Optimization of Fibre Properties Using Single Pass Refining vs Recirculation A Case Study

Chechi Sanjay, Singh Akansha, Srivasta Rajeev, Shukla Shankarshan & Agarwal Narendra

Singh Akansha

ABSTRACT

At Yash Papers Refining is used to modify the pulp fibers to impart them the appropriate characterstics for papermaking. It is the most important aspect of the process, as the cellulosic fiber are modified suitably to bind properly during the formation of paper web resulting in desired structural, optical and chemical properties. This study is directed to analyze effects of refining intensity on pulp and paper properties produced from a mix furnish of bagasse and softwood. The softwood was continuously re-circulated in refiners for hours to achieve higher ^{0}SR and for development of fiber properties. Longer cycle time for refining with recirculation was also leading to shortage of imported pulp as a mix with bagasse pulp at machines. In this continuous recirculation process fiber is damaged drastically in spite of higher power consumptions and not resulting into desired property levels.

This paper describes about the best practices to meet the requirement of pulp and paper properties. The lab scale and plant scale experiments were conducted by using single pass refining and results were compared refining with recirculation. Based on encouraging results the single pass refining was optimized for parameters i.e flow, consistency etc. It is clear from the results that lower consistency refining gives better results at lower flow rates. The results obtained using single pass refining resulted in better strength properties as compared to recirculation even at lower SR levels. This has also resulted into lesser refining energy consumption by meeting pulp demand with reduction in production cost. The imported pulp properties enhancement has also supported in development of new higher value added grades.

INTRODUCTION

This study was conducted in order to enhance the value added segment of our product basket. We targeted to make a paper with higher strength properties within the limited resources available by modifying the long fiber content& process optimization. But, we observed the limitation in increasing the long fiber content due to recirulated refining of the long fiber at the existing situation. The best way to do this was to optimize the process and refining condition.

Yash Papers Ltd; Yash Nagar, Faizabad - 208001 (U.P.)

Refining plays a very important role in improving the strength of the fibers.

The aim of present study was to optimize the refiner conditions in order to enhance the fiber strength properties. This case study deals with two types of refining conditions

1. Recirculation

The pulp slurry is continuously recirculated in the refiner in order to get the desired freeness levels.

2. Single Pass Refining

The pulp slurry is passed through the refiner just once and then to the final chest Irrespective of freeness levels.

This paper deals with gain in fiber strength properties through Single Pass Refining. The freeness of the pulp decrease in two conditions-

1. **Fibrillation**
2. **Cutting**

In case of fibrillation the bonding between the fiber is increased which result in the fall of freeness. Similarly, if cutting action of the fiber takes place, it also results in the fall of freeness.

In order to get better fiber strength properties fibrillation is required not cutting action.

In the process of refining, fibers are trapped in the gaps between the bars crossing where they are subjected to cyclic compression and shear forces which modify the fiber properties. The main target of refining is to modify surface characteristics as well as fiber flexibility in order to develop stronger and smoother paper with good printing properties. In addition sometimes, the purpose is to develop other pulp properties such as absorbency, porosity or visual appearance.

Paper is a tangled web of fibers. The fibers are more or less lying in a flat plane and they are attached to one another at many points of contacts that occurs where one fiber lies across another fiber. The strength of paper is largely determined by the strength of attachment at these fiber crossing points. While it is true that strength of the individual fiber can also be a factor in determining the strength of the resulting paper, it is often the case that paper fails when the fiber-fiber bond fails.

The linkage that occur at the fiber crossing points of paper is made up of hydrogen bonds which are formed between corresponding points on two cellulose or hemicellulose molecules when interconnecting water molecule is removed by drying. Anything that can increase the number of hydrogen bond engaged at a crossing points will increase the strength of the linkage and thus the strength of the paper.

The principle objective of refining thus-

1. To increase the flexibility of cell wall to promote increased contact area.

2. To fibrillate the external surface of the surface of the fiber to further promote the formation of hydrogen bonds and increase the total surface area available for bonding.

