A

PROJECT REPORT

On

“Development of rice straw product

By using mechanical pulping”

Of

MASTER OF TECHNOLOGY

In

PULP AND PAPER TECHNOLOGY

By

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19 May 2019

CANDIDATE DECLARATION

I hereby declare that the work carried out in this dissertation titled **“Development of rice straw product by using mechanical pulping”** is presented on behalf of partial fulfilment of the requirement for the award of the degree of Master of Technology with specialization in Paper Technology, submitted to the Department of Pulp and Paper Technology, Indian Institute of Technology Roorkee, India, under the supervision and guidance of **Dr. S. P. Singh** Pulp and paper department, IIT Roorkee, India.

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This is certifying to that the above statement made by the candidate is correct to the best of my knowledge.

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CERTIFICATE FROM SUPERVISOR

This to certify that the project report entitled "**Development of rice straw product by using mechanical pulping"** submitted to [Department of pulp and paper technology], IIT Roorkee by **HIMANSHU VATS**(Enrolment no.-17546005) in partial fulfillment for the degree of Master of Technology in [Pulp and Paper] IIT Roorkee is a record of bona fide project work carried out by his in the Department of IIT Roorkee, and CPPRI, Saharanpur under our joint supervision and guidance.

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ABSTRACT

The supply of timber has been unable to fulfil the requirements of global demands so it is more necessary to switch toward other alternative raw materials. The agro based residue biomass served the above requirements.

In this study rice straw choose as raw material to convert into a suitable product. The rice straw is one kind of crop residue, which is used as feed for animals, fuel, and fibre. Due to low apparent density and moderate calorific value and high silica content, rice straw left in the field after harvest and open field burning which cause global warming problem. The rice straw having cellulose and hemicellulose, which make the straw products contain acceptable strength properties to make product and replace product made of wood.

The product made by mechanical pulping. The board contain no chemical adhesives, so recovery of chemicals is eliminated which is more difficult due to high silica content in rice straw and does not causes any pollution.

According to result of testing, the rice straw board was made successfully by mechanical pulping. The second objective to enhance the strength of rice straw by blending SW and HW separately without adding any chemicals and these blended, duplex boards are converted into moulded bowl. In this project also work on the comparative study of effect of two pulping variables soaking temperature and disc gap of refiner on the strength index's and % yield.

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ABBREVIATION OF TERMS

S. No.	TERMS	FULL FORM
1.	SW	Softwood
2.	HW	Hardwood
3.	RS	Rice straw
4.	°SR	Degree Schopper Riegler
5.	TI	Tensile index (Nm/g)
6.	BI	Burst index(kPa-m^2/g)
7.	BSI	Bending stiffness index(N-m^7/$kg^{3)}$
8.	OD	Oven dry
9.	TMP	Thermo mechanical pulping
10.	CTMP	Chemi- thermo mechanical pulping
11.	CPPRI	Central pulp and paper research centre

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1.GENERAL INTRODUCTION

1.1 Background:

Rice straw have described some potential uses-

A. Feed

Rice straw is used as feed for animals, but having a problem that is poor digestibility, so it would be treated with NaOH appears to enhance straw digestibility. Despite being a marginal feed, most of the rice straw harvested in 1997 went to animal feed.

B. Fibre

Some of agricultural residues, including rice straw, as a source of non-wood fibres. Rice straw is most suitable for the production of corrugated medium and packing container due to its high bulk; however, the only commercial pulp mills using straw or bagasse exist in developing countries like India and China. But high Silica content create problem in various chemical recovery sections.

C. Fuel

Rice straw can be converted through bioconversion to ethanol, which is a clean-burning transportation-fuel oxygenate. High silica content in rice straw poses problems for both industry and environment. Many researchers have put their efforts to find reliable ways but most are only industry oriented. Bleaching is a crucial step that involves chemical processing which decreases the colour of pulp to make it brighter. Chlorinated compounds were found to exist in the bleaching spent liquors, causing health hazards like liver and kidney damages and hormonal diseases in many aquatic species. Due to such reasons paper and pulp industry switch toward other alternative such as mechanical pulping.

1.2 Objective:

The main objective of this project is beneficial use of rice straw and reducing open field burning to protect the environment problem such as air pollution and global warming apart from that the second objective to enhance the strength of rice straw by blending SW and HW separately without adding any chemicals In this project also work on the comparative study of effect of two pulping variables soaking temperature and disc gap of refiner on the strength index's and % yield.

1.3 Why mechanical pulping:

In rice straw silica content is about 13-20%. Silica is not reacted with any chemicals during pulping. It goes with black liquor in chemical recovery section and create problem such as wear, jamming in evaporator and recovery boiler. Therefore recovery of chemical pulping of rice straw is complicated and costly. So mechanical is best alternative and eco-friendly also.

2. LITERATURE SURVEY

2.1 Introduction:

Worldwide, the forest products industry is a dynamic, vital and growing enterprise. Demand for paper has been forecast to grow by nearly 50% by 2010. This represents a growth rate of 2.8% per year. Demand growth for mechanical wood products is also expected to advance at a rate of 1-2% per year, but raw material (timber) supply for paper making go to decline (8).

Growth in pulp and paper production entails massive felling of trees, which in turn leads to deforestation. Increasing competition for wood supplies coupled with gradually rising costs of wood have generated renewed interest in the use of non-wood plant fibres for papermaking in the highly industrialized countries (13). The use of agricultural-residues in papermaking might be desirable because it averts the need for disposal, which currently increases farming costs and causes environmental deterioration through air pollution and fires, which lead to global warming.

