THE EFFECT OF RECIRCULATION ON PULP PROPERTIES IN REFINING OF BLEACHED HARDWOOD AND SOFTWOOD PULPS WITH A CONICAL REFINER

Petteri Soini
Stock Preparation Division
Sunds Defibrator
Valkeakoski, Finland

Markku Partanen
Fiber Applications
Sunds Defibrator, Inc.
Norcross, GA 30071

ABSTRACT

The effect of recirculation on pulp properties has recently been discussed in some technical papers. Laboratory studies with a disk refiner have indicated that flow recirculation may improve strength properties especially in bleached hardwood pulp refining. The results of trials with bleached softwood pulp were also positive, but to a minor degree.

A series of pilot-scale refining trials were conducted to evaluate the effect of recirculation on pulp properties when the fibers are refined with a modern conical refiner. The effect of recirculation was studied with Scandinavian long-fiber kraft pulp and with South American short-fiber kraft pulp. Both recirculation rate and production rate were altered.

Results of these trials were opposite of the findings of the disc-refiner trials. The recirculation with the modern conical refiner had a slightly negative effect on fiber and sheet properties of the pulps studied. Only the tear strength of hardwood kraft pulp was slightly higher when recirculation was applied.

The only advantage of recirculation with a modern conical refiner seems to be when starting up a refiner to prevent unrefined pulp from entering the paper machine and during short operational shutdowns of the paper machine.

INTRODUCTION

The actual stock flow can vary from the design value as a result of changes in furnish, grade changes or varying production. Each refiner has an optimum flow range, which depends on size and speed of the refiner. A problem will arise when the minimum flow requirements of the refiner are not maintained. When flow falls below a certain minimum, fiber quality suffers and plate life is reduced. The installation of the flow recirculation line can be used to meet flow fluctuations in a refining line.

Overall behavior of a papermill refining system was studied by Kirby [1]. He examined the influence of three different refining parameters - net energy input, specific edge load and degree of recirculation on refined NSSC eucalyptus pulp. Percentage of recirculation did not have any significant effect on refined stock properties except on Bauer McNett +20 fraction. The recirculation effect on Bauer McNett +20 fraction was, however, quite minor.

Conditions in low-consistency refining systems, where the refiner is oversized for the current flow, can exist. The flow recirculation is normally used to maintain minimum flow requirements and for safety reasons [2,3]. Operating against a closed valve or blockage may cause a hazardous situation. The heat generated by an operating refiner can quickly transform water to steam if the refiner is full of stock and there is no flow through the refiner. Under such disturbances, the recirculation line is essential. Installation of a recirculation loop will also maintain constant minimum flow requirements, resulting in stabilized motor loading and improved plate life. Insufficient fiber film on the refiner bar surface will result in bar-to-bar contact, whereby the plate life will be dramatically reduced. With low stock flows, the free floating rotor of a disc refiner will not be self-centered. As a result, the stock will tend to flow to one side, causing uneven plate wear and poor refining result.

Rihs and Josephson [4] stated that according to their study, the flow recirculation with a disc refiner improves all strength properties of sensitive bleached hardwood pulps. However, no significant effects with strong long-fiber pulp were found. According to them, the refiner flow rates must be kept high by means of flow recirculation to prevent strength loss. With sensitive furnishes, the low refiner flow rates reduce fiber length and strength properties and this condition can easily be corrected by flow recirculation.

From the operational and qualitative viewpoint, conical refiners and disc refiners are different. Most recirculation studies have been conducted with disc refiners and the results of these examinations are reported. A mill-scale study with a modern conical refiner proved that the greater the recirculation for given energy, the poorer the strength development of hardwood and particularly softwood pulp [5].

The objective of this study was to find out; what the pulp recirculation does mean for the paper maker when a conical refiner is used. In order to accomplish this, trial series with eucalyptus and pine kraft pulps were conducted with conical Conflo® refiner.

EXPERIMENTAL

Raw Materials

The raw material for hardwood series was ECF bleached eucalyptus kraft pulp from South America. The average fiber length of the unrefined eucalyptus pulp was 0.66 mm and coarseness 0.086 mg/m. Initial refining degree after repulping of the pulp was relatively low, CSF 500 ml.