Figure 3: Refining Process Overview

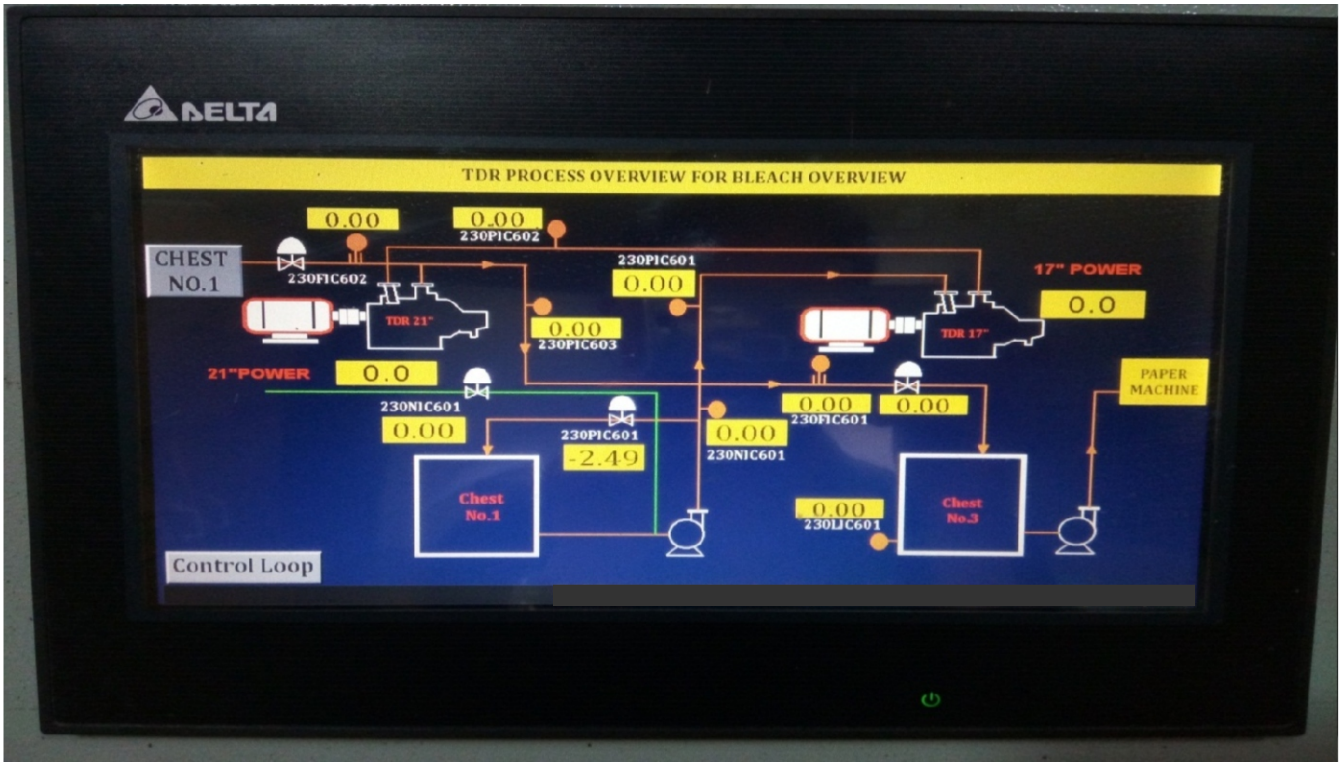
