Preliminary study on the potential of improving pulp quality and energy efficiency in a South African TMP mills

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Keywoods: Fractionation, Hydrocylone, volumetric ratio, base, apex, Mass apex rate, strength properties and fibre morphology

ABSTRACT

The main focus of this work was to evaluate an opportunity for product quality and refining energy efficiency improvement through assessing the current mill practices in South African TMP mills. The fractionation trials were conducted at CSIR laboratory using Hydrocyclone. In order to provide a frame work for mill process improvement, two issues were examined.

Firstly, investigations focused on evaluating the pulp quality of the mill feed pulps. This work was aimed at getting a better understanding on the limitation of the mill refining process. This was accomplished by using the secondary refiner pulps (mill feed). The results data showed that under the current mill practices, the mill is introducing too much refining energy into fibres. The extremely lower value of freeness (32 ml CSF) for base fraction pulps confirmed the scenario.

The second set of trials examined the efficiency of the mill fractionation process in terms of the final pulp quality. Mill's accept pulps were fractionated. The results data indicated that mill screens fractionation process has limited efficiency. Substantial amount of thick walled fibres was found in the mill's accept pulps.

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Approximately 66% by mass of the mill's accept pulps (from the 0.18 mm slotted screens) showed freeness higher than 250 ml CSF. This has a potential negative effect on the product quality.

Our preliminary study has proved that there is significant potential for Hdrocyclone fractionation in this process. This will lead to energy savings due to less intensive main line refining. In addition, the product quality will be improved due to fewer thick walled fibres and less fines in the final pulp. Fewer fines will lead to better dewatering.

INTRODUCTION

The South African mills have been under pressure to improve the efficiency of their pulping process, this has no exception in TMP mills. This due to the limitation on softwood supply and the stiff competition in the local and international markets. The best practice of ensuring the sustainability of the South African TMP mills will be then to improve the energy efficiency and product quality.

It has been a common trend in TMP mills to increase a refining energy as a strategy for achieving target product quality. Consequently, there is an excessive usage of energy and also results in damaging of the fibres [1,3]. Increased refining results in producing pulps furnish with huge amount fines. Fines have detrimental effect on pulp quality and also creates limitations to e.g. thickening, washing and paper machine runnability due to poor drainage.

Pulp quality and energy usage can, however be controlled by adjusting refining energy input. Furthermore, the strategic fibre fractionation post refining has also to be carefully considered. In a modern TMP mills trend have been using the combination of screens and Hydrocylone in their fractionation process [3]. The screens fractionating is based fibre length, thus provides fibre line streams with mixed thin and thick walled fibres when used in the final stage of fractionation process. It has been acknowledged that the use of Hydrocylone after screens results in effective separation of thin and thick walled fibres fraction streams.

Potential benefits includes; improving product quality, minimizing operational problems and refining energy reduction compared to traditional system with screening system only [3]. Furthermore, wastage wood fibre resources in form of fines can be minimized [3]. As due to excessive refining, fractions of pulp with extremely lower freeness are discarded.

However, most of the mills have been reluctant in installing such strategic fractionation system either due lack of sufficient knowledge or lack of capital for re - arranging the refining-fractionation system. Undoubtebly, this restricts further mill process optimization and product quality improvement.

In this study, laboratory fractional trials were performed. The main focus was to evaluate an opportunity for product quality and refining energy efficiency improvement through assessing the current mill practices. The information obtained in this study could be used by the mill to adjust the fractionation process and refining conditions. The ultimate goal being optimal utilization of scarce wood fibre resources, to improve the product quality and mill energy efficiency. This can provide a frame work for improving the profitability and competiveness of the South African TMP mills.

EXPERIMENTAL

In order to provide better under standing on the pulp quality under the existing mill fractionation process, a Hydrocylone fractionation study was performed in CSIR laboratory at Forestry and Forest Products Research Centre (FFP). Pulps were collected from TPM mill of mill A located in South Africa. The pulp samples were secondary refiner, mill's accept and tertially refiner pulps. The experimental work examined two issues.

Firstly, investigations focused on evaluating the pulp quality of the mill feed pulps. This work was aimed at getting a better understanding on the limitation of the mill refining process. This was accomplished by using the secondary refiner pulps (mill feed). Three settings of volumetric (base/apex) ratio were tested. Four trials were performed at each volumetric apex ratio setting. Freeness drop in Canadian standard of freeness (ml CSF) were used to determine which volumetric apex ratio provides optimal fractionation efficiency. Furthermore, mass apex rate and fibre morphology analysis was also evaluated.