The softwood pulp studied was Scandinavian TCF bleached pine kraft pulp. Average fiber length of the unrefined pulp was 2.09 mm and coarseness 0.201 mg/m. Initial refining degree of the pine was CSF 710 ml.

Eucalyptus Refining, Trial 1

The pulp under study was refined with modern conical refiner in a pilot plant. In order to determine the effect of the recirculation, three different recirculation rates, 0%, 50% and 75% were used. Each trial series was performed at net refining energy levels of 0 kWh/t, 30 kWh/t, 60 kWh/t and 120 kWh/t. The first trial series was conducted with a constant production (500 l/min) and consistency (4.5%).

Recirculation trials were conducted as single-pass trials through a refiner. In order to be able to compare recirculation refining to multi-pass refining, a multi-pass trial without recirculation was also carried out. The multi-pass trial was performed with three passes, 30 kWh/t per pass. The purpose of the multi-pass trial was to find out whether recirculation could be used to replace serial refining.

The plate pattern chosen for both hardwood series had a bar width of 2.0 mm and groove width of 2.5 mm. The groove depth of the fillings was 7.0 mm and intersecting angle 23°.

Eucalyptus Refining, Trial 2

The second series of trial was carried out at three different production levels. Recirculation rates in this trial series were limited to 0% and 50%. The lowest production level, 250 l/min, was already below the normally recommended capacity range of the refiner and was chosen because it is representative for start-up periods. Use of recirculation is normally recommended for this low production level. Other chosen flow rates were 500 l/min and 1,000 l/min.

The purpose of this second eucalyptus trial was to demonstrate the normal recirculation case. Here the effect of recirculation was studied when production levels were reduced to half of the original and flow circulation is used to maintain flow volume.

Pine Refining

Third trial series was carried out with a softwood kraft pulp at constant 400 l/min flow rate and 3,5% consistency. Recirculation rates of 0%, 50% and 80% were tested with four different net refining energy consumption levels (50 kWh/t, 100 kWh/t, 150 kWh/t and 200 kWh/t). Fillings, which were selected for the given task, had 4,5 mm bar width and 6,0 mm groove width. Groove depth with these fillings was 10,0 mm and bar angle 36°.

Refining System with flow Recirculation

A pipeline with a flow meter and control valve was installed for the recirculation trials, figure 1. A key factor with the recirculation line design is that the recirculation flow is lead to the suction side of the pump and not to the feed chest. The recirculation percent was calculated based on following Equation (1):

$$\text{Recirculation}\ \% = \frac{Q_{\text{recirculation}}}{Q_{\text{refiner}}} * 100 \qquad (1)$$

The actual production flow can be calculated by subtracting the recirculation flow from the flow which goes through the refiner. The net refining energy consumption was calculated based on the production flow.

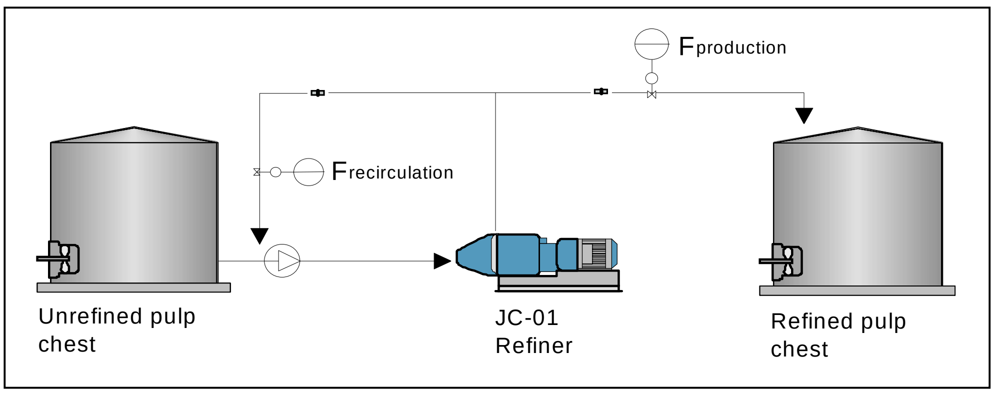

Figure 1. Refining system for recirculation trials.

