diameter to tank thickness ratio.

Assumption:

Agitation occur under fully turbulent conditions

$N_Q = 0.8$

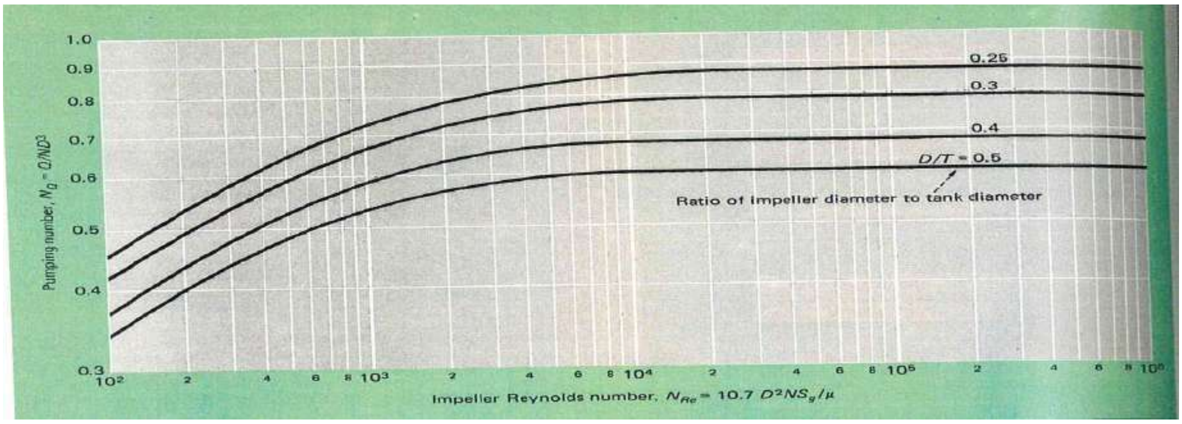


Figure 6.2 Pumping number to tank diameter [31]

6.4.4. Speed of Impeller

$$N = \frac{Q}{Nq \times D^3}$$

Where,

Q = effecting pumping capacity of turbine

N_Q = pumping number

D_t = turbine diameter in ft

= 160.2/.8*.7149^3

N = 73.16 rpm

$$N_{re} = \frac{10.7 \times sg \times n \times d^2}{\mu}$$

Where,

S_g = Specific gravity of fluid = 0.41

N = Speed of impeller

D_t = Turbine diameter in in

μ = Viscosity of fluid = 11.34

$$N_{re} = \frac{10.7 \times sg \times n \times d^2}{M}$$

N = 10.7*.41*73.16*8.57882/11.34

N_{re}= 2082.98 (it will match the assumed value)

6.4.5. Impeller Power

$H_P = (\frac{Dt}{394})\hat{}5 \times n \times s_g \times n^3$

H_p = power of impeller in hp

D_T= tank diameter in inches

N=numberturbines

S_g = specific gravity of fluid

N = speed of impeller

$H= (2.3833/394)5*1*.41*2082.98^3$

= 1120609 hp

6.5. Volume of Reactor

$V = D_t \times D_T^2$

D_t= turbine diameter in ft.

D_T = tank diameter

$V = .7149\times 2.3833^2$

V = 4.060 ft3

Heat Exchanger Design

6.1. Introduction

A heat exchanger is device which used to transfer the heat from one fluid to another, whether the media is separated by a solid wall so they never mix, or if the media is in direct contact. They are frequently used in space heating, cooling, air conditioning, power plants, chemical plants, petrochemical plants, petroleum refineries and the refining of natural gas. The radiator in a vehicle is a classic example of a heat exchanger, in whicha hot engine-cooling fluid, similar to antifreeze, transfers heat to air flowing all through the radiator [25].

6.2. Types of Heat Exchangers

1. Shell and tube heat exchanger
2. Plate heat exchanger
3. Regenerative heat exchanger
4. Adiabatic wheel heat exchanger
5. Fluid heat exchangers
6. Dynamic scraped surface heat exchanger

6.3. Shell and Tube Heat Exchanger

A heat exchanger shell and tube is a type of heat exchanger designs. It is the most frequent type of heat exchanger in oil refineries and other large process industries, and is ideal for applications for high pressure drop. The heat exchangers for the shell and tube comprise of a series of tubes. One collection of these tubes comprises the fluid that must either be heated or cooled. The second fluid runs over the heated or cooled tubes, so that it can either supply the heat or absorb the essential heat. The tube bundle is called a set of tubes and may consist of many types of tubes: simple, lengthwise finned, etc. Shell and tube heat exchangers are usually used for applications with high pressure (pressures above 30 bar and temperatures above 260 °C). This is because the heat exchangers for the shell and thetube are durable because of their structure.

An STHE is divided into three parts. Exchangers are termed by the letter codes for the sections these letter codes are any according to ASME or TEMA standards.

1. The front head
2. The shell
3. The rear head

There are several thermal design features that are to be taken into current account when designing the tubes in the shell and tube heat exchangers. These include:

6.4. Tube

The use of a small tube diameter makes the heat exchanger both lightweight and inexpensive. Nevertheless, the heat exchanger is more likely to foul up quicker, and the tiny scale makes the fouling tough to mechanically clean. Larger tube diameters can beused to triumph over the fouling and cleaning problems. To assess the tube diameter, the space available, the costs and the fouling value of the fluids should be considered.

6.4.1. Tubes Thickness

The thickness of the wall of the tubes is usually determined to ensure:

1. There is sufficient room for corrosion
2. That flow-induced vibration has resistance
3. Axial strength
4. Ability to easily stock spare parts cost

6.4.2. Tube Pitch

When assembling the tubes, it is practical to ensure that the tube pitch (i.e. The center to center distance of adjoining tubes) is not less than 1.25 times the tubes' outside diameter.

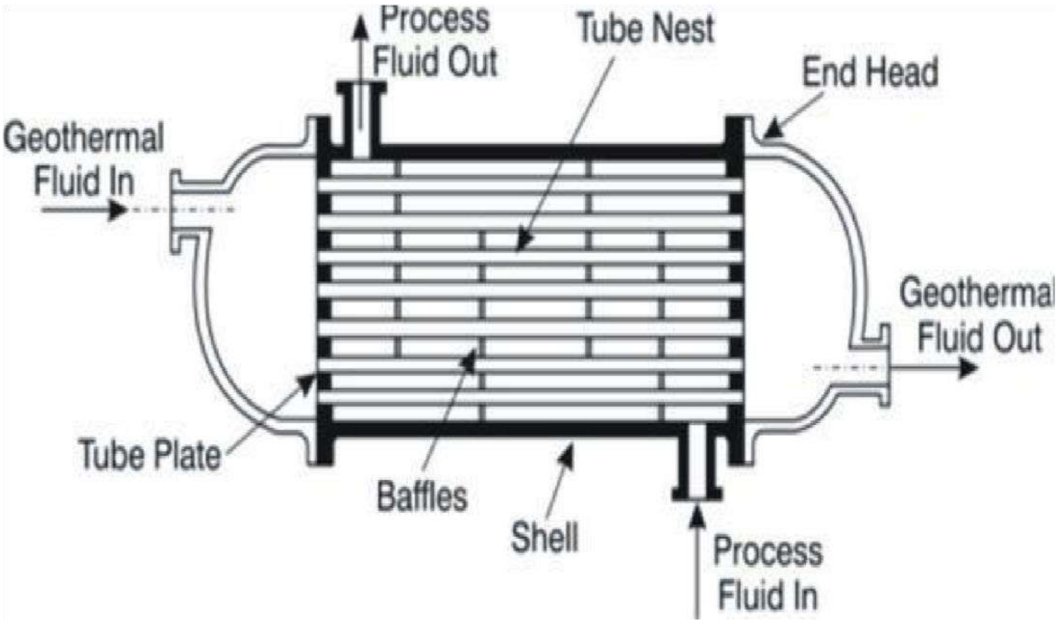


Figure 6.3 Schematics of Shell and tube heat exchanger [25]

6.5. Construction of Shell and Tube Heat Exchanger

6.5.1. Baffles

Baffles serve two functions:

1. Keeping tubes in the suitable location during assembly and operation and preventing displacement of tubes caused by flow-induced eddies
2. Directing the shell-side flow back and forth across the tube area, increasing the velocity and the heat transfer coefficient.

6.6. Classification of Baffles

Baffles are either normal or parallel to the tubes. Accordingly, baffles may be categorized as transverse or longitudinal.