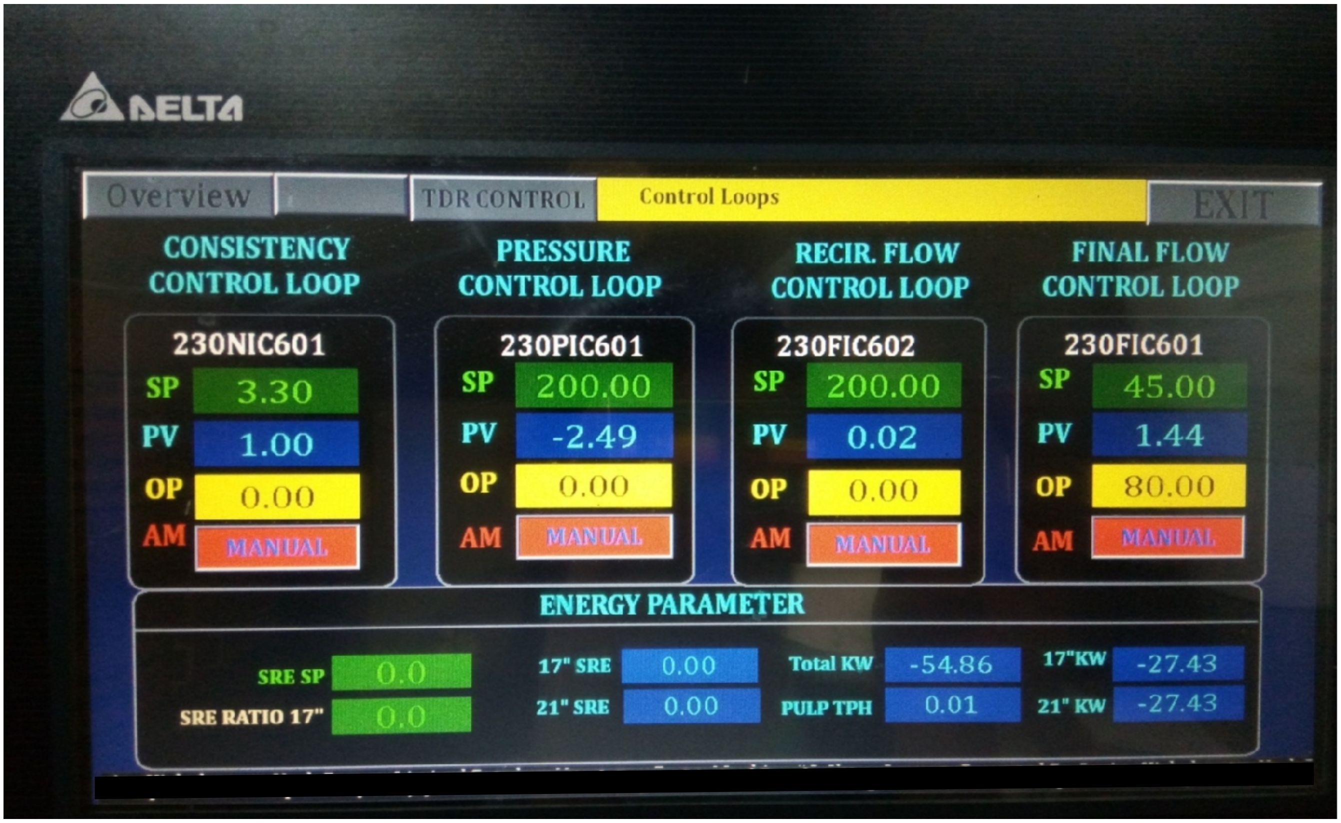