Testing

Refining degree was defined with a freeness test device in accordance with the SCAN-C 21:66 standard. Fiber length (length weighted) and coarseness were measured with a Kajaani FS-200 device. Handsheets were prepared with a laboratory handsheet mold according to SCAN-C 26:76 and SCAN-M5:76 standards.

Paper properties were tested according to the following standards: density SCAN-P 6:75, tensile strength SCAN-P 38:80, tear strength SCAN-P 11:96, burst strength SCAN-P 24:77 and Bentdsen porosity SCAN-P 60:87.

RESULTS

First Trial Series with the Eucalyptus Pulp

This refined eucalyptus pulp was very easy to refine and the final refining degree after the trials was below 200 ml, figure 2. The flow recirculation had slightly negative effect on the refining degree in a given energy level. With the highest energy input we achieved minor improvement on refining degree when 50% recirculation rate was used.

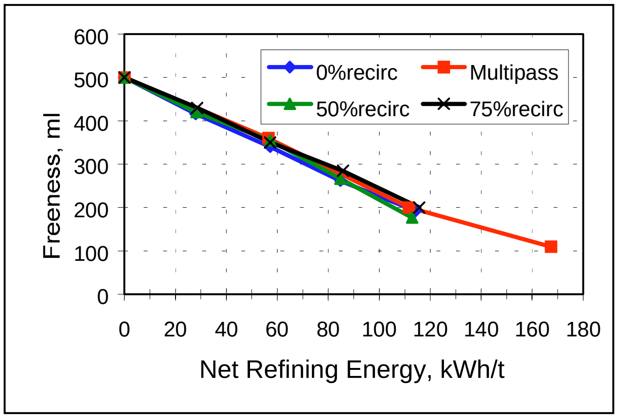

Figure 2. Refining degree vs. net energy consumption.

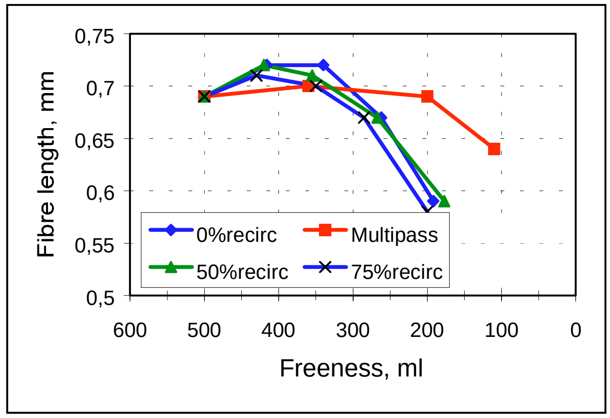

Figure 3. Kajaani FS-200 fiber length vs. freeness.

With the same refining intensity with each recirculation rate the internal differences between the fiber lengths were insignificant in any given refining degree. Minor indication from higher fiber shortening due to recirculation could be seen. The effect of a high load in a single pass can be seen from the difference between multi-pass and single-pass refining, figure 3. Refining with the flow recirculation also straightens the fibers initially which can be seen in the increased fiber length.

According to results it seems that the flow recirculation has a negative effect on the tensile index, figure 4. With light refining this effect cannot be noticed, but it will be emphasized when the pulp has received a higher level of refining energy. To reach a desired tensile index higher energy level is desired with flow recirculation system. This is identical with Mr. Nuttall's trials at mill scale[5]. As expected, more sensitive refining with a serial arrangement will eventually yield higher strength properties than refining with high energy consumption in a single pass.

On the other hand the recirculation can yield somewhat higher tear indices initially. This positive sign from flow recirculation will however disappear when a higher amount of refining takes place, figure 5. This is due to increased refining intensity and too high an energy input in a single stage for sensitive pulp.