6.6.1. Transverse Baffles

The transverse baffles channel the shell-side fluid into the tube bundle at approximately right angles to the tubes, and increase shell fluid turbulence.

Transverse baffles are of two types:

1. Plate baffles
2. Rod baffles

The types of plate baffles are:

1. Disk and doughnut baffles
2. Orifice baffles

6.6.2. Segmental Baffles

The segmental baffle is a circular disk that has a segment removed (with baffle holes). A significant number of shell and tube exchangers primarily employ segmental baffles. This cutting is denoted as the cut of the baffle and is commonly expressed as a percentage of the inside diameter of the shell.

The segmented baffle is often called a single segmental baffle. Cross flow bundles heat transfer and pressure drop are greatly affected by the baffle break. The shrinkage ranges from 20 to 49 percent with the most common being 20-25 percent, and the optimum baffle cut id generally
percent with the most common being 20-25 percent, and the optimal baffle cut it generally

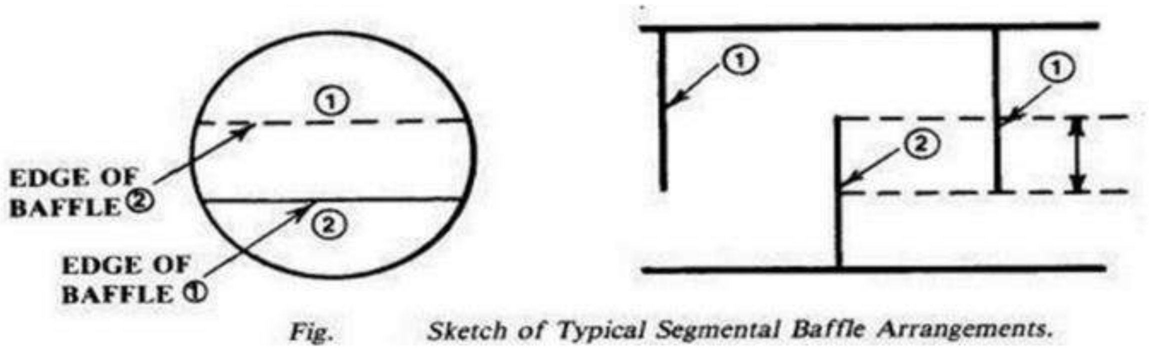


Figure 6.4 Baffles arrangement inside the shell

20 per cent, as it provides the greatest transfer of heat for a given drop less than 20 percent of baffle cuts will result in a drop in high pressure. As the baffle cut rises above 20 per cent, the flow pattern is increasingly deviating from the cross flow and may result instagnant regions or areas with lower flow speeds;

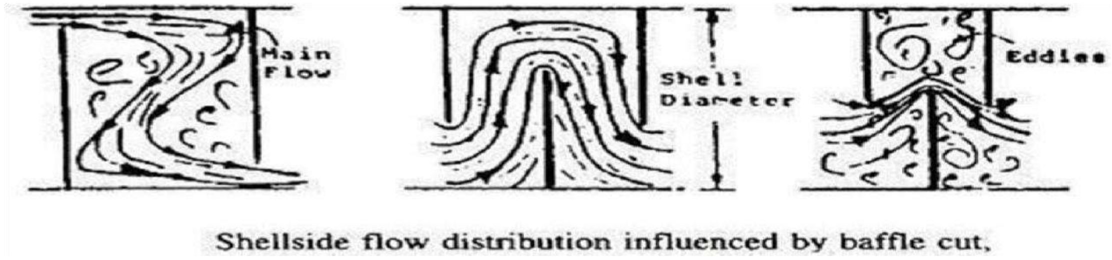


Figure 6.5 Shell side flow distribution

6.7. Tube Pitch

The shortest distance from center to center between the closet tubes is called the pitch of the tube. Although the square pitch has the advantage of simpler external washing, the triangular pitch is often chosen because it allows more tubes to be used in a given diameter of the shell.

6.8. Objective of Design

To design a heat exchanger for exchanging the heat between the slurry and the (water, glycerol) solution.

Given data:

(Water + glycerol) solution

Flow rate of solution =16575 kg/hr

Inlet temperature of solution = 86 °C

Outlet temperature of solution = 100°C

Slurry (water + glycerol + rice husk)

Flow rate of slurry = 18232.5 kg/hr

Inlet temperature of slurry = 140 °C

Outlet temperature of slurry = 120°C

Side	**Fluid**
Shell side	Slurry (water + glycerol + rice husk)
Tube side	(water + glycerol) solution

Shell side fluid properties:

Properties	**Units**	**Temperature at 130°F**
Viscosity	Lb/ft.hr	27.44 (calculate by weighted average method)
Thermal conductivity	Btu/hrft°F	0.068
Specific gravity	Unit less	0.41

Tube side fluid properties:

Properties	**Units**	**Temperature at 93°F**
Viscosity	lb/ft.hr	65.43 (calculate by weighted average method)
Thermal conductivity k	Btu/hr ft °F	0.107

Calculation of Shell & Tube Heat exchanger:

Heat duty:

$$\mathrm{Q = \ mCp\Delta T}$$

Where;

m = mass flow rate of mother liquor.

Cp = heat capacity

ΔT = temp. Difference

T_1 = 140 ℃ **t_1=86**℃

T_2 = 120 ℃ **t_2=100**℃

$\mathrm{Q = \ 40194\frac{Kg}{hr}} \times 6.53\mathrm{kj/kg℃} \times 34℃$

$$\mathrm{Q = 120\ KW}$$

$$\Delta Tlm = \frac{(T_1 - t_2) - (T_2 - t_1)}{\ln(\frac{T_1 - t_2}{T_2 - t_1})}$$

$$\Delta Tlm = \frac{(140 - 100) - (120 - 86)}{\ln(\frac{140 - 100}{120 - 86})}$$

$$\boldsymbol{\Delta Tlm = 37}℃$$

Now find R;

$$R = \frac{T_1 - T_2}{t_2 - t_1}$$

$$R = \frac{140 - 120}{100 - 86}$$

$$\boldsymbol{R = 8.57}$$

Now find S;

$$\boldsymbol{S = \frac{t_2 - t_1}{T_1 - t_1}}$$

$$S = \frac{100 - 86}{140 - 86}$$

$$\boldsymbol{S = 0.25}$$

Figure 12.1 from Coulson and Richardson, the value of F_t = 0.68

Corrected Temperature,

$$\Delta T_m = \text{Ft} \times \Delta T_{lm}$$

$$\Delta T_m = 0.68 \times 42.5$$

$\boldsymbol{\Delta T_m = 25.16}$℃

Assume from figure 12.1 of Coulson and Richardson, the value of U;

U= 500 W/m^2.℃

Find provisional Area,

$$A = \frac{Q}{U\Delta Tm}$$

$$A = \frac{1020\ KW}{500\,\frac{W}{m^2}\,℃ \times 37\ ℃}$$

$$\boldsymbol{A = 81\ m^2}$$

We choose the diameters;

Outer diameter = D_o = 19 mm

Internal diameter = D_i = 17 mm

Length = L= 4.88 m copray Nickel from Coulson and Richardson

Area of one Tube = $\pi D_o L$

Area of one Tube = 3.14× 0.019 m × 4.267 m

Area of one Tube = 0.2545 m^2

$$\boldsymbol{No. of\ tubes = \frac{Provisional\ area}{area\ of\ oone\ tube}}$$

$$No. of\ tubes = \frac{81}{0.2545}$$

$$\boldsymbol{No. of\ tubes = 318\ tubes}$$

Assume triangular pitch factor;

$$Bundle\ diameter\ D_b = D_o \times (\frac{N_t}{K_1})^{1/n1}$$

$$Bundle\ diameter\ D_b = 0.019 \times (\frac{318_t}{0.249})^{\frac{1}{2.207}}$$

$$\boldsymbol{Bundle\ diameter\ D_b = 0.48\ m = 485\ mm}$$

Now find shell diameter;