Figure 4: Control Loop



Automation and Control strategy

Instrumentation plays very important role in optimization of any process. Before starting the trial for optimization of refining process the following instruments and measurements were ensured in refining street

1. Pulp flow transmitter
2. Stock consistency transmitter and controller
3. Pressure transmitter
4. Refining Load

All the instruments were commissioned and calibrated to ensure reliability of results during trial.A centralized PLC control panel was also installed for proper monitoring and controlling of process parameters (Figure 3 & 4).

Hand sheet formation and Testing

60 GSM pulp hand sheets were prepared in the British Standard laboratory Hand sheet making machine, followed by pressing and drying. The hand sheets were conditioned at 65% relative humidity, at 27^{0}C for 4 hrs and then tested for physical properties using standard methods.

Analytical Techniques

Handsheets for physical strength testing were tested according to Tappi Test Method T 220 om-88

Grammage of handsheets was measured as per Tappi Test Method T 410 om-02

Burst Factor of handsheets was measured as per Tappi test Method T403 om-02

Tear Factor of handsheets was measured as per Tappi Test Method T 414 om-98

Experimental Work

Trial 1 (Consistency Optimization)

Trials were taken at different consistency of pulp in a series refiner of 17" followed by 21" refiner. Consistency optimization is important as

1. It increases the probability of fiber mat formation.
2. Fiber strength potential is maximized.
3. Plate life potential is maximized.
4. Variation is minimized.

Readings were taken at a constant flow of 50 m3/hr(Table 1)

Observations

1. The Burst Factor increases by decreasing the consistency of Pulp.
2. The tear factor also observed retained along with best achieved burst

Trial 2 (Flow Optimization)

Hydraulics is important while the optimizing the refiner

Table 1: Effect of Refining consistency on physical pulp properties

Consistency %	4.5	4.2	3.9	3.5	3.3
Burst Factor	29.4	26	24.4	22.9	35.8
Tear Factor	196.9	185.0	187.5	191.9	190.4

1. Rotor is stable and centered
2. Increases probability of fiber mat formation
3. Fiber strength development potential is maximized
4. Plate life potential is maximized
5. Variation is minimized

The pulp slurry of different consistency was refined at different flow rates. (Table 2A-2E)

Table 2A: Effect of varying flow @ 3.3 % consistency

Flow	Initial	20 m^3/hr After 21" Refiner	30 m^3/hr After 21" Refiner	40 m^3/hr After 21" Refiner	50 m^3/hr After 21" Refiner
MT/Hr		0.66	0.9	1.3	1.6
Burst Factor	11.8	42.9	39.6	37	35.8
Tear Factor	150.4	173.7	200	168.6	168.1
Refiner Load 21"/17" (Amp)	180/160	90/91	120/122	160/155	180/163
Pressure (kg/cm2)	1.1	2.8	2.4	2.1	1.9

Table 2B: Effect of varying flow @ 3.7 % consistency

Flow	Initial	20 m^3/hr After 21" Refiner	30 m^3/hr After 21" Refiner	40 m^3/hr After 21" Refiner	50 m^3/hr After 21" Refiner
MT/Hr		0.7	1.1	1.5	1.9
Burst Factor	9.2	36.3	33.8	31	22.9
Tear Factor	101.4	204.7	206.3	191.9	173.2
Refiner Load 21"/17" (Amp)	180/160	85/92	120/126	165/136	170/160
Pressure (kg/cm2)	1.2	2.5	2.3	1.9	1.8

Table 2C: Effect of varying flow @ 3.9 % consistency

Flow	Initial	20 m^3/hr After 21" Refiner	30 m^3/hr After 21" Refiner	40 m^3/hr After 21" Refiner	50 m^3/hr After 21" Refiner
MT/Hr		0.8	1.2	1.6	2.0
Burst Factor	9.9	33.1	28.6	27.6	24.4
Tear Factor	91.2	239.4	202.8	187.3	178.5
Refiner Load 21"/17" (Amp)	180/160	82/90	107/100	133/125	150/160
Pressure (kg/cm2)	1.1	2.8	2.4	2.1	1.9

Table 2D: Effect of varying flow @ 4.1 % consistency

Flow	Initial	20 m^3/hr After 21" Refiner	30 m^3/hr After 21" Refiner	40 m^3/hr After 21" Refiner	50 m^3/hr After 21" Refiner
MT/Hr		0.8	1.2	1.6	2.1
Burst Factor	10.7	35.3	34.6	32	26.0
Tear Factor	105.4	200	192.6	176.2	157.5
Refiner Load 21"/17" (Amp)	180/160	100/104	120/126	130/132	140/137
Pressure (kg/cm2)	1.2	2.4	1.9	1.8	1.5