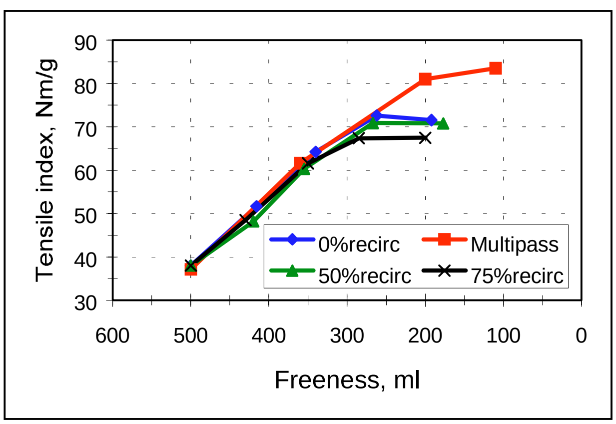

Figure 4. Tensile index vs. refining degree.

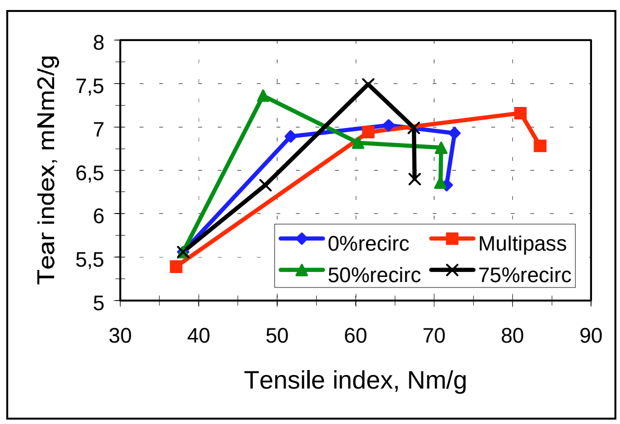

Figure 5. Tear index vs. tensile index.

Conclusions from the First Trial Series

From this first trial series, we can conclude that we are not able to replace two refiners with one refiner using flow recirculation. The effects of flow recirculation for a paper maker are minimal as no clear evidence from improved pulp properties were found.

Property	*Effect*
Energy	slighly increased
Fibre length	slighly decreased
Bulk	initially decreased
Tensile index	slighly decreased
Tear index	initially increased
Burst index	Not effected
Bendtsen porosity	Not effected

Table 1. The effect of flow recirculation on the properties of eucalyptus pulp.

Second Eucalyptus Series

Decreased production had a positive influence on refining energy consumption. At the same energy level, a lower freeness level was achieved when the production was cut to half from 2.4 t/h (figure 6). This was mostly due to decreased specific edge loads which has a positive effect when processing a short fiber eucalyptus pulp. When the production was reduced further, the same effect could not be noticed as the specific edge load was already at a low level (figure 7).

The flow recirculation was used as a substitute for decreased production to maintain the same flow rate through the refiner. In this case the flow recirculation had a slightly negative effect on energy consumption compared with the situation in which recirculation was not used.

The fiber length of eucalyptus pulp was affected by the production rate and refining intensity. With the higher production rates, the fiber shortening effect was greater (figure 8), but still notable at lower productions as well. Contrary to expectations, the recirculation had a negative effect on fiber length with this kind of arrangement. Differences in fiber length had very little effect on bulk, which was not significantly affected.

Although decreased production and lower refining intensity improved strength properties in both cases, the recirculation itself had a negative influence. The tear - tensile combination without recirculation was remarkably better than with the flow recirculation (figures 9 and 10).

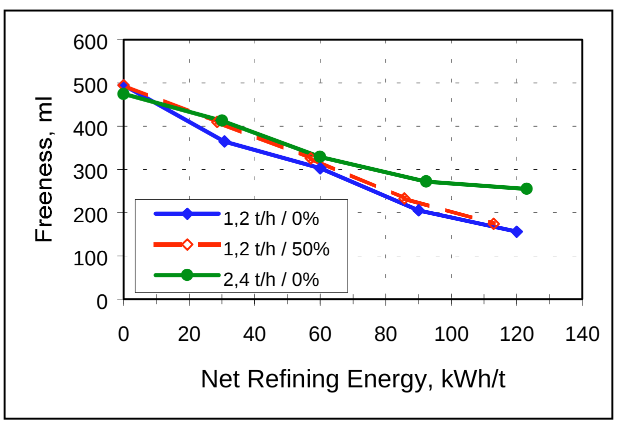

Figure 6. Refining degree vs. net energy consumption.