The second set of trials examined the efficiency of the mill fractionation process in terms of the pulp quality. The optimal volumetric apex ratio setting determined in step one was used for fractionating mill's accept pulps, similarly, four trials were performed.

The fractionation trials were carried out using Noss Hydrocylone test canister rig (see Figure 1). The rig was connected to the pilot low consistency refiner flow system which is provided with mixing tank and positive displacement pump. For each trial, the pulp sample was mixed with water in the refiner chest tank provided with an agitator to desired trial feedstock consistency of 10 g/ℓ. The feed pressure was kept in the range of 2 – 2.3 bar and flow rate was adjusted to 100 – 110 ℓ/min which was the desired Hydrocyclone operating condition specifications.

To minimize the pressure drop along the Hydrocylone rig during the sampling, the base and apex fractions sampling point were maintained at the same height. The base and apex line valves were opened simultaneously and the pulp slurry in the respective streams were collected in the container at a specified time (50 seconds) and measured. This was aimed at determining whether the base and apex valve setting gives the desired trial volumetric apex ratio.

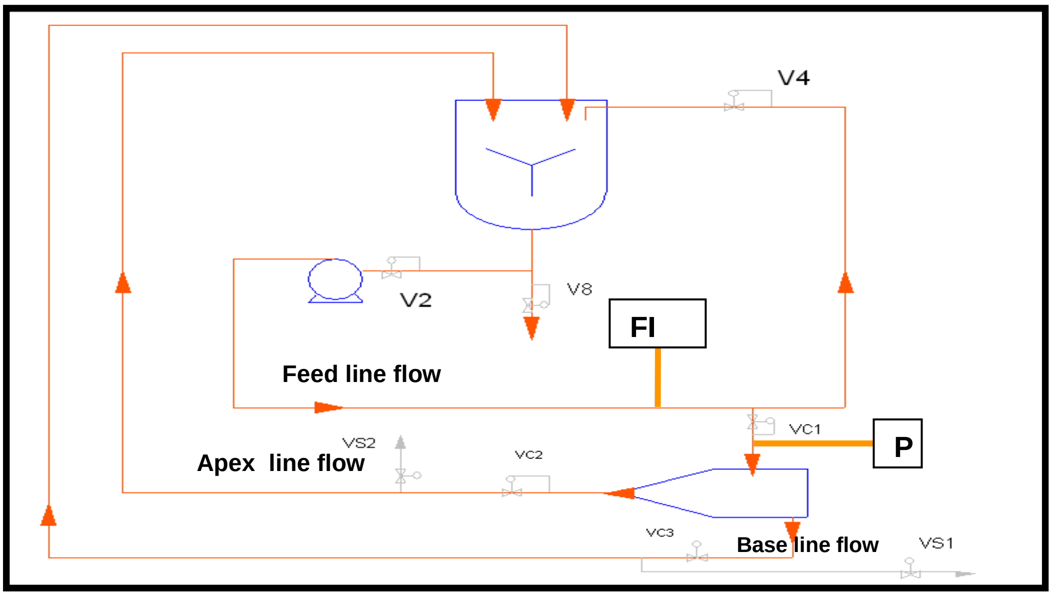

Figure 1: Flow diagram for the low consistency refiner system in which the Noss Hydrocylone canister rig was coupled to perform the laboratory fractionation trials

Evaluation of pulp quality

The Canadian Standard Freeness (CSF) measurement was performed according to TAPPI test method T227 om-94. Hand sheets were prepared according to T205 sp-95. The prepared hand sheets were left in a conditioned room 23 ℃ ± 0.5 ℃ and relative humidity 50% ± 1 for 24 hours prior to testing. TAPPI standard methods were used for all physical tests that were performed on the hand sheets. The fibre morphology analysis tests were performed using the kajani fibre analyzer according to instructions supplied by the manufacturer.

RESULTS and DISCUSSION

Evaluation of fractionation efficiency

The effects of volumetric (base/apex) ratio on fractionation efficiency were evaluated based on the freeness drop. Freeness drop data in ml CSF are detailed in Table 1, the freeness values results data are based on the average values of the four trials for each volumetric base/apex settings.