Table 2E: Effect of varying flow @ 4.5 % consistency

Flow	Initial	20 m^3/hr After 21" Refiner	30 m^3/hr After 21" Refiner	40 m^3/hr After 21" Refiner	50 m^3/hr After 21" Refiner
MT/Hr		0.9	1.4	1.8	2.3
Burst Factor	9.7	31.7	30.3	29.4	25.6
Tear Factor	106.2	191.5	213.3	196.9	154.3
Refiner Load 21"/17" (Amp)	180/160	180/100	120/124	135/137	140/136
Pressure (kg/cm2)	1.1	1.1	2.1	1.8	1.5

Trial 3 (Long Fiber Grade Optimization)

In this study the grades& sources of the long fibers were changed and the properties were analyzed by keeping the flow and consistency constant for each grade. The three grades of long fibers of different origin were taken into consideration and there burst factors were compared (Table 3A-3C)

Table 3A: Effect of species and flow @ 3.3 % consistency

Flow (m^3/hr)	Grade 1	Grade 2	Grade 3
20	44.7	35.2	70.5
30	41.2	33.4	54.8
40	39.0	32.1	53.1

Table 3B: Effect of species and flow @ 3.9 % consistency

Flow (m^3/hr)	Grade 1	Grade 2	Grade 3
20	32.1	36.3	68.4
30	30.6	33.9	50.7
40	29.6	32.2	39.2

Table 3C: Effect of species and flow @ 4.2 % consistency

Flow (m^3/hr)	Grade 1	Grade 2	Grade 3
20	34.0	35.0	66.1
30	36.6	30.6	50.8
40	37.7	28.4	42.5