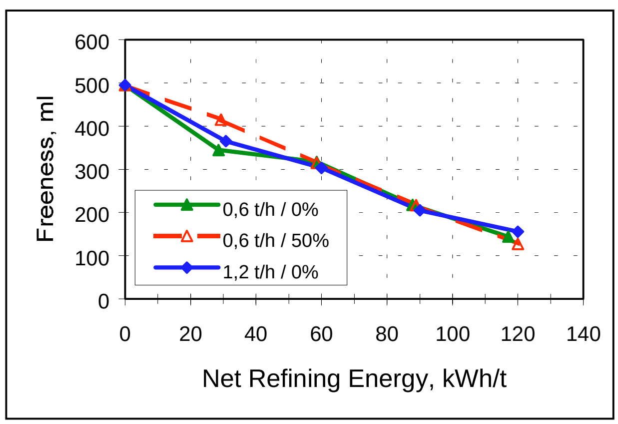

Figure 7. Freeness vs. net energy consumption.

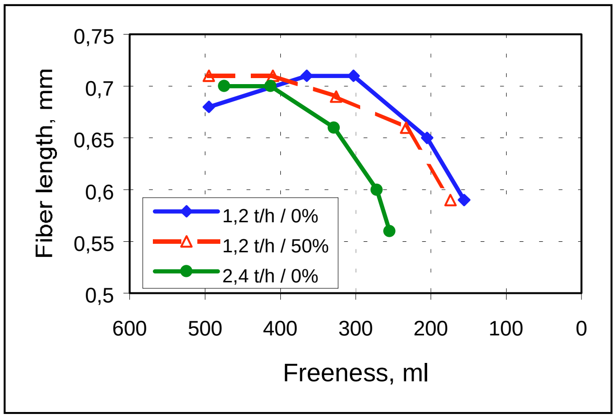

Figure 8. Fiber length vs. freeness.

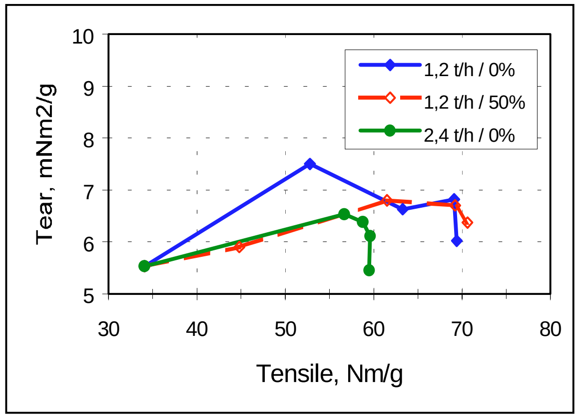

Figure 9. Tear index vs. tensile index.

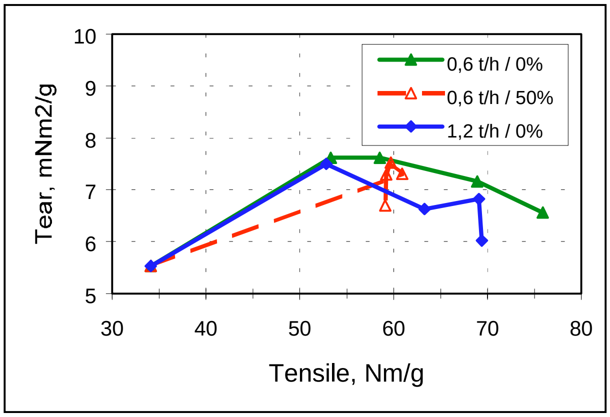

Figure 10. Tear index vs.tensile index.

Conclusions from the Second Trial Series

This trial series, where recirculation was used to replace the production loss, did not shed any new light on the effects of flow recirculation. Results from the second trial were almost identical with the first trial, where we found out that use of flow recirculation had a slightly negative effect on pulp properties.

Pine Kraft Series

Sufficient recirculation had a slightly positive effect on refining energy consumption of pine kraft pulp. Using 50% flow recirculation to move the refiner up to the right flow area gave some 5% energy savings to gain a freeness level of 400 ml, figure 11. Higher recirculation rates of 80% had an adverse effect due to improper operating area and greater clearance.