D_s = 485+68 = 533 mm

D_s = 533 mm

Mean Temperature find;

$$Mean\ Mother\ loquor\ Temperature = \frac{140 + 120}{2}$$

$$\boldsymbol{Mean\ mother\ liquor\ Temperature = 130}\ ℃$$

Now find Tube cross-sectional area;

$$\text{Tube cross} - \text{sectional area} = \frac{\pi Di^2}{4}$$

$$\text{Tube cross} - \text{sectional area} = \frac{3.14 \times (17)^2}{4}$$

$$\text{Tube cross} - \text{sectional area} = 226\ \text{mm}^2$$

Tubes per pass find;

$$\text{Tubes per pass} = \frac{No. of\ tubes}{2}$$

$$\text{Tubes per pass} = 169$$

$$Total\ flow\ area = tubes\ per\ pass \times tube\ cross\ sectional\ area$$

$$Total\ flow\ area = 169 \times 226\ mm^2$$

$$Total\ flow\ area = .035934\ m^2$$

Now find mass velocity;

$$Mass\ velocity = \frac{11.165\ kg.m^2}{sec.\times 0.035}$$

$$Mass\ velocity = 310\ kg/m^2sec$$

Total density = 2261 kg/m^3

Now find linear velocity;

$$Linear\ velocity = \frac{mass\ velocity}{total\ density}$$

$$Linear\ velocity = \frac{310\ kg.m^3}{m^2.\mathrm{sec}\times 2261\ kg}$$

$$Linear\ velocity = 0.1371\ m/sec$$

$$\boldsymbol{\frac{hidi}{kf} = JhRePr^{0.33}\left(\frac{\mu}{\mu w}\right)^{0.14}}$$

Find Re, and Pr;

$$Re = \frac{\rho v di}{\mu}$$

$$\boldsymbol{Re = 202}$$

$$Pr = \frac{Cp\mu}{kf}$$

Putting values then find Pr;

$$\boldsymbol{Pr = 176}$$

Putting values then find h$_i$

$$\boldsymbol{h_i = 246\ \frac{W}{m\text{°C}}}$$

Shell Side Coefficient:

Now find choose Baffle spacing;

$$Baffle\ Spacing = \frac{Ds}{5}$$

$$Baffle\ Spacing = \frac{533}{5}$$

$$\boldsymbol{Baffle\ Spacing = 106\ mm}$$

Find Tube Pitch;

$$\boldsymbol{Tube\ pitch = 1.25 \times D_0}$$

Use triangular pitch as shell side fluid is clean;

$$Tube\ pitch = 1.25 \times 19mm$$

$$\boldsymbol{Tube\ pitch = 23.75\ mm}$$

Cross sectional area of shell side.

$$Cross\ flow\ area\ of\ shell\ side = \frac{Tube\ Pitch - Do}{Tube\ pitch} \times Ds \times Baffle\ spacing\ in\ m^2$$

$$Cross\ flow\ area\ of\ shell\ side = \frac{23.75-19}{23.75} \times 533 \times 106 \times 10^{-6}$$

$$Cross\ flow\ area\ of\ shell\ side\ As = 0.011\ m^2$$

Now find Mass velocity,

$$mass\ velocity\ Gs = \frac{mass\ flow\ rate}{area}$$

$$mass\ velocity\ Gs = \frac{18232.5\ kg.hr}{hr \times 0.011 \times 3600\ sec}$$

$$\boldsymbol{mass\ velocity\ Gs = 460 \frac{kg.}{m^2.sec}}$$

Now find d_e

$$d_e = \frac{1.10}{do} \times ((tube\ pitch)^2 - 0.917do^2)$$

$$\boldsymbol{d_e = 17.11\ mm}$$

$$Temperature = \Delta Tm = \frac{100 + 86}{2}$$

$$\boldsymbol{Temperature = \Delta Tm = 93}℃$$

Density of water = 2361 kg/m^3

Cp of water = 6.32 kj/kg.℃

Kf of water = 0.879 W/m.℃

Viscosity = 0.000451 Pa.sec

Now find Reynolds Number;

$$Re = \frac{Gs\ de}{\mu}$$

$$Re = \frac{460\ kg \times\ 17.11\ mm}{m^2.sec\ \times 0.000451\ Pa.Sec}$$

$$\boldsymbol{Re = 11171}$$

Find Pr Number;

$$Pr = \frac{Cp\mu}{kf}$$

$$Pr = \frac{6.32kj \times 0.000451\ Pa.sec.m.℃}{kg.℃ \times 0.879W}$$

$$\boldsymbol{Pr = 5}$$

Choose 25 percent Baffle cut from figure 12.29 Coulson and Richardson volume 6th;

J$_h$ = 3.3×10^{-3}

$$h_s = \frac{kf \times Jh \times Re \times Pr^{0.33}}{de}$$

$$h_s = \frac{0.879W \times 3.3 \times 10^{-3} \times (11171) \times (5)^{0.33}}{m.℃ \times 17.11 \times 10^{-3}m}$$

$$\boldsymbol{h_s = 3241 \frac{W}{m^2.℃}}$$

Overall Coefficient:

We know that the thermal conductivity of Cupro nickel alloy = 50 W/m.℃

Take the fouling coefficient from table 12.2; heavy organics is 2000 W/m^2. ℃. And for cooled water; take value 3000 W/m.℃

$$\frac{1}{Uo}=\frac{1}{hs}+\frac{1}{2000}+\frac{\mathrm{Do}\times 10^{-3}\times \ln\frac{Do}{Di}}{2\times K_{CNA}}+\left(\frac{Do}{Di}\times\frac{1}{3000}\right)+\left(\frac{Do}{Di}\times\frac{1}{hi}\right)$$

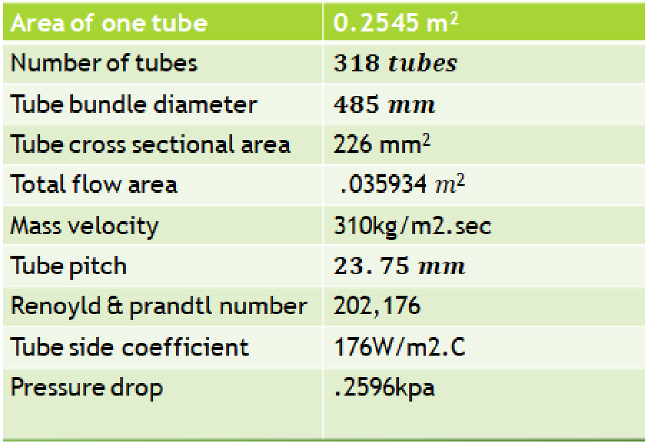
$$\frac{1}{Uo}=\frac{1}{3241}+\frac{1}{2000}+\frac{19\times 10^{-3}\times \ln\frac{19}{17}}{2\times 50}+\left(\frac{19}{17}\times\frac{1}{3000}\right)+\left(\frac{19}{17}\times\frac{1}{246}\right)$$

$$\boldsymbol{U_o=91\,\frac{W}{m^2.{}^{\circ}\mathrm{C}}}$$

Pressure drop at shell side:

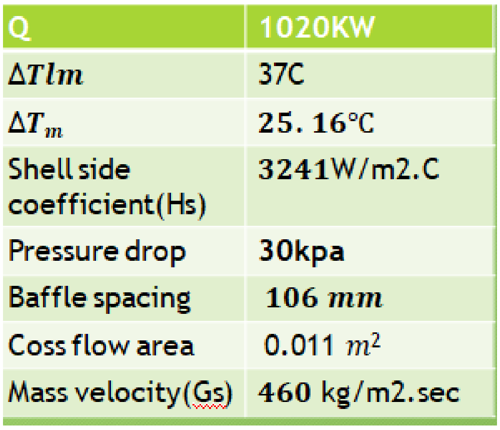
$= 8j_f(D_s/D_e)(L/lb)(\,\boldsymbol{\mu}Us^2/\boldsymbol{\mu W})^{-.14}$ =30kpa

Pressure drop at tube side: =.2596kpa



Area of one tube	0.2545 m^2
Number of tubes	**318 *tubes***
Tube bundle diameter	**485 *mm***
Tube cross sectional area	226 mm^2
Total flow area	.035934 m^2
Mass velocity	310kg/m2.sec
Tube pitch	**23. 75 *mm***
Renoyld & prandtl number	202,176
Tube side coefficient	176W/m2.C
Pressure drop	.2596kpa

tube side specifications:



Q	1020KW
ΔTlm	37C
ΔT_m	25. 16℃
Shell side coefficient(Hs)	3241W/m2.C
Pressure drop	30kpa
Baffle spacing	**106 *mm***
Coss flow area	0.011 m^2
Mass velocity(Gs)	460 kg/m2.sec

shell side specifications:

Decanter Centrifuge Design

A centrifuge is a machine, which is used to separate the components having different densities due to its high rotational speed. Decanter is used when there is a high content of solid particles (up to 60%) in suspension, and these decanters normally used for a continuous process. Another suitable device can also be used which is cheaper as compared to decanter. Decanter is an important device which separates the solid particles from liquid, therefore it plays a significant role in different chemical industries [37].