It was observed that there is a clear distinction between control pulps (unfractionated pulps), base fraction and apex fraction pulps. The base fraction pulps exhibited extremely lower value of freeness compared to control and apex fraction pulps. Thin walled fibres are flexible and consolidate well on each other, resulting in poor water drainage rate (lower freeness). While thick walled fibres behave oppositely.

Thin walled fibres and fines were effectively captured in the base fraction stream while thick walled fibres were collected in the apex fraction stream. Similar trends have also been reported in previous studies (1, 3-8). In order to determine how the apex fraction pulps from the laboratory Hydrocylone fractionated pulp differs from mill reject pulps the two pulp samples were compared. Laboratory apex fraction pulps exhibited higher freeness values compared to the mill reject pulps. The results data indicates that under the current mill practices, substantial amounts fines are recycled unnecessarily to the tertially refiner. This could be avoided if Hydrocylone could be used.

Table 1: Freeness at different volumetric (base/apex) ratios, fractionating the secondary refiner pulps - mill feed

Batch no	Accept/reject flow split (ℓ/min)	Freeness (ml CSF)	
		Base fraction stream	Apex fraction stream
1	64/32	22	480
2	78/22	18	547
3	89/11	32	571
unfractionated		189	
Mill reject		361	

Moreover, the extremely lower value of freeness (18-32 vs. 90 ml CSF anticipated) for base fraction shows how the pulps are excessively refined. This may be due to an excessive energy input during refining as an attempt to improve the pulp quality. To avoid operational and final product quality problems, approximately 34% of the feed may need to be discarded (see Table 2 at optimum volumetric base/apex ratio of 78/22). Definitely this is wastage of wood resources which can be avoided.

However, effect of volumetric (base/apex) ratio at different setting on freeness could not be determined. It was anticipated that increase in accept volumetric ratio could result in forcing the thick walled fibre to base stream, resulting in a less freeness drop.

Effect of volumetric (base/apex) ratio on mass apex rate

Mass apex rate plays a vital role in the decision of employing a fractionation process in the mill. The pulp mass split at the fractionation unit may also be required to match with the pulp mass balance required in the mill [1]. In this context, the mass apex rate at different volumetric (base/apex) ratio settings was evaluated. The results are illustrated in Table 2. Operating the Hydrocylone at a volumetric base/apex ratio of 78/22, gave the mass apex rate of 66% (apex thickening factor of 3), this value was very close to mill specification of 70%. The pulps from this setting were used for fibre morphology analysis, the results are discussed in the next section.

Table 2: Apex rate by mass at different volumetric (base/apex) ratio settings

Batch no	Base/Apex flow split (ℓ/min)	Apex rate (%)
1	64/32	86±2.8
2	78/22	66±2.2
3	89/11	44±3.2

Effect of fractionation on fibre morphology

The pulp samples from volumetric apex ratio of 78/22 were used to study the effect of Hydrocylone fractionation on fibre morphology. Fractionation resulted in base and apex fraction streams with pulp having different fibre morphology properties. The results data are the average of the four trials and are detailed in Figure 4 – 8 (**Note**: **control**: denotes unfractionated, **LB**: Laboratory base fraction pulps and **LA**: denotes Laboratory apex fraction pulps). It can be seen that base fraction stream contains pulps with shorter fibres length, huge amount of fines, fibre with small width and less thick walled fibres compared to control and apex fraction stream pulps. This result agrees with the trend observed in the freeness results in previous section.

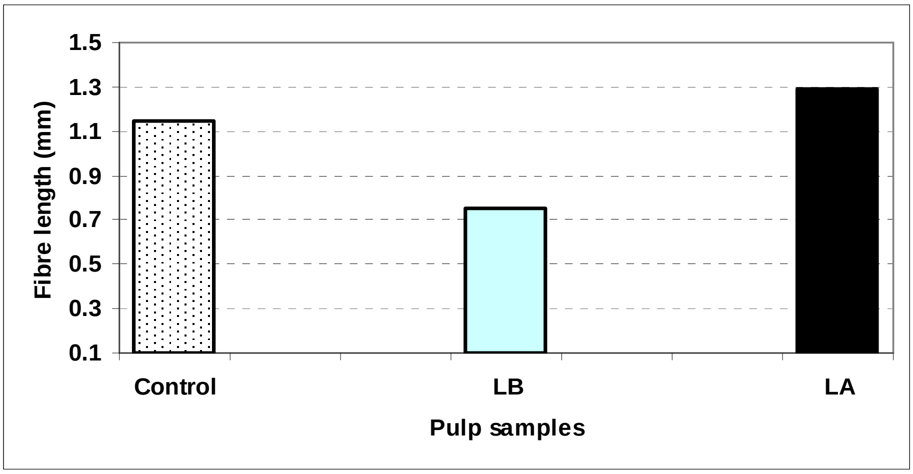

Figure 2: Comparison on fibre length for different pulp samples at volumetric ratio of 78/ 22%