Fiber shortening in pine kraft refining was lower when less recirculation was used, figure 12. This phenomenon was reversed, when high energy and high intensity were used (NRE 200 kWh/t and SEL 4.0J/m). Based on this we have evidence that recirculation may be able to prevent fiber shortening when intense refining takes place.

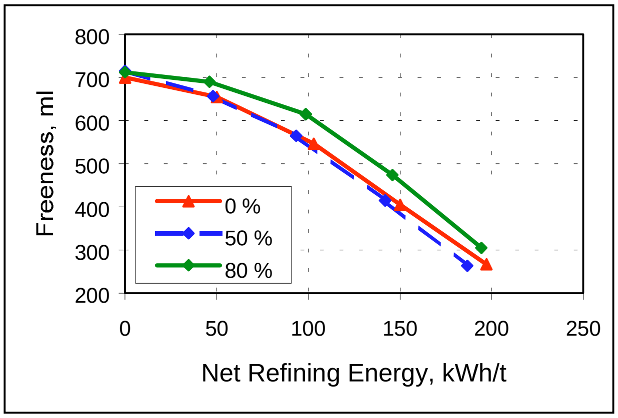

Figure 11. Freeness vs. net energy consumption.

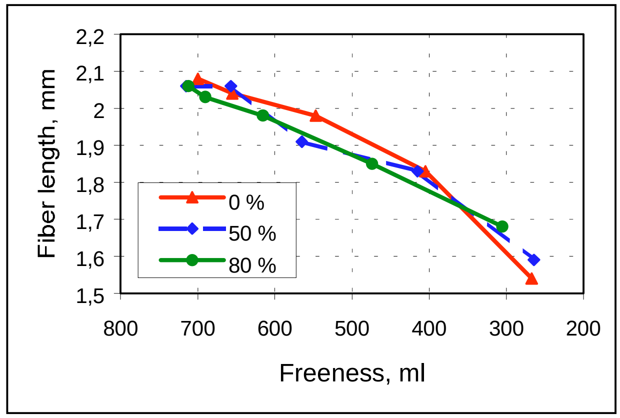

Figure 12. Fiber length vs. freeness.

With this particular pine kraft, the recirculation had a slightly negative effect on both tensile and tear indices. When flow recirculation is used higher net refining energy is required to obtain given tensile index, figure 13. This negative effect was not as strong in our pilot scale trials as it was according Mr. Nuttal's mill trials. In our trials we however gained some 5 Nm/g in tensile index and 1mNm^2/g in tear index with the highest energy input together with the recirculation. Like with the tensile, the differences with the tear index were during the initial refining and lower refining degrees. A remarkable initial tear index decrease was found out when recirculation flow was increased, figure 14.

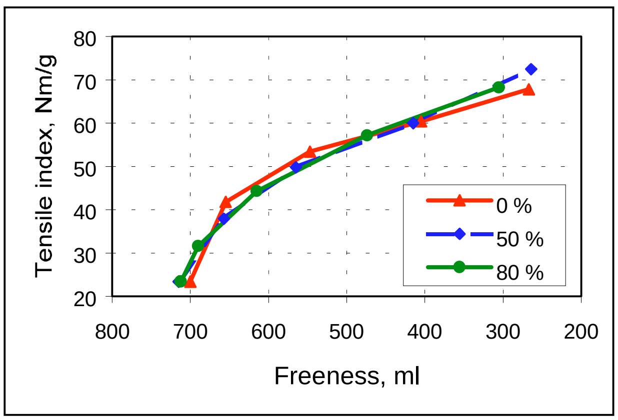

Figure 13. Tensile index vs. freeness.

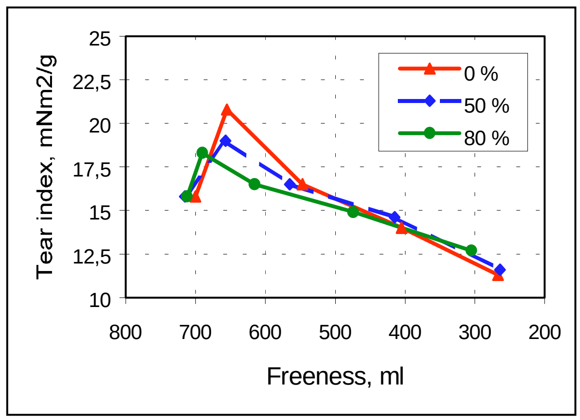

Figure 14. Tear index vs. tensile index.