In the given scenario, increasing use of alternative raw materials for pulp and paper manufacture particularly in developing countries could be a remedial solution to the escalating demand for fibrous raw material.

2.2Status of raw materials for paper industry:

Taking 1995 as the base year, world's pulping capacity is projected to increase by 9.2% by the year 2000. The demand for pulp is expected to rise by 4.3% per annum in developing countries as compared to that of 13% per annum in developed countries. On an average, paper consumption in developed countries is 150 kg/person compared to just 12 kg/person in developing countries (12). The per capita consumption of paper and paperboard is bound to rise as economic development continues in the developing countries.

During the last twenty-five years, there has been a great increase in global non-wood pulping capacities. In 1970, non-wood pulp production was only 6.7% of the worldwide pulp production. By 1993, it had risen to 10.5% and is expected to rise to11.3% by the end of 1998 .Because of this increased use andopportunities for further substitution for wood based fibres, it is important to examine the potential benefits and problems associated with the use of non-wood plant fibres in pulp and paper industry(8).

The demand for non-wood plant fibres for papermaking is expected to increase in the highly industrialized nations of Europe and North America due to the above environmental concerns like depleting forest resources and disposal of agricultural residues. This will require knowledge of the processes and developments already in place in the countries already using these raw materials in the paper industry. Already, a number of non-wood fibres are commonly used in many countries for papermaking. Straws are by far the largest source of non-wood fibres followed by bagasse and bamboo.

With the rapid development of the global economy and population growth the average consumption of paper based product increased. The supply of woody raw materials would not be sufficient. Non wood raw material is best alternative. Using non –wood fibre for pulp and paper production has some positive points such as the following:

(i) Reducing wood and pulp imports in countries with deficient wood resources.
(ii) Fulfil the global demand of paper based products economically.
(iii) Affecting the value of some agro based residue thereby increasing the profitability of agrarian holding.

The rice straw was usually disposed of by open field burning it produced visible smoke and responsible for global warming. Asian farmers are responsible for 92% of the world rice production. Recently the rice straw is used as animal feed, fibre suitable for production of corrugated medium, fuel such as bioethanol.

Worldwide rice straw is most important agriculture product, every year 600 million tons rice straw is produced. Traditionally it is dispose by open field burning, this practice responsible for air pollution, white smoke, soil pollution and global warming.

This project is concern to manufacturing a suitable product of rice straw by mechanical actions, which are cutting, soaking, refining, forming and drying. In the above process no chemicals involve so it not causes any pollution in the environment.

2.3 Refiner Mechanical pulping:

In the production of mechanical pulp, chips fed in to a refiner are broken down into randomly oriented matchstick-like particles with circulation in the refiner zone. The fibres mostly located tangentially on the refiner bars moves outwards. If the fibres are shorter than the width of the grooves, they will tend to be in the grooves causing a considerable fractionation of the pulp.

Preheating: Found that preheating is not too important but temperature in refining is soft the fibres and lignin present in the fibre, so fibrillation become easy and increases fibre length and strength.

Plate gap: The average power consumption is increase if the disc gap is reduced (If the feed rate remains constant) this increases the specific energy. It also increases refining intensity (14).

3.EXPERIMENTAL WORK DETAIL

3.1 Raw material analysis:

- 3.1(a) Extractive content is calculated by socxlet apparatus using solvent, mixture of ethanol and toluene in 1:2, at 70 ºC for 5 hours.
- 3.1(b) Lignin content is calculated by taking 1g OD extractive free raw material is treated with 15 ml,72% w/w sulfuric acid by magnetic stirrer at 90 ºC for 4 hours. Allow the insoluble material (lignin) to settle down. Separate the lignin by vacuum filtration.

Figure 1: Vacuum filtration

3.1 © For Calculating the holocellulose for which 5g OD extractive free raw material in Erlenmeyer flask is dissolved in 150ml solution containing in which 1.5g sodium chlorite and 10 drops of acetic acid is added after each hour for 3 hours. The flask is loosely covered and is put in a thermostat regulated at 70 ºC.

Figure 2 :Holocellulose determination.

- 3.1(d) Ash content is calculated for which 3g OD is placed in furnace at 575 ºC for 7 hours.

Figure 3 :Ash content determination.

3.2 Boards formation:

After harvesting the rice straw was stored for making pulp. The flowchart shown in fig: 4, is the whole process of making the paper board. Firstly rice straw is cut into small pieces by ordinary cutter than soaking into water such that bath ratio 1:10, for 3 hours. This slurry of rice straw is refined in Sprout Waldron refiner. Hand sheets are formed by following TAPPI T 205, than pressing at 50 psi for 5 min lastly air dried for 24 hours.Using the above procedure made rice straw 300 GSM board, 300 GSM softwood triple layer board and combined board.