Setting tanks and clarifiers are also used in many industries. In these devices, all the solid particles deposit and then reach to the base of the tank due to gravity. This kind of separation is not considered so good because it is a very slow process and the results are not so good. So, centrifugal force is used to increase the speed of the process. The effect of centrifugal force is about 4000 times more than that of gravitational force [38].

Various types of decanter centrifuges are used in different industries, which are conveyer, horizontal and vertical centrifuges as here, we use horizontal cleaning decanter centrifuge. Different kinds of horizontal continuous decanter centrifuges are used which offer low maintenance solutions well as effective method to clarify the continuous liquid. Horizontal bowl centrifuges are also called centrifugal decanters, decanter centrifuges or decanter machines. These decanters are mainly used to separate the liquids from considerable amounts of the solids. The principle of the decanter centrifuge is basically based on theory of the gravitational separation [39]. For example, if there is a vessel filled with the mixture of water and mud, after some time, the mud is settled down at the bottom of the vessel due to its weight. The water will be enforced in upward direction when mud compact at the base of vessel and a clear separation is created between water and solid.

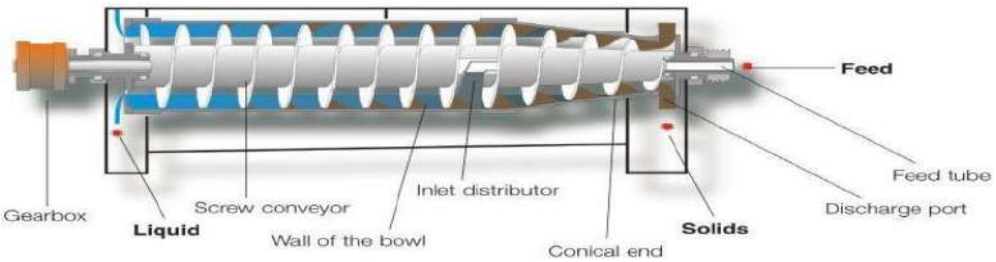


Figure 6.6 Centrifuge Decanter

6.1. Working

A conveyor or pipe is used to bring the slurry in centrifuge machine. This conveyor is also used to rotate this slurry through the nozzle into bowl where the dense solid particles are pressed or pushed in outward direction against moving walls of the bowl and the liquid particles with low density are collected and a concentric inner layer is formed in the decanter centrifuge.

The plates having different sizes are used to differ the depth of sediments and liquid. The solid particles are then continuously removed by using a screw conveyor which moved at different speed. Then the solid particles ploughed out from pond and arrived at in conical beach.

The bowl moved about at high speed to produce the centrifugal force. This force compacted solid particles and expelled the liquid. A clarified liquid phase is produced at opposite side of the baffles and bowl within centrifuge machine which is used to separate the phases into correct flow path. Speed of the screw conveyor adjusted mechanically with the help of (variable frequency drive).

The solid particles removed and cleaned liquid is released from a different output. The decanter centrifuge has an ideal ability to clean the liquid so can be used in waste water treatment. However, these centrifuges play a significant role in various industries. The centrifuges do not require any foundation to build upon and very simple to install.

6.2. Sedimentation Principle

The decanter works basically by the sedimentation. Sedimentation is a process which helps to separate the suspended solid particles from liquids due to the difference in the densities of liquid and solid. When density difference is very high, gravity provides sufficient driving force is occurred to separate the solid particles from liquid in a very logical time period with a large tank that clarifiers and inclined plate separators. On the other hand if density difference is small or the size of particles is small, it requires a large period of time to separate the particles, and separation force should be increased by imposition of the centrifugal force. This mixture is then inserted into the centrifuge with the help of connecting pipe and on top of the conveyer. After that conveyor takes slurry into the bowl area with the help of a nozzle.

This bowl rotates at a very high speed to create the gravitational forces. This rotation separates solid particles from the liquid material in just few seconds. The solid material moves upwards in conveyer and then released from the nozzle. After removing solid particles, purified liquid is also discharged through a separate output. When one shift is over, wash and clean the bowl. This machine is very easy to operate as well ore workers are not required. The introduced mixture had to be accelerated at high speed because if acceleration is not done it can badly affect the separation process.

6.3. Benefits Compared To Other Types Of Separation Equipment

This horizontal decanter centrifuge is a high speed process which separates the solids particles from one or two types of liquid phases, so increased the profitability and productivity. It has the capacity to handle a broad range of the solid particles having diameter in a range of about 5mm to few microns.

1. Continuous operation
2. Solid and liquid separation in a single continuous process
3. Excellent quality
4. Lower maintenance cost
5. Low capital cost
6. Reduce energy consumption
7. Recovery of valuable raw materials
8. High score machine material

6.4. Design Parameters

There are some factors that affect separating ability of the centrifuge. These are as following

1. Centrifugal force
2. Clarifying area
3. Suspension volume
4. Equivalent clarifying area
5. Beach angle
6. Retention time

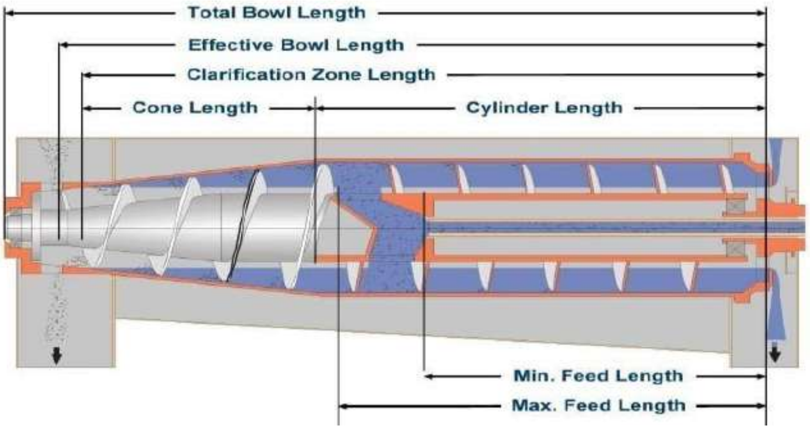


Figure 6.7 Internal measurement of decanter [39]

The measurements and parameters which an engineer will require to carry out the comparison between various centrifuges are following:

1. D_W = weir diameter (m)
2. L_{cyl} = cylindrical length (m)
3. α = cone angle (°)
4. D_B = inner bowl diameter (m)
5. n = bowl speed (rpm)

6.5. Centrifugal Force

To design a centrifuge, the most important parameter which comes to mind is the centrifugal force. The maximum centrifugal force developed inside the centrifuge plays a significant role in its angular rotational speed. The g force can be defined as “the multiple of gravitational constant which is obtained in centrifuge”

A formula for calculating g-force at the periphery of bowl is:

$G = n^2 \times D_B / 1800$

Here:

G = G-force and

n = Bowl speed (rpm)

6.5.1. Bowl Diameter

Usually the bowl has the diameter of about 200 to1000 mm

$D_B = 400$ mm

$2\ D_B = r_0$

$R_0 = 800$ mm

6.5.2. Bowl Speed

Bowl speed is normally from 3000 rpm to 3800 rpm.

$n = 3400$ rpm

$Ac = \dot{\omega}2 \times r0$

$A_c = (2\pi \times n_{rps})^2 \times r$

$A_c = (2\pi n_{rpm}/60\,)_2 \times r$

$A_c = 101310$ m/s^2

Now

$G = (3400)^2 \times (400 \times 10^{-3})/1800$

$G = 2568$ m/s^2

As a result the g- value or centrifugal acceleration will augment with bowl speed and diameter. A large decanter running at same g-force as the smaller one will provide a better separation of solid and liquid. This means that when there are two centrifuges having different diameters but same bowl speeds, unit with large size will produce more g-force, so provide a better separation of solid and liquid.

6.5.3. Suspension Volume (Vs)

The suspension volume of the decanter can be measured as total content of liquid zone in the bowl. The suspension volume (V_s) consists of two components:

1. The volume contained in cylindrical section (V_{cyl})
2. The volume contained in conical section (V_{cn})

It can be calculated as follows:

$V_{cyl} = \pi/4 \times (D_{B2} - D_{W2}) \times L_{cyl}$

$V_{cn} = \pi/8 \times (D_B - D_W)/\tan\alpha \times ((D_{B2} + D_B \times D_W + D_{W2})/(3 - D_{W2})$

Here,

D_B = inner bowl diameter (m)

D_W = weir diameter (m)

L_{cyl}= length of cylindrical section (m)

A = cone angle (^{o})

6.5.4. Cylindrical Length

The length of the clarifying section of decanter is taken according to l/d ratio. Generally this ratio is 2, 3, and 4.