Conclusion from the Third Trial series

To conclude the results of this third trial series, we can say that the flow recirculation should not be used with the normal long fiber refining cases. The normal pine kraft refining means optimized specific edge loads and energy consumption of 120 kWh/t or below in one stage. With high energy input in one stage and high specific edge load the recirculation can improve the refining result and hence prove itself useful.

Property	*Effect*
Freeness, ml	decreased
Fibre lenght	decreased
Bulk	increased
Tensile index	decreased
Tear index	decreased
Bendtsen porosity	increased

Table 2. The effect of flow recirculation on the properties of pine pulp to CSF 500 ml.

RECOMMENDATIONS FOR PROPER RECIRCULATION LINE

The greatest benefit of recirculation line can be achieved during start-up and during short paper machine shutdowns. During the start-up, a recirculation line can be used to circulate unrefined pulp back to the feed chest until the refining gap is closed. When the refiner has been loaded to net power, the valves can be changed to send the pulp to the paper machine. The new linear rotor position sensors are able to reduce this loading time considerably since the open gap clearance can be maintained despite plate wearing. When there is a brief shutdown on the paper machine, the refiner can left to idle and stock is circulated back to the feed chest. This prevents a no-flow condition in the refiner and the pulps from overheating. In these cases the circulated pulp is recommended to be sent to feed chest.

Traditionally, refining line recirculation has been recommended when there is wide variation in line production and when the minimum flow is below the operating range of the refiner. All refiners have an optimal refining flow range and operating below this range may cause operational problems like plate contacts and a high pressure pulses.

If a recirculation line is used in normal refining conditions and net refining energy control strategy is applied to control the refiner, the recirculated stock needs to be sent to the suction of the pump. The control of the refiner’s power should be based on forward flow and circulated flow should not be included in production calculations for the net refining energy control. In this manner, the net refining energy control works correctly.

A low continuous flow through the recirculation line to keep it open is always necessary.

CONCLUSION

These trials indicate that pulp recirculation has a slightly negative influence on pulp properties when a conical refiner is used. This influence is only slight and does not have any significant importance when recirculation is used for maintaining minimum flow requirements in a low-consistency refiner.

Eucalyptus refining trials proved that recirculation had only a slight negative, if any, effect on pulp properties. Only tear strength was initially improved when flow recirculation was used. These trials proved the fact, that serial refining cannot be replaced with one refiner and recirculation.

With proper flow recirculation, some energy savings could be achieved in the pine kraft case under extreme refining conditions and a high energy input. However, for the same tensile index value almost the same refining energy consumption was required. The use of recirculation decreased the tear strength of pine kraft initially and had generally a slightly negative effect on pulp properties.

Recirculation of pulp can be beneficial during start-up of a refiner to minimize the amount of unrefined pulp entering the paper machine. In addition, during short paper machine shutdowns, the refiner can be left idling and the pulp recirculated back to the feed chest. If recirculation is used under normal conditions and refiner is net energy controlled, the pulp has to be sent to the suction side of the pump and the production calculation should be based on forward flow.

REFERENCES

1. Kirby, P.L., Analysis of a mill refiner system using specific edge load theory, Appita 34(1), 1980, p.25-28.
2. Antku, J., Maintaining minimum flow requirements of the twin-disc refiner, Tappi J., 67(10), 1984, p.112.
3. Lukins, J., A refiner control design, Tappi Papermakers Conference. Seattle, WA, April 8-10, 1991, p.523-532.
4. Rihs, J., Josephson, W.J., Refining systems with flow recirculation, Pira Conference Proceedings, 4th International Refining Conference, Fiuggi, Italy, March, 1997, 8p.
5. Nuttal, G., Optimization of pulping and refining - the effect of recirculation on energy usage and quality, Progress reports for the FTA, February, March and July 1998.