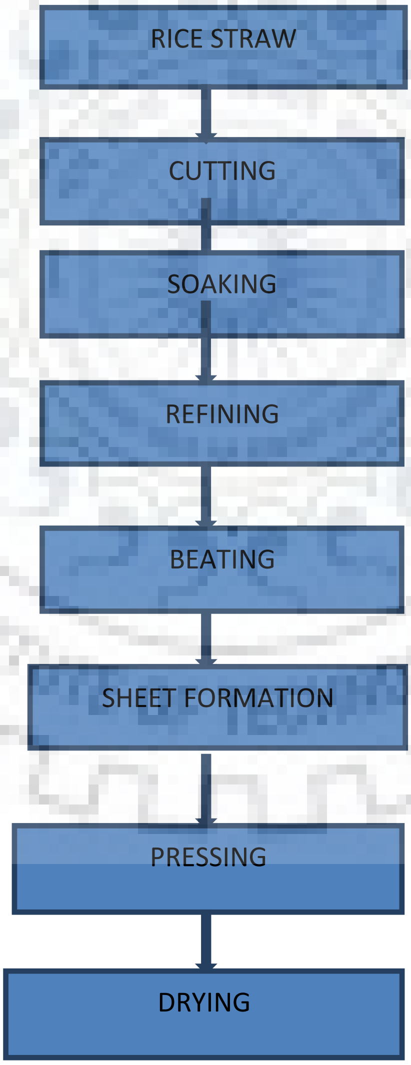

Figure 4 : Boards formation process.

3.3Boards testing:

The rice straw boards are complex non homogeneous material so that the mechanical properties of rice straw boards must be calculated very carefully. Boards testing are carried out in the humidity chamber in which 25 ºC and 65% relative humidity. The average value of tensile index (T 494 om-01), burst index (T 403 om-15), bending stiffness index (T 489 om-08) calculated.

4.RESULTS

4.1 Composition of rice straw (w/w):

Table 1: Composition of rice straw

S.No.	Constituent	% Average value
1.	Extractive	5
2.	Lignin	15.87
3.	Holocellulose	63.52
4.	Ash	16.47

4.2 mechanical pulping results:

% Moisture content of rice straw= 13.88%

Soaking of rice straw.

OD weight=250 g

Bath ratio=1:12

Temp=80, 90, 110 °C.

Time=3 hours.

Mechanical pulping is done in CPPRI by using Sprout Waldron refiner in two cycles at 20&10 thou and 15&8 thou.

Squeeze the pulp and store it

% yield, energy consumption and °SR of samples are calculated and reported in table No: 8.

4.3BOARDS TESTING RESULTS:

Table 2: Soaking temp=80℃, disc gap= 20, 10 thou (RS, °SR=12) Comparison of properties of boards

S. No.	Properties	Rice straw Board	SW+RS Blend Board	HW+RS Blend Board
1.	GSM	365	326	335
2.	Thickness(mm)	0.890	0.590	0.640
3.	Bulk(cm^3/g)	2.438	1.809	1.910
4.	Tensile index(N-m/g)	8.990	22.632	17.970
5.	Burst index (KPa-m^2/g)	0.396	1.344	1.406
6.	Bending stiffness index (N-m7/Kg^3)	0.410	0.595	0.536

Table 3 : - Soaking temp=90℃, disc gap= 20, 10 thou (RS, °SR= 14) Comparison of properties of boards

S. No.	Properties	Rice straw board	SW+RS Blend Board	HW+RS Blend Board
1.	GSM	347.5	328.5	340
2.	Thickness (mm)	0.865	0.610	0.670
3.	Bulk (cm^3/g)	2.489	1.856	1.971
4.	Tensile index (N-m/g)	9.162	24.520	20.240
5.	Burst index ($KPa-m^2/g$)	0.298	1.512	1.127
6.	Bending stiffness index($N-m7/Kg^3$)	0.420	0.640	0.5627

Table 4 : Soaking temp= 110℃, dics gap 20, 10 thou RS (°SR= 20) comparison of boards

S. No.	Properties	RS Board	SW+RS Blend Board	HW+RS Blend Board
1.	GSM	310	355	362
2.	Thickness (mm)	0.860	0.650	0.685
3.	Bulk (cm^3/g)	2.774	1.830	1.892
4.	Tensile index (N-m/g)	11.870	25.850	21.860
5.	Burst index ($KPa\text{-}m^2/g$)	0.159	1.822	1.221
6.	Bending stiffness index($N\text{-}m7/Kg^3$)	0.479	0.704	0.661

Table 5 : Soaking temp=80℃, disc gap= 15& 8 thou (RS, °SR= 34) Comparison of properties of boards

S.No	Properties	RS Board	SW+RS		HW+RS	
			Duplex	**Blend**	**Duplex**	**Blend**
1.	GSM	326	320	305	338	314
2.	Thickness (mm)	0.785	0.581	0.540	0.740	0.560
3.	Bulk (cm^3/g)	2.407	1.814	1.770	2.180	1.783
4.	Tensile index (N-m/g)	10.775	26.570	23.790	20.260	16.920
5.	Burst index (KPa-m^2/g)	0.450	2.257	2.136	1.352	1.034
6.	Bending stiffness index(N-m7/Kg^3)	0.304	1.107	0.347	0.741	0.333

Table 6 : Soaking temp=90℃, disc gap= 15& 8 thou (RS, °SR= 37) Comparison of properties of boards

S.No	Properties	RS Board	SW+RS		HW+RS	
			Duplex	**Blend**	**Duplex**	**Blend**
1.	GSM	306	300	307.3	325	292
2.	Thickness (mm)	0.740	0.560	0.585	0.620	0.570
3.	Bulk (cm^3/g)	2.423	1.866	1.903	1.907	1.952
4.	Tensile index (N-m/g)	11.010	31.230	25.310	22.030	21.520
5.	Burst index ($KPa\text{-}m^2/g$)	0.384	2.337	1.994	1.407	1.263
6.	Bending stiffness index($N\text{-}m7/Kg^3$)	0.603	1.073	0.623	1.085	0.522