a. Grade 1
b. Grade 2 and
c. Grade 3

Figure 1A: Effect of consistency on burst @ 20 m^3/hr

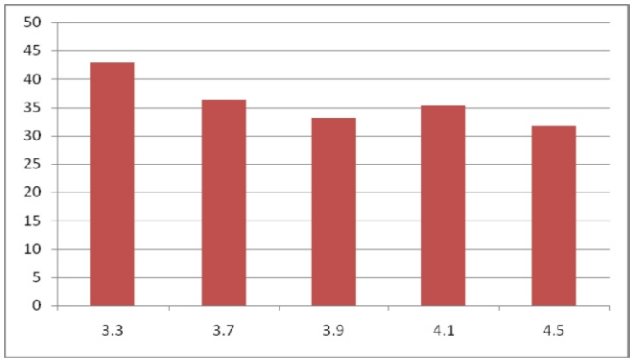


Figure 1B: Effect of consistency on burst @ 30 m^3/hr

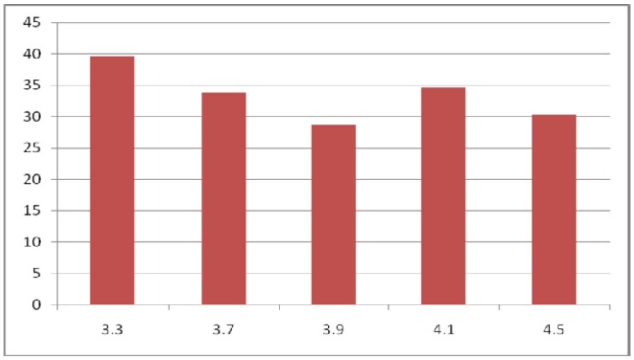


Figure 1C: Effect of consistency on burst @ 40 m^3/hr

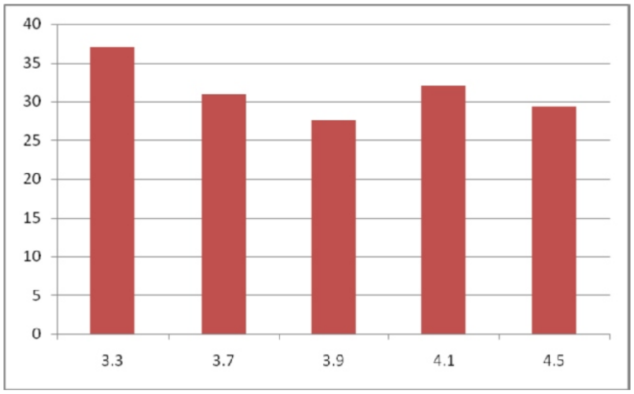
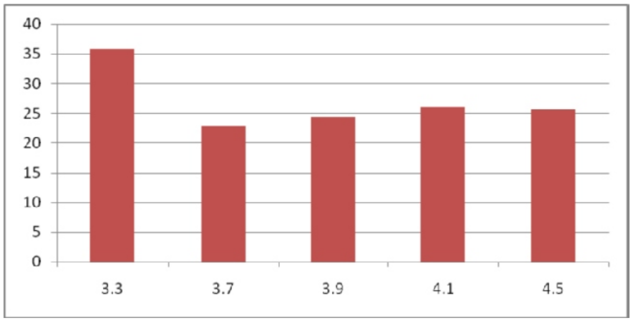


Figure 1D: Effect of consistency on burst @ 50 m^3/hr



Results and Discussion

1. At any particular consistency strength property is increasing with reduced flow rate level.As we reduce the flow rate, retention time in the refiner is increased which results in better treatment of individual fiber

2. At any particular flow rate, it is observed that with decreasing stock consistency strength properties is best achieved (Figure 1A-1D). As mentioned in the previous point that decreasing the flow increases the retention time and hence at a lower flow rate, decreasing the consistency reduces the amount of fiber entering the refiner which results in increased and proper refining of the fiber

3. Grade 3 of long fiber shows better strength properties as compared to other two grades. This can be due to difference in the inherent fiber characteristics of softwood species& intensity of refining impact on this particular species (Figure 2A-2C)

4. This study has also resulted into easier selection of softwood pulp grade a per final product properties requirement

Cost Benefit

1. By using single pass refining we achieved a reduction of 1% long fibers in the papermaking resulting in a saving of Rs. 1.18 Crore p.a (Table 4)

2. The energy consumption has been decreased in single pass refining as compared to recirculation (Table 5A-5C)

3. The paper produced through single pass refining shows better strength properties as compared to recirculation.

4. The paper thus produced added value by increased NSR

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Figure 2A: Effect of species & flow on burst @ 3.3% consistency