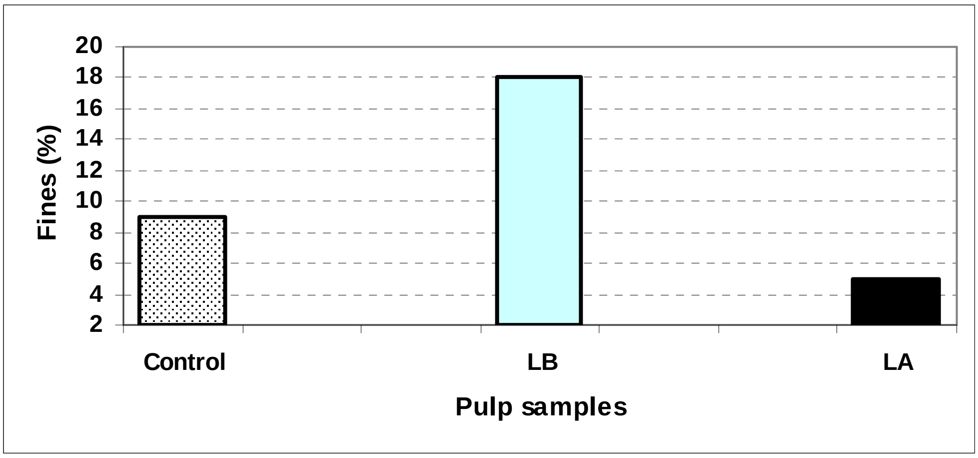

Figure 3: Comparison on number of fines for different pulp samples at volumetric ratio of 78/ 22%

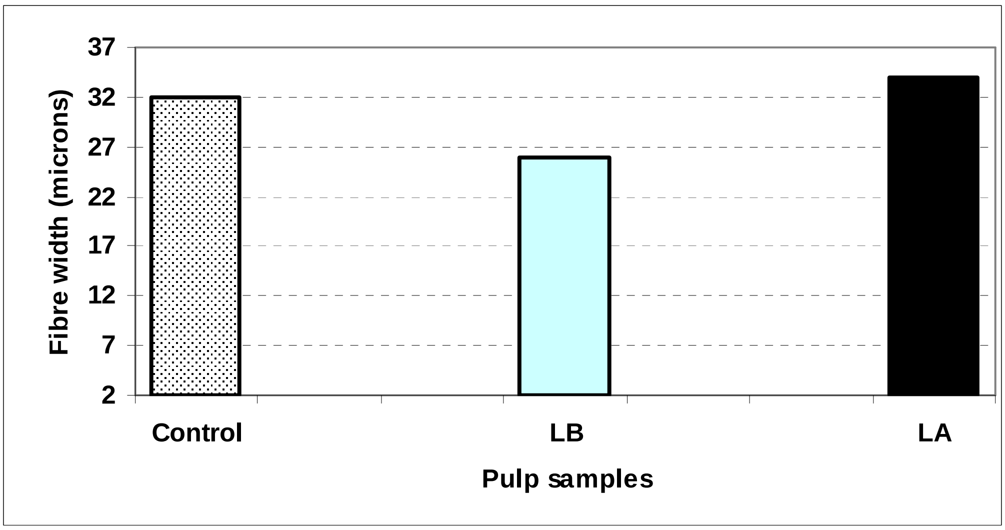

Figure 4: Comparison on fibre width for different pulp samples at volumetric ratio of 78/22%