Table 7: Soaking temp=110℃, disc gap= 15& 8 thou (RS, °SR= 44) Comparison of properties of boards

S.No	Properties	RS Board	SW+RS		HW+RS	
			Duplex	**Blend**	**Duplex**	**Blend**
1.	GSM	368	342.5	356	335	335.5
2.	Thickness (mm)	0.870	0.585	0.660	0.580	0.660
3.	Bulk (cm^3/g)	2.364	1.708	1.854	1.752	1.967
4.	Tensile index (N-m/g)	12.320	37.523	29.870	25.693	22.56
5.	Burst index ($KPa\text{-}m^2/g$)	0.533	2.400	1.935	1.346	1.318
6.	Bending stiffness index($N\text{-}m7/Kg^3$)	0.581	1.183	0.887	0.926	0.832

Table 8: Process outcome Vs process variable

S. No	Process Outcome	Disc Gap 20-10 thou			Disc Gap 15-8thou		
		80 ℃	**90** ℃	**110** ℃	**80** ℃	**90** ℃	**110** ℃
1.	**% Yield**	73.40	69.64	66	74.57	72.47	71.55
2.	**Refiner energy consumptions per 250 g OD pulp in Kwh**	1.5	1	0.9	1.6	1.1	1.2

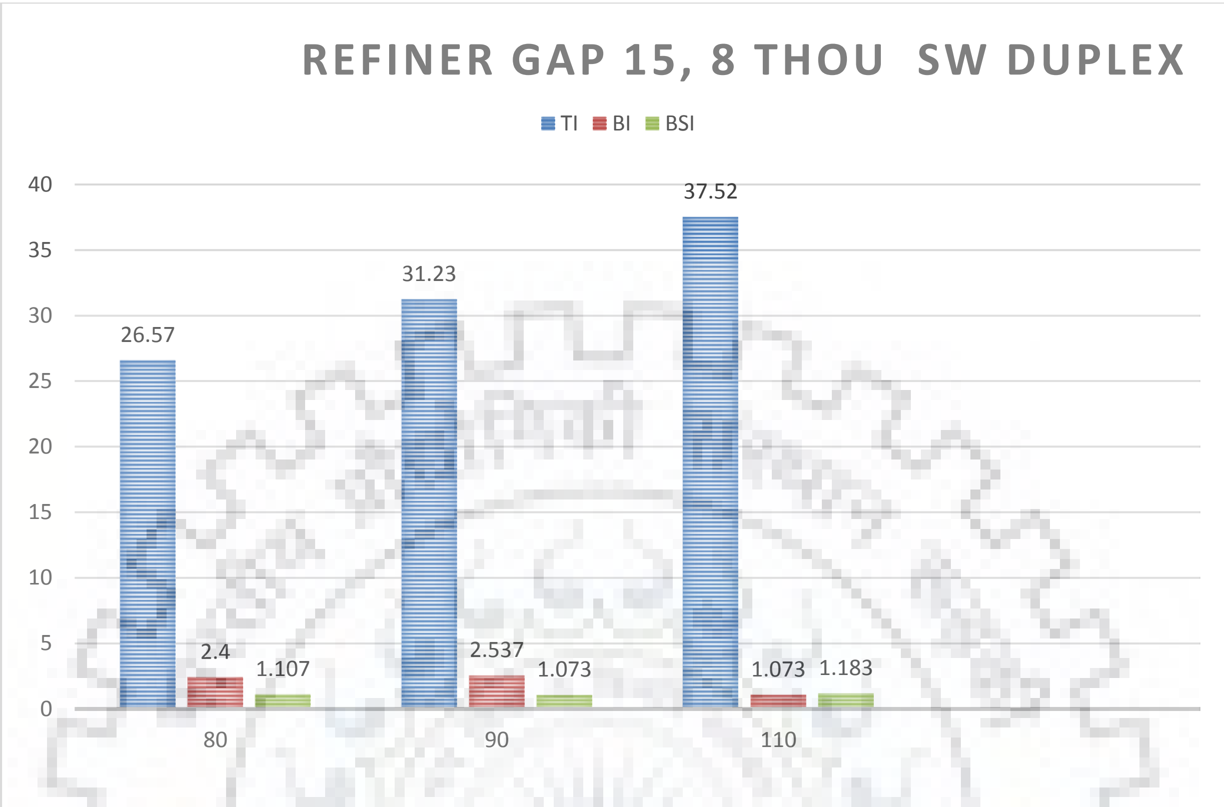

Figure 5: Strength index Vs temp of SW duplex board at plates gap 15, 8 thou

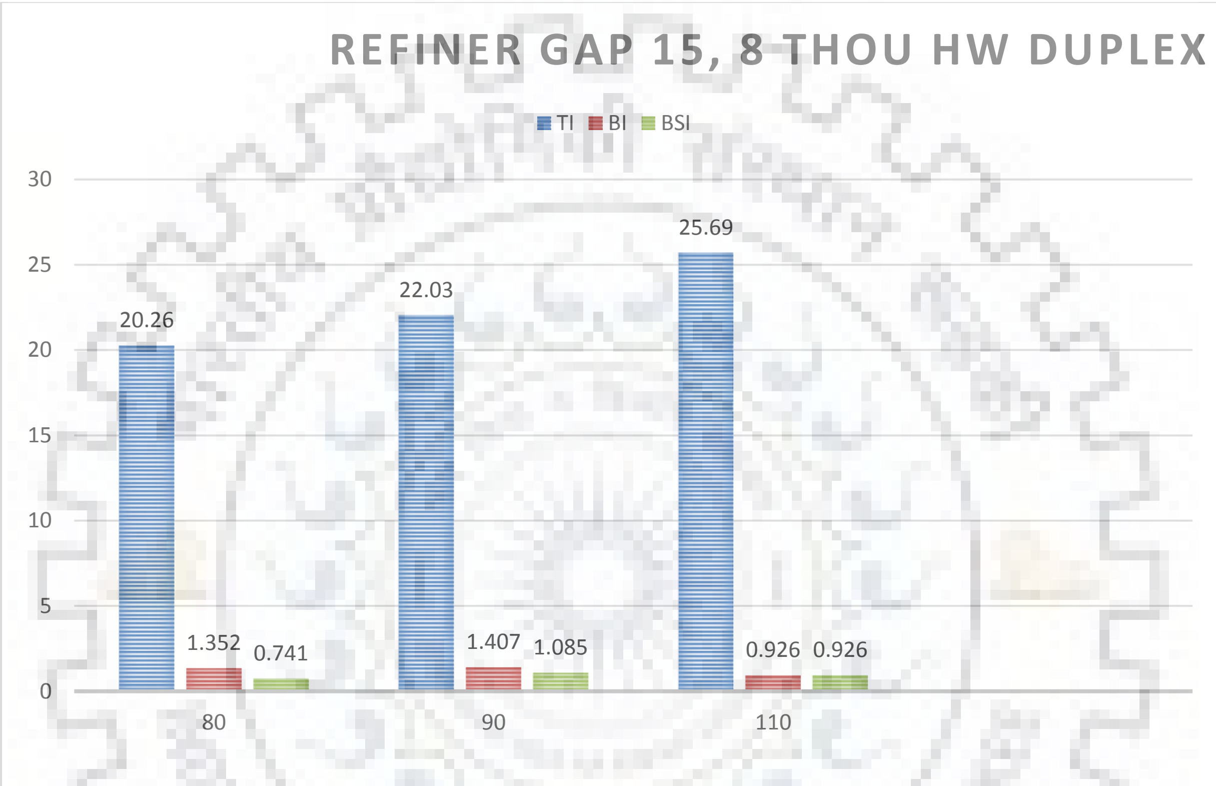

Figure 6: Strength index Vs temp of HW duplex board at plates gap 15, 8 thou

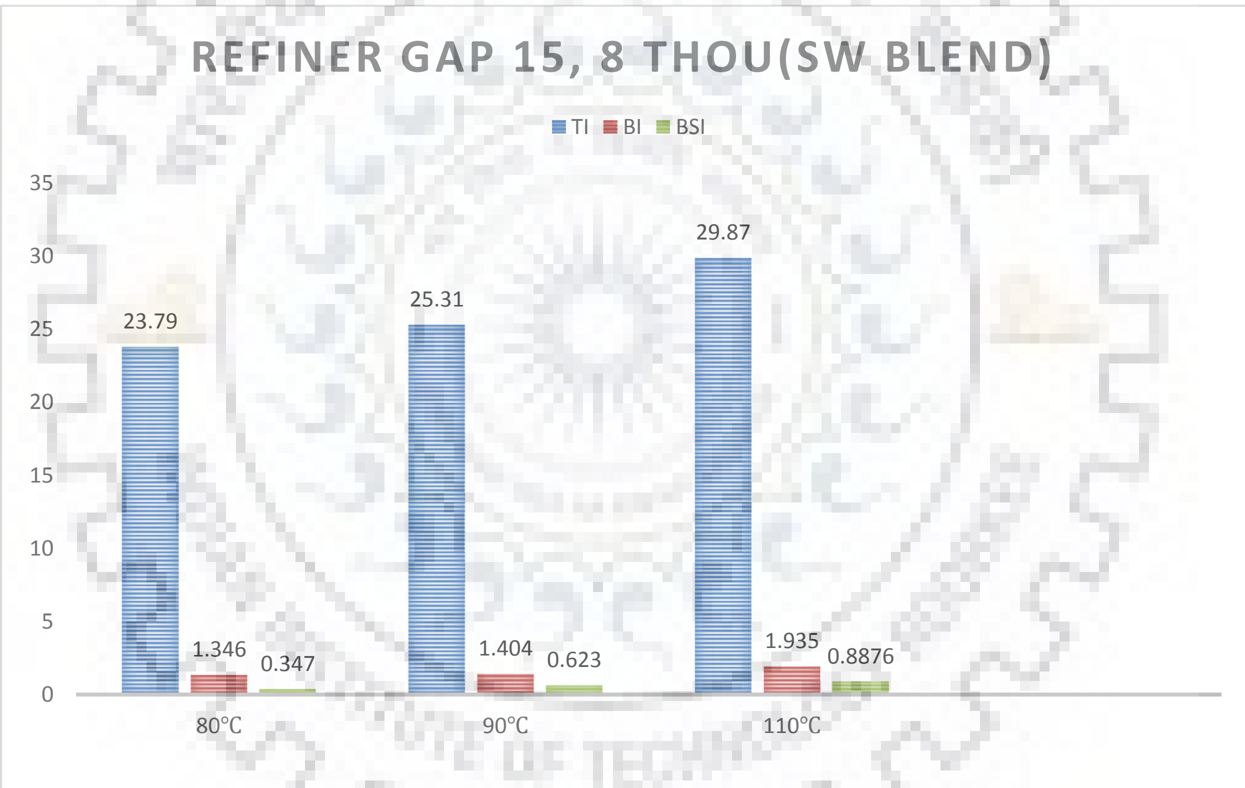

Figure 7 : Strength index Vs temp of SW blend board at plates gap 15, 8 thou

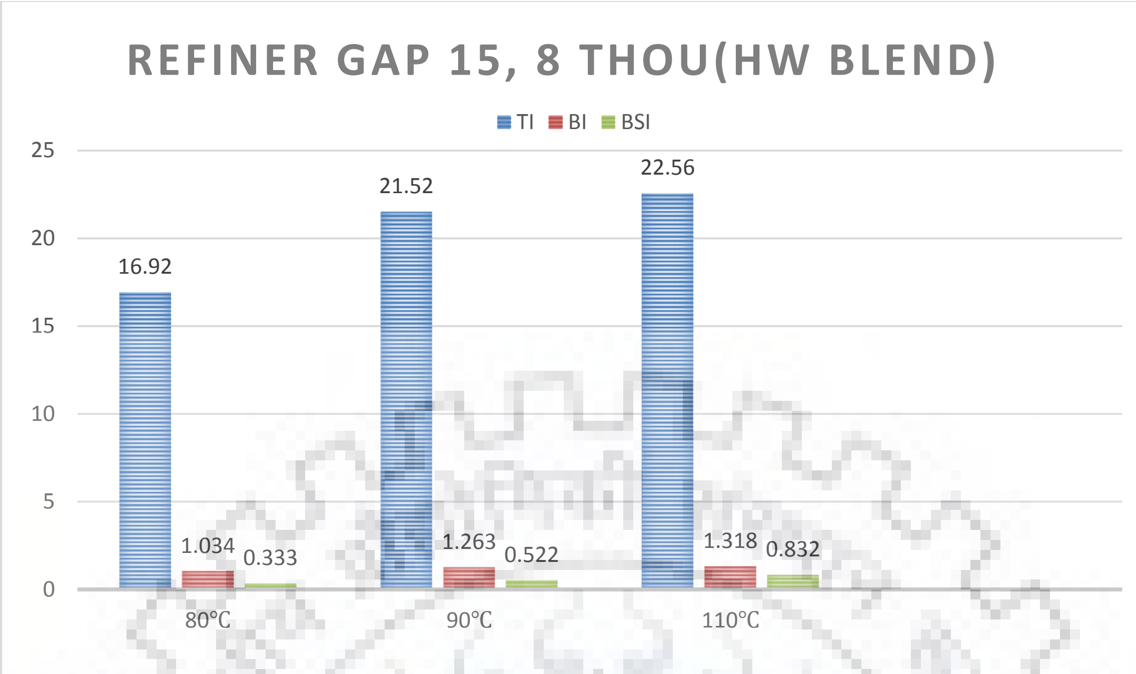