$L/d = 4$

$L/400 = 4$

$L = 1600$ mm

6.5.5. Cone Angle

15° to 20° cone angle is very favorable to transport the sediments effectively using scroll, with an advantage of the large suspension volume.

Cone angle (α) = 17°

6.5.6. Weir Diameter

Diameter of weir is the length of line from one edge of the weir to the opposite edge, passing through center of the circle formed by weir.

$D_w = 280$ mm

Now

$V_{cyl} = \pi/4\times (400^2 - 280^2) \times 1600$

$V_{cyl} = 0.0150$ m3

And

$V_{cn} = \pi/8\times (400 - 280)/\tan 17^0 \times (400^2 + (400\times 280) + 280^2)/ (3 - 280)^2$

$V_{Cn} = 0.007$ m3

So

$V_S = V_{Cyl} + Vcn$

$V_{S=}$ 0.022 m^3

The effect of suspension volume in the centrifuge decanter can be compared that where larger settling volume leads to a better degree of the separation. In a decanter, the same hold proper for suspension volume. All other parameters being equal, a larger suspension volume will provide best results in separation process.

6.5.7. Retention Time

The suspension volume offers a very reasonable estimation as a basis for the calculation of retention time of centrifuge, providing an estimation of the time period in which slurry resides in centrifuge under the effect of the centrifugal force. The retention time can be calculated as follows:

$T_r = 3600 \times V_s/Q$

Here

T_r = retention time (sec)

Q = volumetric feed rate (m^3/h)

A centrifuge with longer retention time, can separate the materials more efficiently. The larger suspension volume leads to a higher retention time. This does, however, not give any indication whether available retention time is actually enough to get the desired extent of separation. The actual retention time required for every particular sludge will be different and affected by various parameters which are as following:

1. Viscosity of the liquid phases
2. Relative densities of the phases
3. Particle size
4. Ratio of phases

6.5.8. Beach Angle

When these solid particles are transported along beach of the decanter, a force is acting on solid particles in the direction of liquid pool, this force is called “slippage force”. This force mainly depends upon the value of difference between the surrounding medium and specific gravity of solid.

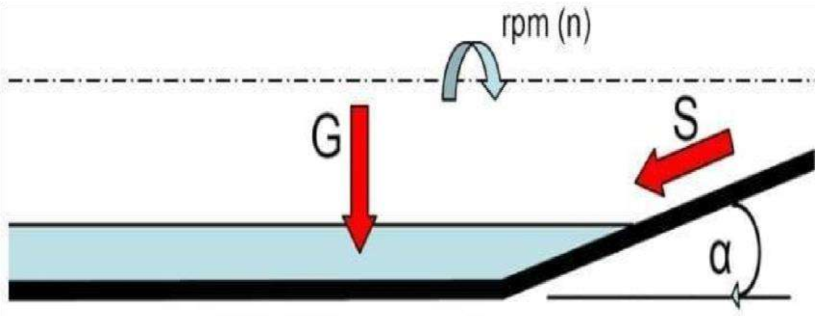


Figure 6.8 Slippage force on beach of reactor [39]

The slippage force can be calculated as follows:

$S = G \times \sin \alpha$ Here:

G = gravitational force generated by centrifuge

A = cone angle of centrifuge

$S = 2568 \times \sin 17^\circ$

$S = 750\ m/s^2$

Centrifuge having small cone angle can produce lower slippage forces. A low cone angle is advantageous when solid particles are not in compact form and have a very soft texture, such as in case of the digested sewage sludge. A small cone angle is also beneficial when working with the well compacted form of solid.

6.5.9. Clarifying Area

This is a very significant parameter which is used to make one centrifuge show more effective as compared to others. Clarifying area is the wetted surface of the bowl interior side. The difficulty is that, every producer using special formula to calculate it. There is no standard formula to calculate clarifying area.

$A_c = \pi \times D_B \times L_{cyl}$Here:

A_c = clarifying area (m^2)

D_B = inner bowl diameter (m)

L_{cyl}= cylinder length (m)

$A_c = (3.14) \times (400) \times (1600)$

$A_c = 2.0\ m_2$

6.5.10. Equivalent Clarifying Area

In order to obtain an idea about relative settling capacity of the centrifuge, one can calculate the sigma value or equivalent clarifying area by using the formula as

$\Sigma = A_c \times G$

$\Sigma = (\pi \times n^2 \times D\ ^2 \times l\ )/1800$

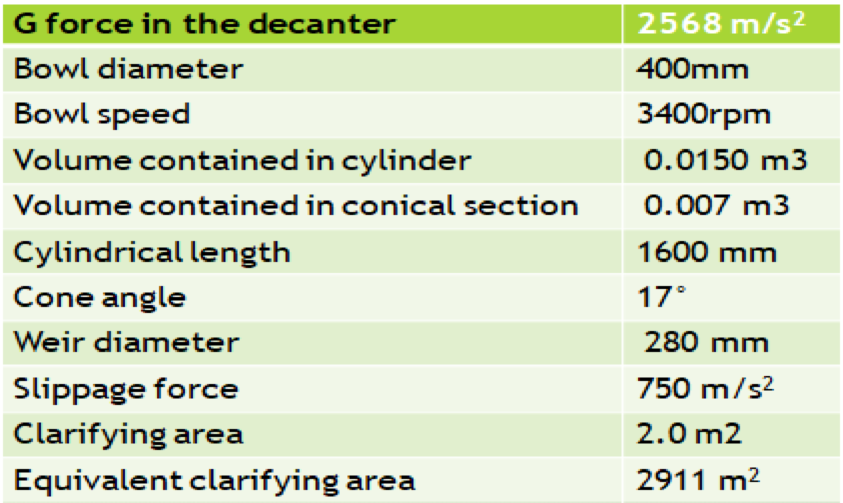
B cyl

$\Sigma = (\pi \times 3400^2 \times 425^2 \times 800)/1800$

$\Sigma = 2911\ m^2$

So, the effect of diameter of the bowl is more obvious when compared with length of bowl. High speed of the bowl and increased length of the cylindrical section of centrifuge will improve the settling and separation of the fine solids which give a clearer liquid phase. These are the initial formulas and calculation to design a centrifuge decanter.

Specification sheet



G force in the decanter	$2568\ m/s^2$
Bowl diameter	400mm
Bowl speed	3400rpm
Volume contained in cylinder	0.0150 m3
Volume contained in conical section	0.007 m3
Cylindrical length	1600 mm
Cone angle	17°
Weir diameter	280 mm
Slippage force	$750\ m/s^2$
Clarifying area	2.0 m2
Equivalent clarifying area	$2911\ m^2$

Chapter 7

INSTRUMENTATION AND CONTROL

7.1. Introduction

Control system plays a vital role in any large continuous plants like the one we have designed so far. Although the objectives to be achieved through control system varies according to the requirements. The general requirements given in literature are as follows [40].

1. Safety
2. Environmental regulations
3. Product specification and production rate
4. Economic plant operation

Whereas we are required to fulfill all the requirements mentioned above in our control system design. During the design of the equipment the following steps are taken under consideration.

7.1.1. Need Of Instrumentation And Control

1. Selection of controlled, manipulated and measure variables
2. Selection of control strategy and control structure

7.2. Control Scheme Of Agitator Mixer

Schematic control of mixer is based on the controlling flow rates of input and output streams. This is done via PLCS, controllers and computers. Volumetric flow meters use ultrasonic wave technology [41]. This liquid flow meter can be combined with a control valve or pump to constitute a compact liquid dosing device. Flow transmitter are basically installed right after the pump to generate signal to the flow controllers and thus the flow rate is controlled through control valves. It must then be attached to an actuator which utilizes this control signal for activating the ultimate control component [42].