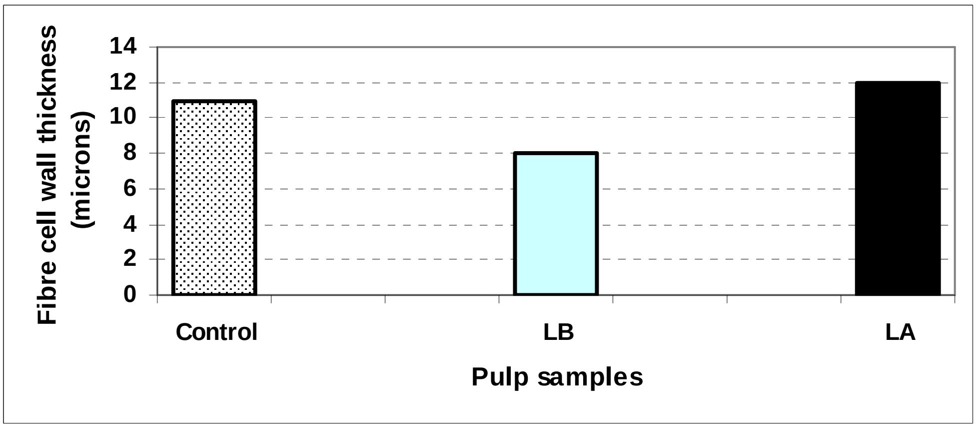

Figure 5: Comparison on fibre cell wall thickness for different pulp samples at Volumetric ratio of 78/22%

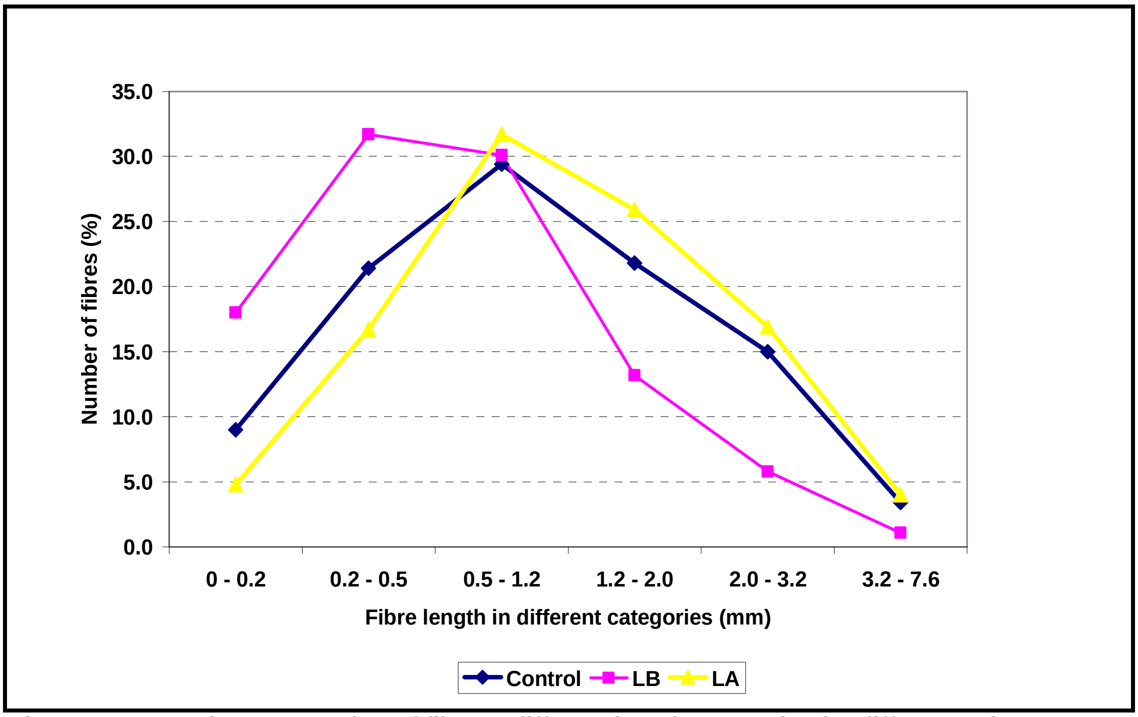

Figure 6: Comparison on number of fibre at different length categories for different pulp samples

Fractionation of Mill accept sample

In order to understand the effectiveness of the fractionation process at the Mill, the mill's accept pulps were fractionated in the laboratory. The results data are the average of the four trials on freeness (Table 3). It seemed that the mill screens (0.18 mm slots) are accepting a lot of thick walled fibres (unwanted material). Referring to mass apex rate at 78/22 (Table 2), approximately 66% by mass of the accepts of the slotted screens have a freeness of more than 250 ml CSF. This results indicates potential effect on product quality as the presence of substantial amount of thick-walled fibres in the mill accept may result in producing paper with inferior strength properties. The freeness results data are also supported by the trend of the fibre morphology results data (see Figure 7-11).