Figure 8 : Strength index Vs temp of HW blend board atplates gap 15, 8 thou

℃

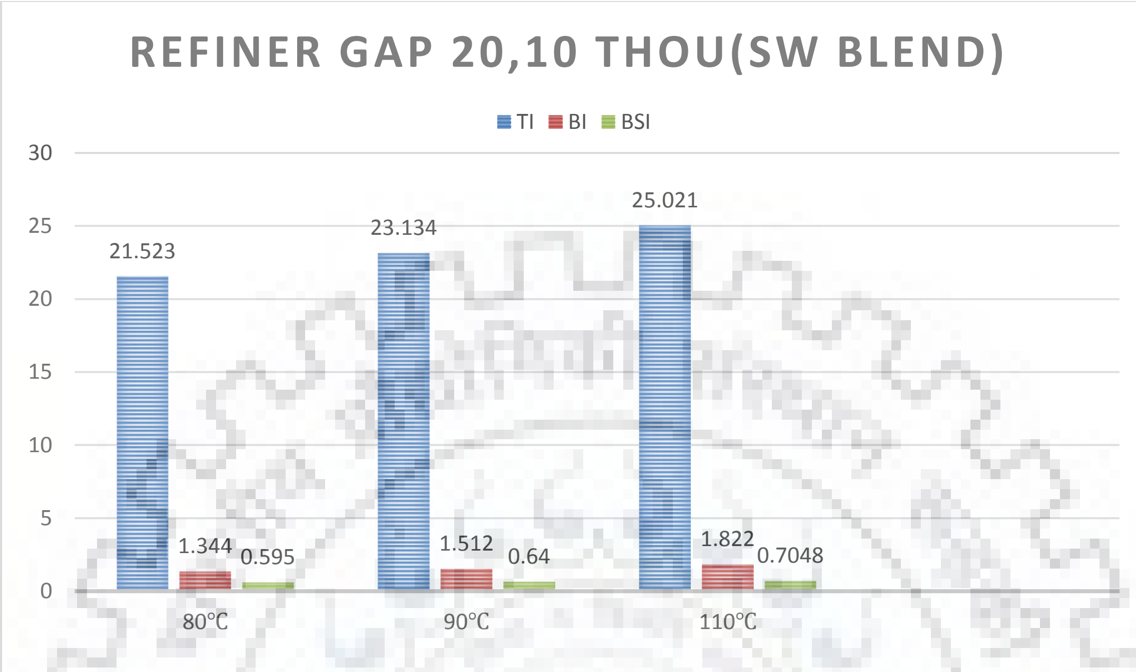

Figure 9: Strength index Vs temp of SW blend board at plates gap 20,10 thou

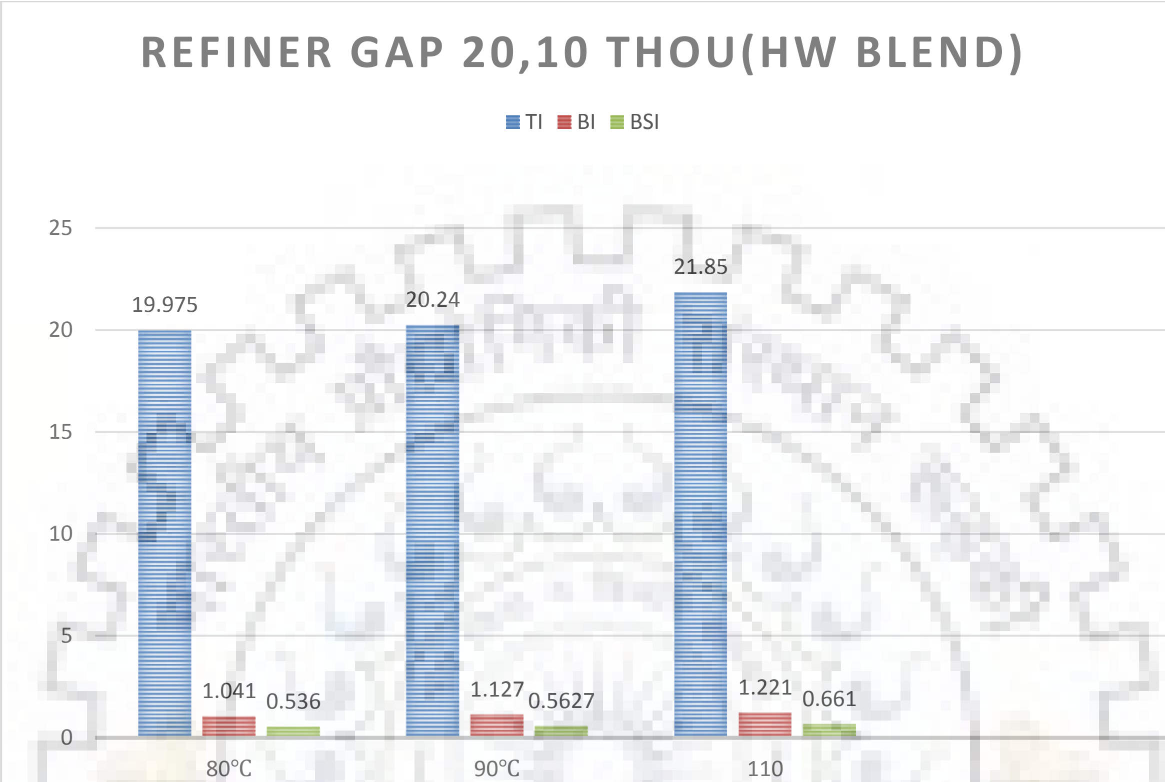

Figure 10 : Strength index Vs temp of HW blend board at plates gap 20,10 thou

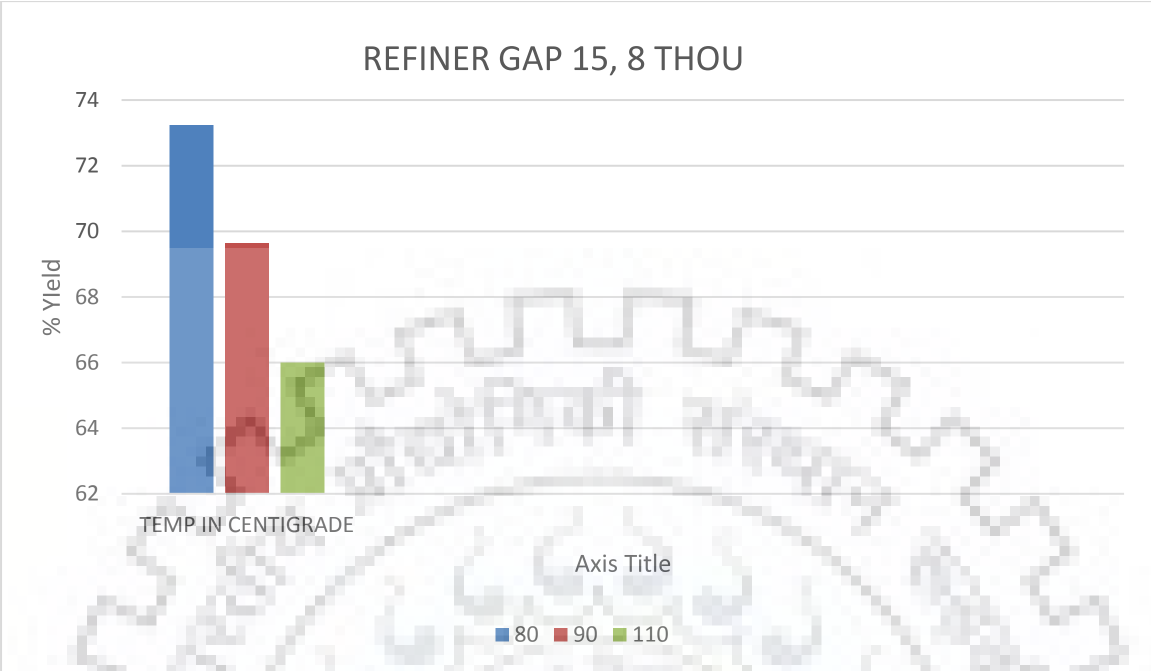

Figure 11: Effect of soaking temperature on % yield at 15, 8 thou.