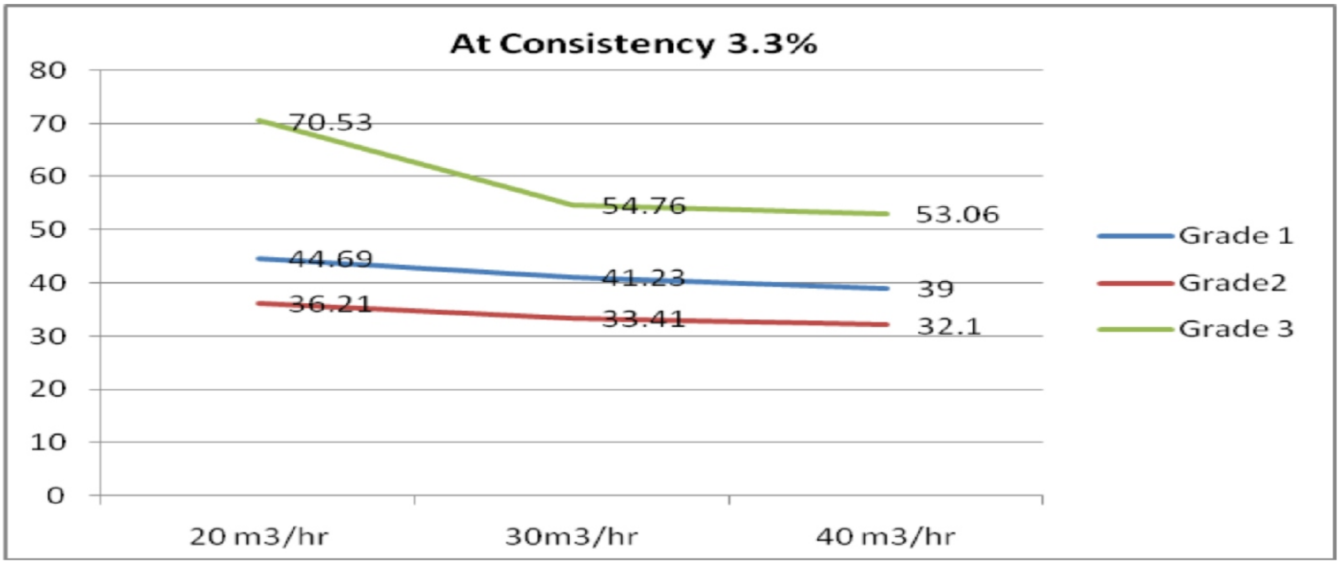

Figure 2B: Effect of species & flow on burst @ 3.9% consistency

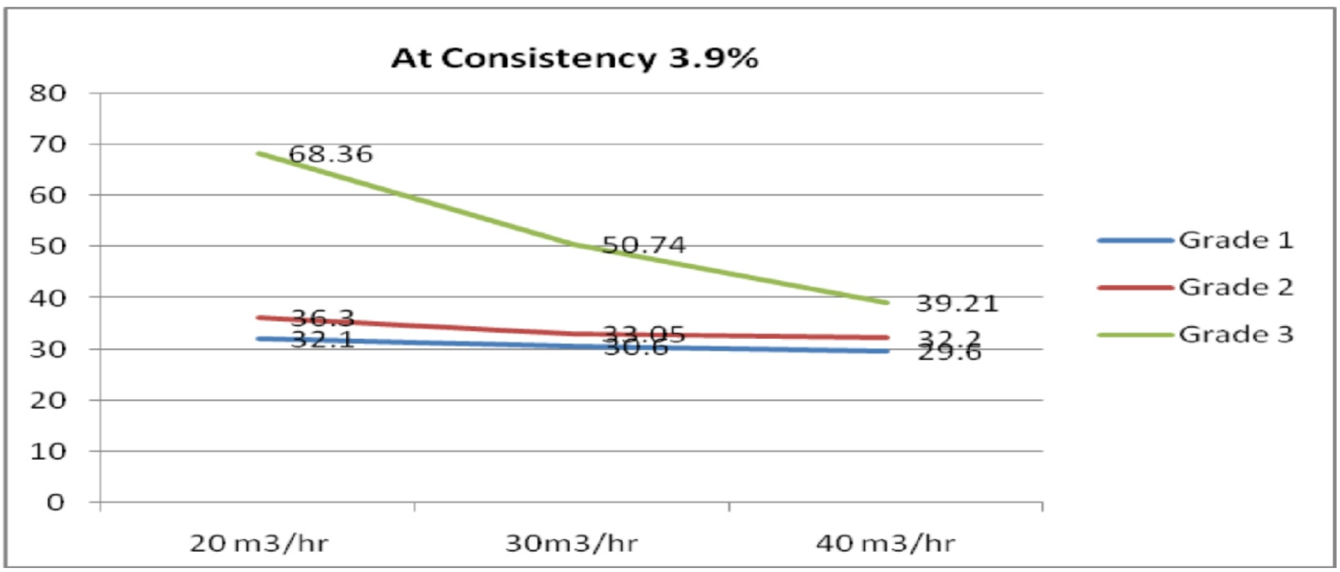

Figure 2C: Effect of species & flow on burst @ 3.3% consistency

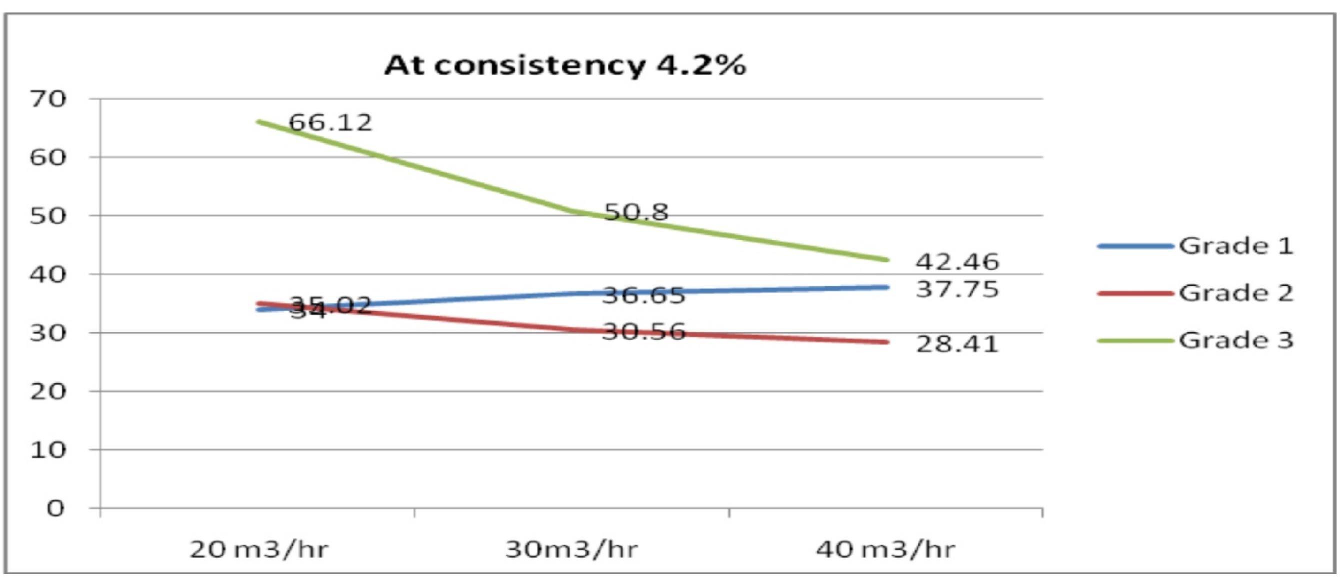

Table 4: Cost Benefit by Softwood Reduction

S.No.	Parameters	September (1-30)	October (1-30)
		with circulation	Single pass
1	Softwood	15%	14%
2	Bagasse Tear	42.0	41.6
3	Bagasse Burst Factor	16.07	15.82
4	Savings	15.0 - 14.0 = 1.0%	
5	Softwood Saving/Month	18 tons/Month	
6	Saving/year	261 Tons/Year	
7	Cost	216*55000 = 1.18 Cr	

Table 5A: Power Conversion (Amp to Kwh)

Power (Kwhr.)= √3* Voltage* Current* Power Factor	
Voltage	440 V
√3	1.732
Current	21" - 180 Amp & 17" - 160 Amp
Power Factor	0.88

Table 5B: Running Load

Refiner Running Load Data		
Refiner	**Current (Amp)**	**Power (Kwhr)**
21"	180	109.73
17"	160	97.54

Table 5C: Power Saving

S.No.	Particular	Recirculation	Single Pass
1	Running hrs	13.25	6.97
2	Batch Size	65 m3 @ 3.3 cy% = 2.14 MT	30 m3 / hr.@ 3.3% cy = 0.99 MT
3	Recirculation time	4 hrs	
4	Net output	2.14* (13.25/4) = 7.08 MT	0.99* 6.97 = 6.9 MT
5	Power consumption/Day (Kw/day)	2746.32	1444.71
6	Power consumption/year (Kw/year)	906285.6	476754.3
7	Power consumption saving/year	429531.3	
8	Cost Saving (Per Unit Cost - Rs.3)	Rs. 1288593	

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