Table 3: Freeness after fractionating of the Mill accepts sample at volumetric base/apex ratio of 78/22% (which gave the apex mass rate of 66%)

Freeness (ml CSF)		
Mill accept (unfractionated)	**Base fraction stream**	**Apex fraction stream**
***70**	**28**	**256**

***Note: The standard mill accept pulp freeness is 90 ml CSF**

Fibre morphology results data are illustrated in Figure (7-11). Note: **MA**: mill's accept pulps, **LB (MA):** base fraction pulps after fractionating mill accepts, **LA** (**MA**): apex fraction pulp after fractionating mill accepts. Fibre with longer fibre length (Figure 7), less content of fines (Figure 8), bigger fibre width (9), thick walled fibres (Figure 10) and more fibre with fibre length > 1.2 mm (Figure 11) were collected in apex fractions stream. While the opposite was observed in base fractions stream.

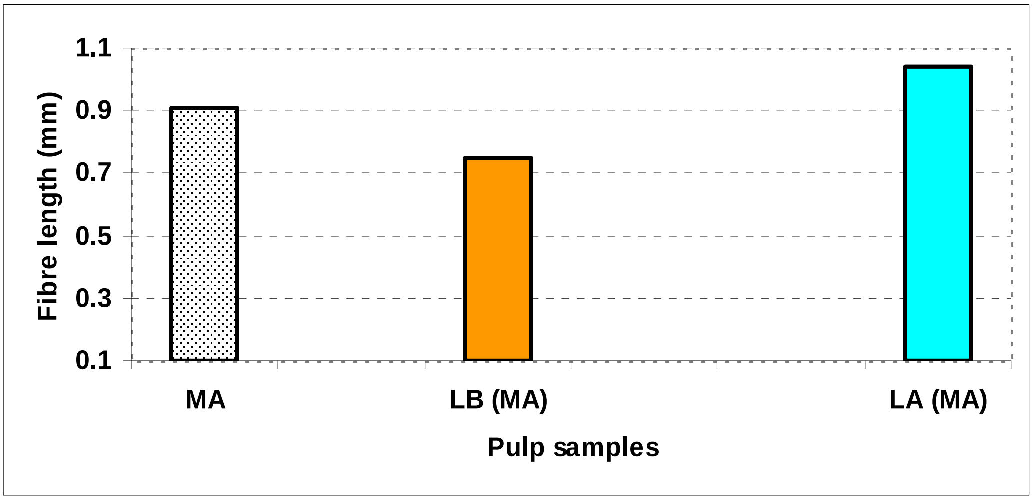

Figure 7: Comparison between mill accept pulps and laboratory fractionated samples of mill accept pulps on fibre length

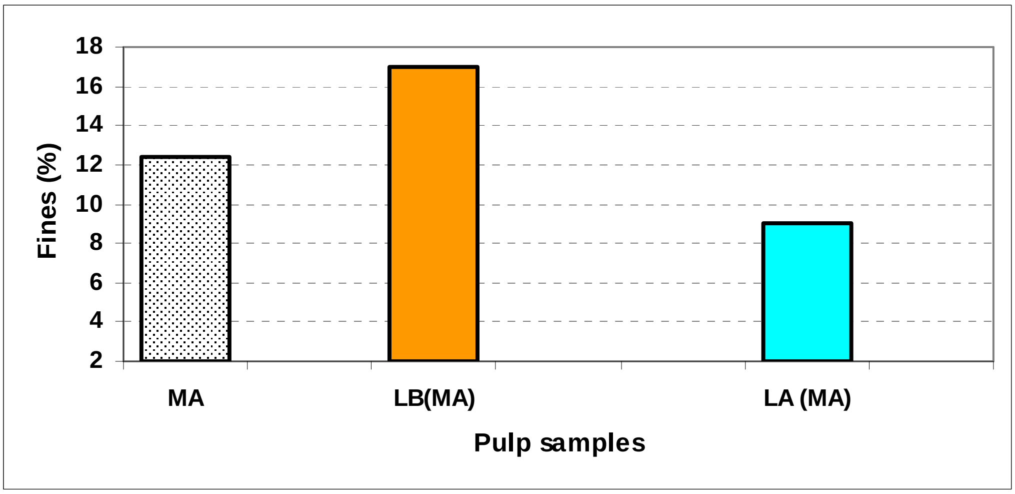

Figure 8: Comparison between mill accept pulps and laboratory fractionated samples of mill accept pulps on fines