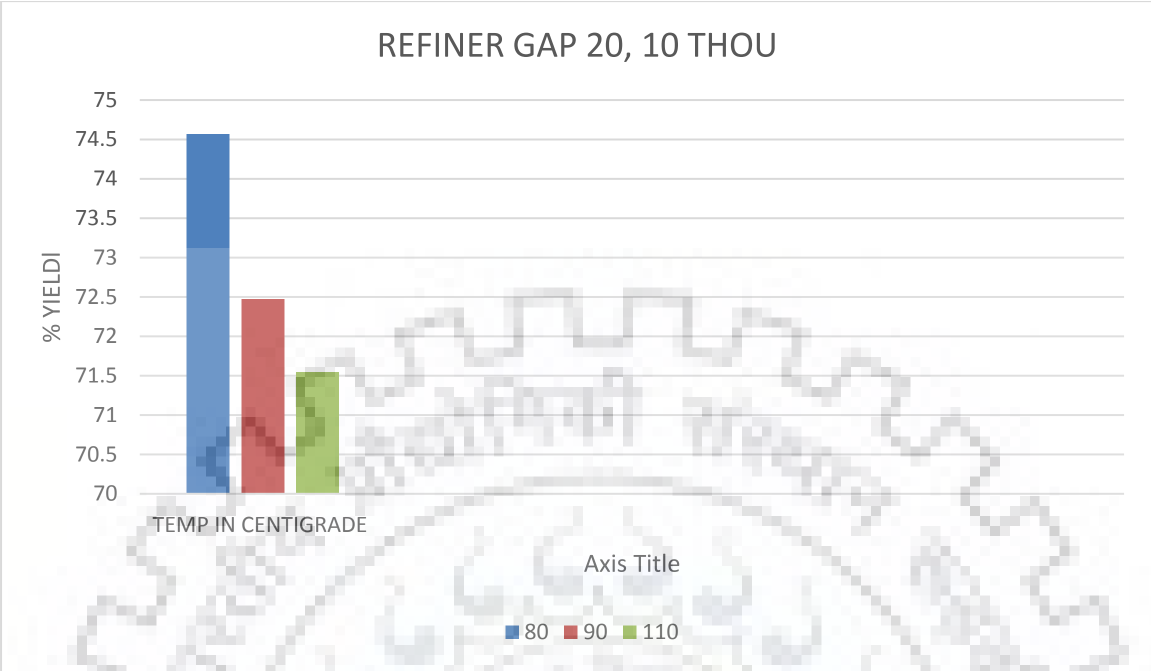

Figure 12: Effect of soaking temperature on % yield at 20, 10 thou

5. COMPARASION WITH YASH PAPER PRODUCT:

Unbleached agro pulp (°SR=32) molded bowl

Cost= 4.4 Rs per piece

Capacity= 180 mL

GSM= 355

Tensile Index= 31.26 N-m/g

Burst index= 2.67 KPa-m²/g

Bending stiffness index= 2.90 N-m7/Kg³

Table 9: Comparison with Yash paper product

S. No.	Properties	Yash Paper Bowl	SW+RS duplex board at 15, 8 thou	
			Soaking at 90 °C	Soaking at 110 °C
1.	GSM	355	300	342.5
2.	Tensile index (N-m/g)	31.26	31.23	37.52
3.	Burst index (KPa-m²/g)	2.67	2.257	2.537
4.	Bending stiffness index(N-m7/Kg³)	2.90	1.073	1.183

6. CONCLUSION:

In this project, board was made using rice straw by mechanical pulping. It should be concluded as follows:

1. The rice straw board is making successfully using the following method. The manufacturing consisting of cutting, soaking, refining, beating, forming, pressing and drying. Mechanical method adopted in the refining process of rice straw, therefore the straw pulp is mechanical pulp. No chemical compound involve though out the process. The board made in this method is biodegradable and environment friendly.
2. Chemical recovery process is completely eliminated.
3. Rice straw is converted in board by which is moulded bowlis made. So open field burning of rice straw is reduced.
4. Bowl made by hand pressing having better formation than pressing in hydraulic press.
5. With the help of softwood blending in rice straw , the bending stiffness index increases 2 times, burst index increases 5.33 times and tensile index increases 3 times.
6. Strength properties of boards are increase by increasing soaking temperature of rice straw but % yield is decrease.
7. Strength properties of boards are increase by reducing gap between the refiner plates within a range.
8. Duplex board have superior bending stiffness index, tensile index and burst index than blend board.
9. SW+RS duplex board at disc gap 15, 8thou and soaking temperature have strength index's values close to the Yash paper bowl index's values.

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