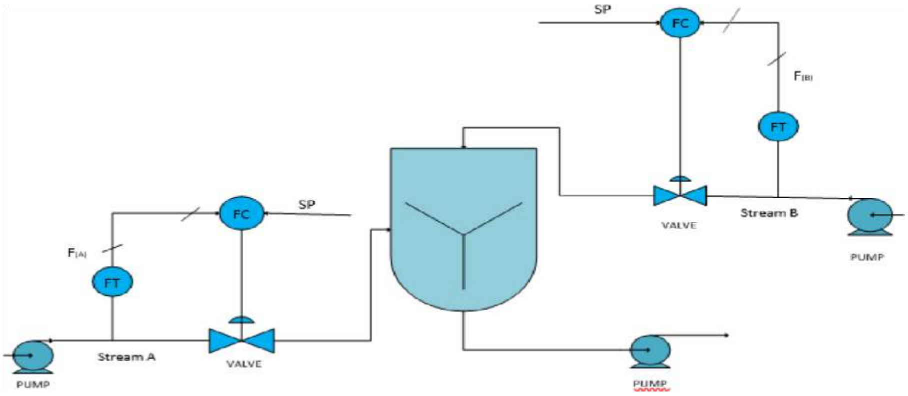


Figure 7.1 Control mechanism of stirring Reactor [30]

7.3. Control Scheme Of Decanter Centrifuge

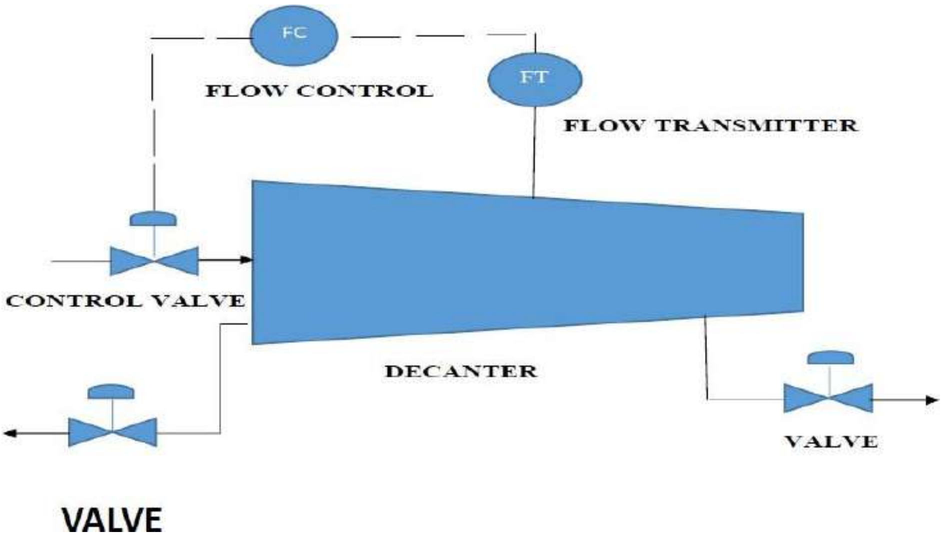


Figure 7.2 Control scheme on decanter[39]

Flow meters for aqueous slurries are reliable, accurate and seldom require adjustment after initial calibration. Moreover, they are ready for connection to PLCS, computers and controllers. The most common models used on decanter plants are eddy current and ultrasonic type. Flow meters are used on the feed line after the feed pump. Flow transmitter send the signal to controller which control the input valve and change the flow rate according to the requirement.

7.4. Control Mechanism Of Centrifugal Pump

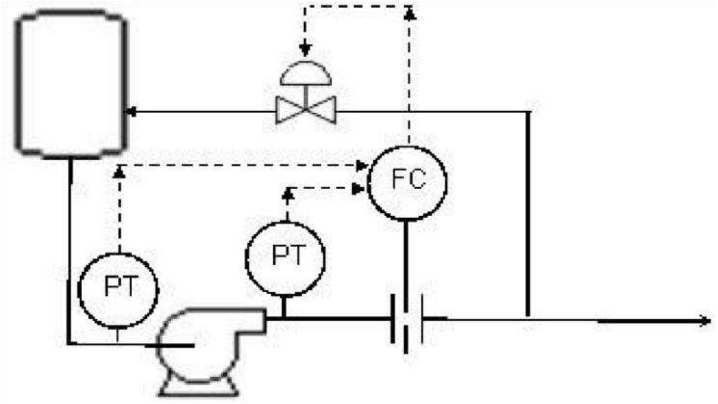


Figure 7.3 Control scheme on centrifugal pump[36]

7.5. Level Controller

In this control configuration level controller is used to control the level in the tank. There are three levels

1. High liquid level
2. Low liquid level

When the level of liquid is high or the level of liquid is low then the controls automatically stop the flow and when the liquid level is at normal condition then the operation proceed efficiently.

7.5.1. Temperature And Pressure Sensors

There is a control configuration both in the suction line as well as in the discharge line in order to operate the process efficiently. When the temperature and the pressure is not according to the desired conditions then the shutdown switch stop the process until the desired conditions has been prevailed.

Similar procedure is used for the discharge line in order to control the process and maintains uniform process.

7.5.2. Flow Controller

When the outlet valve is closed then the pressure inside the pump has been increased so in order to maintain the pressure inside the pump there is pressure controller in the discharge line and there is also the flow control in order to control the flow rate of the discharge streams.

If the flow rate is not according to set values, then the fc controller automatically closed the valve in order to stop the process and when the flow rate is in according to the set value then the process proceed.

Chapter 8

COST ESTIMATION

8.1. Overview

Cost engineering or engineering economics relates to this area of practice, application of Scientific methods and rules for approximating problems, costs control, profitability analysis, business planning, project management, planning and scheduling. It is necessary that engineers are aware of the different types of costs during plant manufacture and operation

[43]. <u>Estimation of equipment cost</u>

Equipment	**No. Of equipment**	**Per equipment cost in 2010 ($)**	**Total cost in 2010 ($)**
Shredder	1	100635	100635
Heat exchanger	1	29281	29281
Centrifuge decanter	1	836762	836762
Helical stirring reactor	1	374413	374413
Centrifugal pump	5	8337	41687
Total	1382778 $		

Purchased cost in 2022 = purchased cost in 2010 × (cost index in 2022/cost index in 2010)

Cost index in 2010 = 532.9

Cost index in 2022= 596.2

Purchased cost of equipment in 2022 = 1547030 $

8.1.1. Total Capital Investment

Total capital investment = fixed capital investment (FCI) + working capital investment (WCI) [44].

Fixed capital investment

FCI = direct cost + in-direct cost

8.1.2. Direct Cost

Items	% purchased equipment	Cost total ($)
Purchased equipment	100	1547030
Installation	40	618812
Instrumentation and control	14	216584
Piping	38	587871
Electricity	15	232054
Buildings	25	386757
Utilities	35	541460
Safety, miscellaneous	3	46411
Land	5	77351
Total		4254330

8.1.3. In-Direct Cost

Items	Dependency	Total cost ($)
Engineering & supervision	40% of purchased cost	618812
Legal expenses	10% of direct cost	425433
Construction & contractor Fee	5% of direct cost	212716
Contingency	8% of direct cost	340346
Total indirect cost		1597307

Now

FCI = 4254330 $ + 1597307 $

Fixed capital investment = 5851637 $

8.1.4. Working Capital

WCI = 15% of FCI

WCI = 0.15× (5851637) = 877745.5 $

Now,

Total capital cost = FCI + WCI

Total capital cost = 5851637 + 877745.5 = 6279382.5 $

8.2. Total Product Cost

8.2.1. Direct Production Cost

1	Operating labor cost	= 0.10×(TPC)
2	Utility cost	= 0.20×(TPC)
3	Maintenance & repair cost	= 0.04×(FCI) = 234065.48 $
4	Laboratory & testing cost	= 0.15× (Labor cost)
5	Laboratory & testing cost	= 0.15×(0.10×TPC)
6	Patents & royalties	= 0.03×(TPC)
7	Direct product cost	= 1+2+3+4+5
8	Direct product cost	= 0.10×(TPC) + 0.20×(TPC) + 234065.48 $
9		= + 0.015×(TPC) + 0.03×(TPC)
10	Direct product cost (DPC)	= 0.345×(TPC) + 234065.48

8.2.2. Fixed Charges [18]

1. Deprecation	=	0.10×(FCI)	=	585163.7 $
2. Local tax	=	0.015×(FCI)	=	87774.55 $
3. Insurance	=	0.01×(FCI)	=	58516.37 $
3. Fixed charges	=	1+ 2 +3	=	731454.6 $

8.3. Plant Overhead Cost

Plant overhead cost = 60% of labor

Plant overhead cost = 0.60×[0.10×(TCP)]

8.3.1. Administrative Expenses

Administrative expenses = 25% of labor cost

Administrative expenses = 0.25× [0.10×(TPC)]

8.3.2. Distribution And Market Expenses

Distributions & market expenses = 10% of total product cost

Distributions & market expenses = 0.10×(TPC)