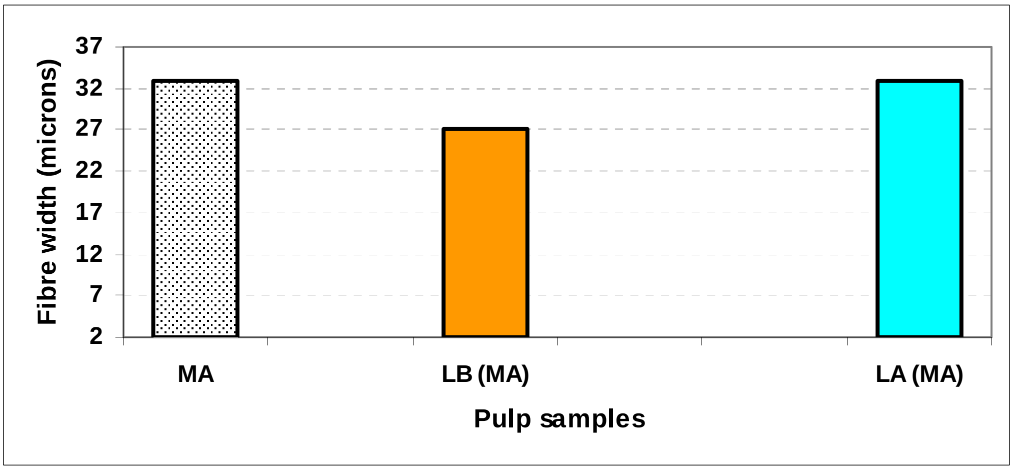

Figure 9: Comparison between mill accept pulps and laboratory fractionated samples of mill accept pulps on fibre width

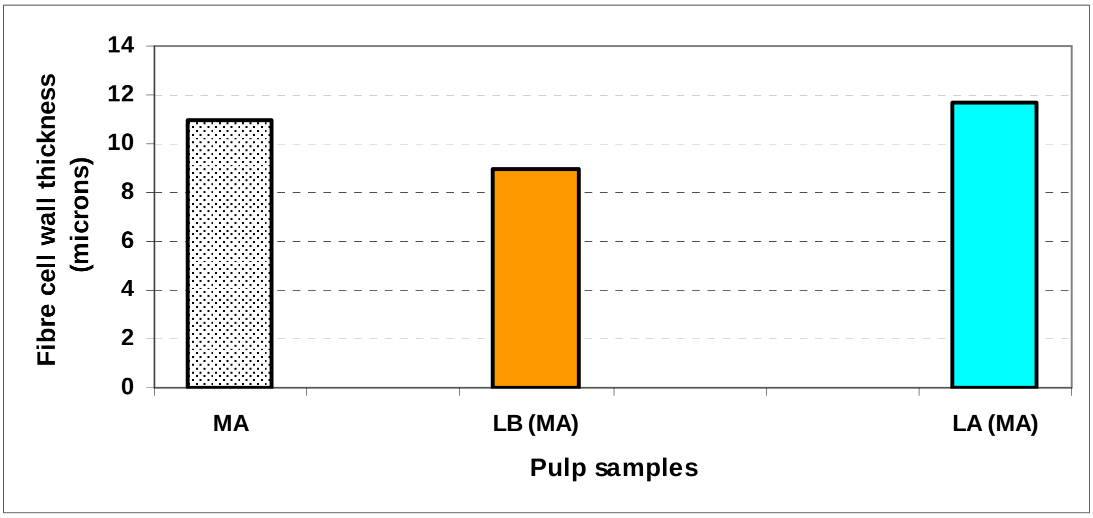

Figure 10: Comparison between mill accept pulps and laboratory fractionated samples of mill accept pulps on fibre cell wall thickness