R & D cost

Research & development cost = 5% of FCI

Research & development cost = 292581.85 $

Interest

Interest = 8% of FCI

Interest = 468130.96 $

Now,

Total product cost = A + b + c + d + e + f + g

Total product cost = 0.345×(TPC) + 234065.48 + 731454.6

+ (0.60)× [0.10(TPC)]) + (0.25× [0.10 TPC)])

+ 0.10×(TPC) + 292581.85 + 468130.96

TPC = 1726232.89 + 0.53 (TPC)

1-0.53 TPC = 1726232.89

TPC = 3672835.94 $

8.4. Profitability Analysis

Income

Wholesale selling price per sheet (2×4ft) in Pakistan = 872 Rs = 5.57 $

Total income = selling price × quantity of product

QUANTITY OF PRODUCT (FIBERBOARD) = 5654 SHEETS / DAY = 1696200 SHEETS / YEAR

Total income = 5.57 $ × 1696200= 9447834 $

8.4.1. Net Profit

Let the tax rate is 40 %

Taxes = 0.40 (gross profit) = 2309999.22

Net profit = Total income – taxes

Net profit = 9447834 – 2309999.22 = 7137834.78 $

Chapter 9

HAZARD AND OPERABILITY STUDY

9.1. Introduction

It is a methodical strategy to identify expected hazard and operating issues. A formalorderly thorough assessment to the procedure and planning realities of a creation office. A subjective method dependent on "control words" to help incite considerations about theroute deviations from the planned working conditions can prompt risky situations or operability issues. HAZOP is basically for security and risks are the principle concern. Operability issues debase plant execution (item quality, creation rate, benefit). For HAZOP, impressive designing knowledge is required - engineers working autonomously could create various outcome [45].

9.2. Hazop Study Of Decanter Centrifuge

Guide word	Deviation	Causes	Consequences	Recommendations
No	Not flow	Valve closed	Solution becomes concentrated	Proper monitoring
Less	Less flow	Valve not fully opened	Concentration of solution is disturbed	Proper monitoring
More	More flow	Waterpassing through the valve even when valve is closed	Overflow	Install indicator level

9.2.1. Hazop Study Of Shell And Tube Heat Exchanger

Deviation	Causes	Consequences	Safeguards	Recommendation
Less flow of cooling water	Pipe leakage or blockage	Process fluid temperature change is too low or remains Constant	Installation of flow rate	High temperaturealarm
More flow of Cooing water	Failure of inlet cooling water valve to close	Temperature of process fluid decreases Output of process fluid temperature too Low	Installation of flow meter	Low temperaturealarm
More pressure On tube side	Failure of process fluid valve	Bursting of tubes	Installation of pressure gauge	Install high pressure alarm
Corrosion of tubes	Hardness of cooling water Leakage of tube and cooling Water goes in	Contamination of process fluid Less cooling and cracking of tubes	Proper maintenance	Install operator alert

9.3. Hazop Study Of Centrifugal Pump

No	Parameter	Guide words	Causes	Consequences	Recommendations
1	Flow	No	Inlet line rupture or clogging, inlet plug valve closed, No material	No reaction takes place inside the reactor, process gets disturbed	Periodic maintenance of control valves visual inspection of pipelines
		Less	Isolation valve closed partially or malfunction, line clogging or leakage	Reaction gets disturbed	Periodic maintenance and of valves, direction indications on valves
		More	Wrong setting of valve	Reactor temperature increases, reactor level rises	Proper maintenance of valves, direction indications on valves, breather valve

Chapter 10

USE OF COMPUTER TOOL

10.1. Introduction

We used different software's during our project for our calculations. The process calculations like material & energy balances were performed in MS Excel.

Design calculation of equipment are also performed by using MS Excel. For the physical and chemical properties, Aspen Plus was used. The process flow diagram (PFD) is created in Microsoft Visio. The process simulation diagram (PSD) is created in aspen plus.

Following computer tools are used.

1. Excel
2. Microsoft Visio
3. Aspen Plus

10.2. Process Simulation Program

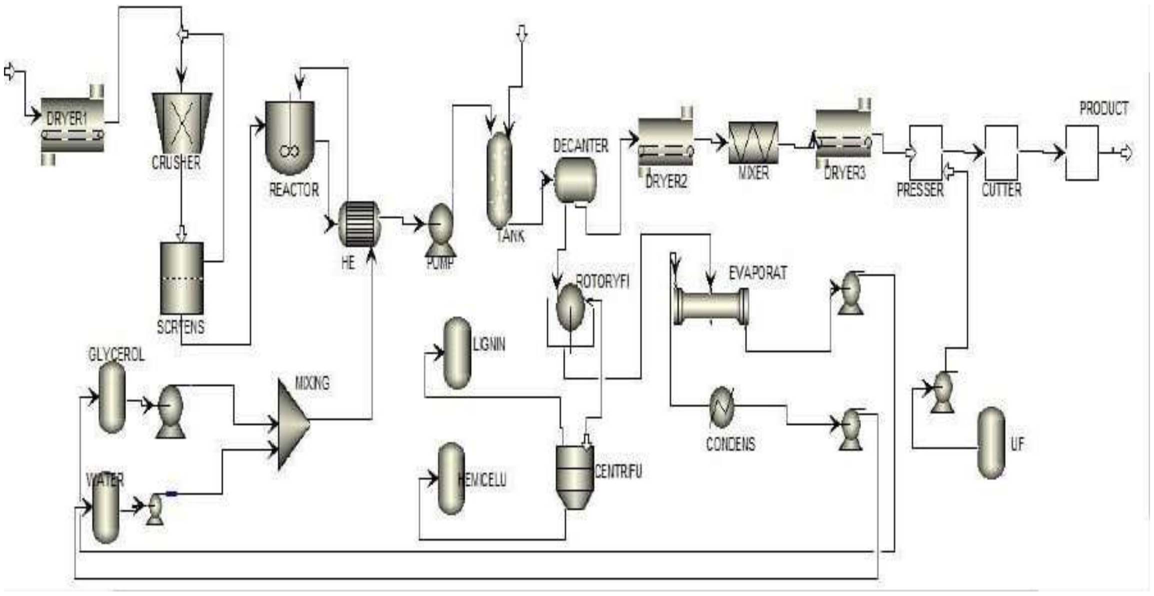
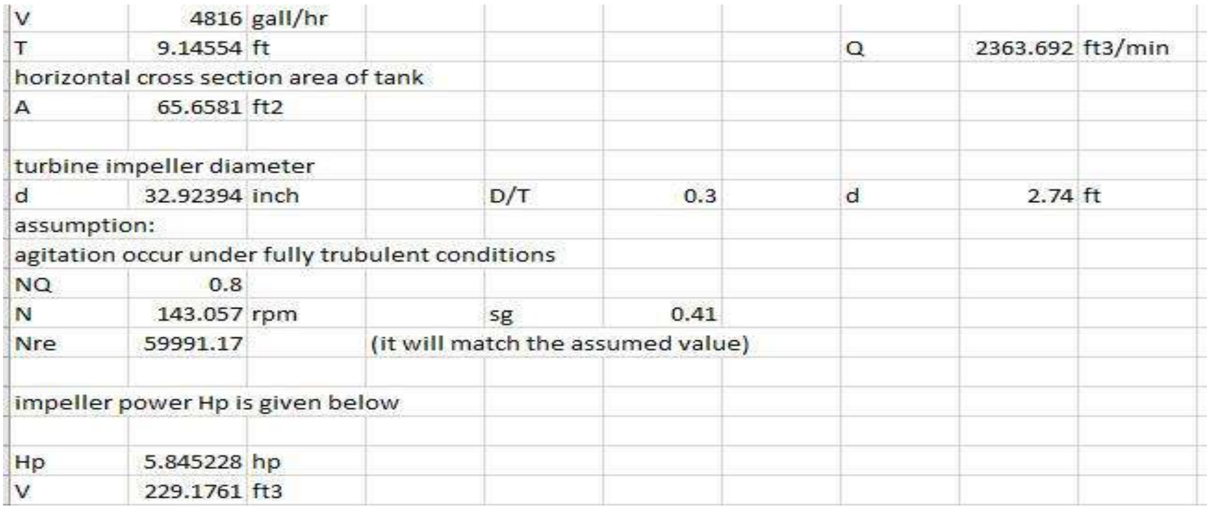


Figure 10.1 Process flow diagram of fiberboard synthesis

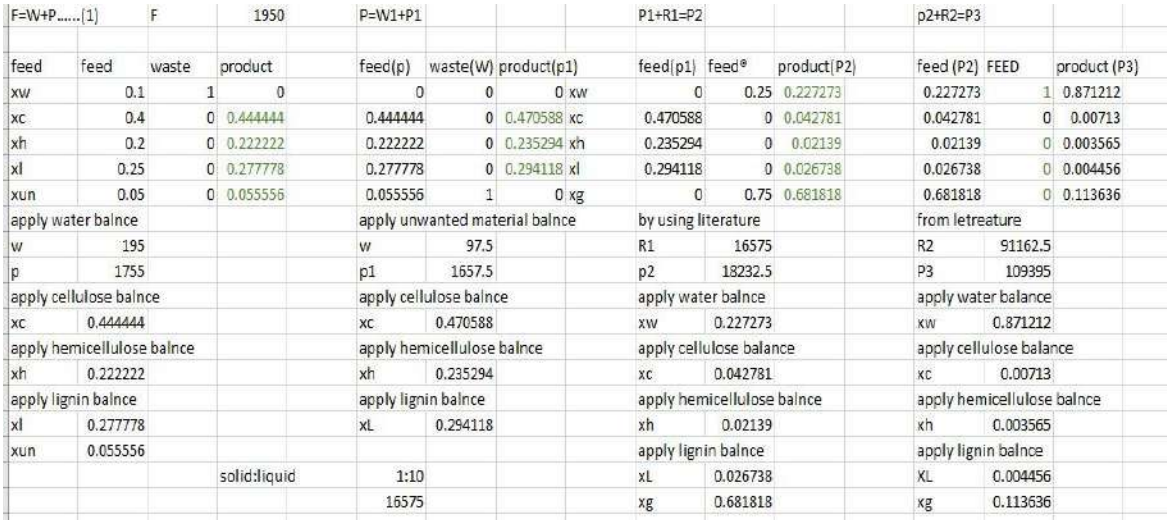
This process flow diagram indicates the overall process description.

Design of mixing reactor:



V	4816	gall/hr							
T	9.14554	ft					Q	2363.692	ft3/min
horizontal cross section area of tank									
A	65.6581	ft2							
turbine impeller diameter									
d	32.92394	inch		D/T	0.3		d	2.74	ft
assumption:									
agitation occur under fully trubulent conditions									
NQ	0.8								
N	143.057	rpm		sg	0.41				
Nre	59991.17		(it will match the assumed value)						
impeller power Hp is given below									
Hp	5.845228	hp							
V	229.1761	ft3							

Material balance:



F=W+P......(1)		F	1950		P=W1+P1				P1+R1=P2				p2+R2=P3		
feed	feed	waste	product		feed(p)	waste(W)	product(p1)		feed(p1)	feed®	product(P2)		feed (P2)	FEED	product (P3)
xw	0.1	1	0		0	0	0	xw	0	0.25	0.227273		0.227273	1	0.871212
xc	0.4	0	0.444444		0.444444	0	0.470588	xc	0.470588	0	0.042781		0.042781	0	0.00713
xh	0.2	0	0.222222		0.222222	0	0.235294	xh	0.235294	0	0.02139		0.02139	0	0.003565
xl	0.25	0	0.277778		0.277778	0	0.294118	xl	0.294118	0	0.026738		0.026738	0	0.004456
xun	0.05	0	0.055556		0.055556	1	0	xg	0	0.75	0.681818		0.681818	0	0.113636
apply water balnce					apply unwanted material balnce				by using literature				from letreature		
w	195				w	97.5			R1	16575			R2	91162.5	
p	1755				p1	1657.5			p2	18232.5			P3	109395	
apply cellulose balnce					apply cellulose balnce				apply water balnce				apply water balance		
xc	0.444444				xc	0.470588			xw	0.227273			xw	0.871212	
apply hemicellulose balnce					apply hemicellulose balnce				apply cellulose balance				apply cellulose balance		
xh	0.222222				xh	0.235294			xc	0.042781			xc	0.00713	
apply lignin balnce					apply lignin balnce				apply hemicellulose balnce				apply hemicellulose balnce		
xl	0.277778				xL	0.294118			xh	0.02139			xh	0.003565	
xun	0.055556								apply lignin balnce				apply lignin balnce		
			solid:liquid		1:10				xL	0.026738			XL	0.004456	
					16575				xg	0.681818			xg	0.113636	

Chapter 11

ENVIRONMENTAL IMPACT

11.1. Overview

An environment impact assessment is an evaluation of the conceivable positive effect or negative effect which the venture may have on the regular habitat. The reason for the appraisal is to guarantee that consider natural effects used to conclude whether to continue with the venture. The international association for impact assessment (characterizes an ecological effect appraisal as "the way toward distinguishing, anticipating, assessing and alleviating the biophysical, social, and other important impacts of advancement recommendations before significant choices being taken and responsibilities made [46].

The expanding ecological mindfulness and worries of the soundness of backwoods, natural life variety, biomass efficiency, environment, and the organic sink guides exploration to elective fiber recourses. Yearly plant materials are promising contender for elective lignocellulose fiber composites. A few yearly plant strands like flax, hemp, jute, kenaf, bagasse, corn, and bamboo have been the subject of broad exploration for the production of non-wood molecule and fiberboards [47].

The agro-straw materials are plentiful, modest, and promptly accessible wellsprings of lignocellulose filaments. The fundamental test for board makers is to change over the farming straw materials into molecule sheets medium thickness fiberboards or high-thickness fiberboards in a sound specialized and practical interaction. Various kinds of binder, urea formaldehyde resin urea-formaldehyde tars, and methylene diisocyanate assessed in pilot-scale.

11.1.1. Objectives Of EIA

1. To adopt the best measurable techniques in order to protect the environment from hazardous effluents and those rules meet environmental objectives and there are standards to make the environment clean.
2. To gives the opportunity to the community and the public as appropriate, during the evaluation of recommendations.

3. To boost up the people who are favorable to their environment policy to apply gradual effectiveness in environmental performance and the development of best methods for environmental management.
4. To confirm that before the decision taken advice is provided to the government

A greenhouse gas is a gas which absorbs and transport effective radiant in the infrared radiations range. Ozone depleting cause the adverse impact on roots of the plants. The necessary greenhouse gases are water vapors, carbon dioxide, methane, nitrous oxide, and ozone.

11.2. Pollutants Emissions

E1 outflow class can be accomplished, if the formaldehyde substance having pitch is less 0.2% by mass. Urea formaldehyde saps having more than 0.5% free formaldehyde by mass surpass outflow class E_2, and are not acknowledged. Since the formaldehyde substance of the urea-formaldehyde tar effects the emanation of formaldehyde in the relieved item.

Assuming the urea formaldehyde sap has low fixation, it won't impact the climate then again in the event that the focus has been expanded, it causes certain disease like skin disease, in capacity of breathing, vision and lungs malignant growth.

11.3. Effects On Ecosystem

When urea formaldehyde resin breaks then emits hazardous gases to the environment for example carbon monoxide and formic acid.

Urea formaldehyde may emit formaldehyde which is hazardous for human health due to less water resistance. When the concentration of formaldehyde emission into the air 3.0-5.0 ppm, then its cause increase in cancer risk.

11.4. Product Life Cycle

The purpose of this study is the development high quality information on the process of synthesis fiber board which will affect the environment. The information form the institution of scientific appraisal that are utilized to gives helpful data to addresses the problem by consumers and controllers.

To build up the ecological execution of fiber board, a daily existence cycle stock was done that comprises of a bookkeeping, all things considered, and yields of an item from its assets in the ground through creation alluded to as a support to-item entryway study. The information can be utilized to set up the exhibition of fiberboard for some green kind norms, rules, and approaches. Issues in which the information can be utilized incorporate maintainability, a worldwide temperature alteration, environmental change.

Chapter 12

CONCLUSION

It is stated that fiberboard panels can be produced from agro-industrial waste i.e. Rice husk. As the population of the country increases and the need of materials will also increase so the demand of the fiberboard will be increases in the near future hence large scale production of fiberboard is our main concern. It is economically feasible and less costly than the other method of producing fiberboard panels from wood. This method is suitable is such a way that it eliminates the deforestation for fiberboard production. The fiberboard produced from rice husk has high tensile properties as compared to wood straw.

Manufacturing of green fiberboard from agro-waste is most economical and environmental friendly method. In future need of material will also increases.

The major equipment used for the manufacturing of green fiber board are heat exchanger, helical stirring reactor, decanter centrifuge, shredder, screens, pumps and evaporator. The cost analysis for these equipment's was done effectively. Also impact of the manufacturing process of on the environment.

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