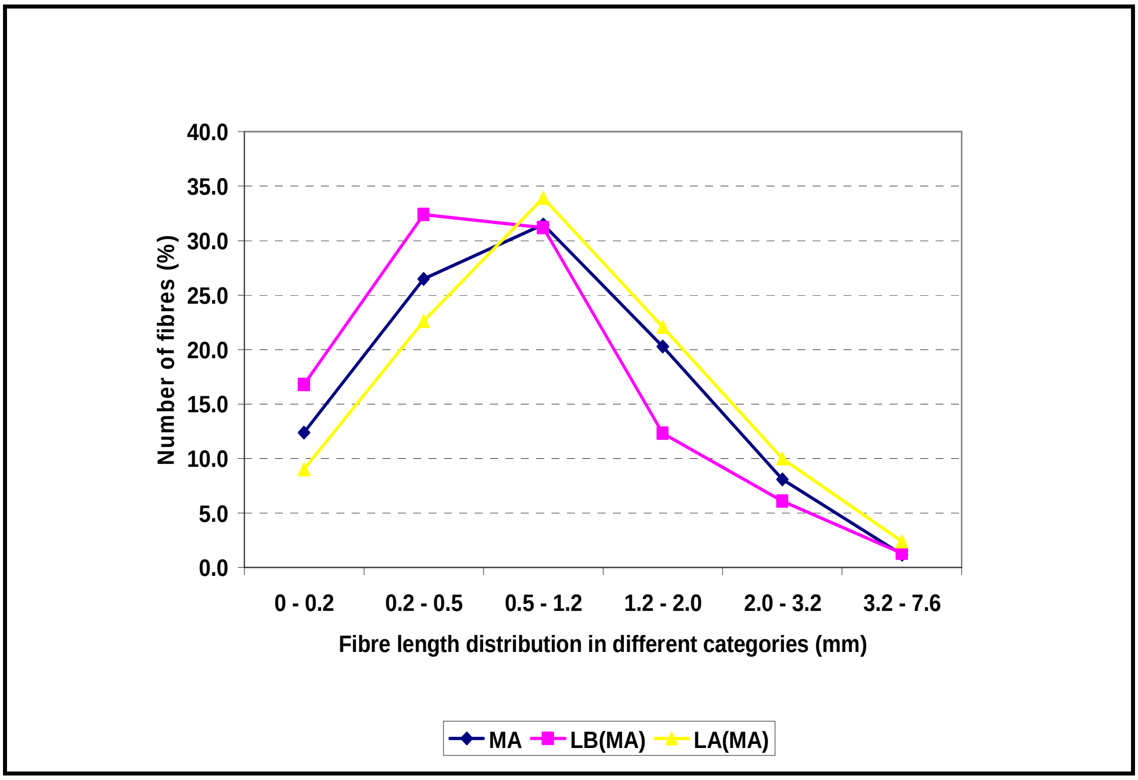

Figure 11: Comparison between mill accept pulps and laboratory fractionated samples of mill accept pulps on fibre length distribution in different categories

Comparison on strength properties

To study the effect of fractionation on pulp strength properties, selected strength properties were evaluated as shown in Table 4. An attempt to make a hand sheets for the base fraction pulps after fractionating the mill feed sample in laboratory failed. This is due to poor drainage as freeness values were extremely lower (18 ml CSF).

Comparing mill's reject pulps and apex fraction pulps from laboratory mill feed fractionated pulps, mill reject exhibited a higher Tensile Index (60%) and Tear Index (62%). This may be due to presence fines and thin walled fibres in the mill reject pulps which improves bonding ability. This result also supports the freeness data in Table 1, which apex fraction pulps from laboratory mill feed fractionated pulps showed a high value of freeness (approximately 52% higher). These results also confirmed that Hydrocylone fractionation can provide effective separation of thick and thin walled fibres from the pulp stock furnishers compared to screens.

Table 4: Comparison on strength properties

(Note: Mill feed was fractionated using volumetric ratio of 78/22)

Sample ID	Mill accept	Mill reject	Mill feed fractionated in laboratory (apex fraction pulps)
Properties			
Tensile Index (KNm/kg	11.42	10	6.24
Burst Index (kpa.m^2/kg	1.24	1.33	1.4
Tear Index (mN.m^2/kg)	2.9	3.4	2.1

SUMMARY AND CONCLUSIONS

- The potential of using a Hydrocylone in the fibre fractionation process was demonstrated. The study revealed that Hydrocylone fractionation can provide effective separation of thick and thin walled fibres from the pulp stock furnishers compared to screens.

- Under the current mill practices, the mill is introducing too much refining energy into fibres, with consequent excessive generation of fines in main mill feed line. The extremely lower value of freeness (18 ml CSF) for base fraction pulps from the laboratory mill feed fractionated pulps confirms the scenario. To avoid operational and final product quality problems, approximately 34% of the feed may need to be discarded. Definitely this is wastage of wood resources which can be avoided.

- Mill screens fractionation process has limited efficiency. This was revealed by the substantial amount of thick walled fibre in the mill accepts. This has a potential negative effect on the product quality.

- Our preliminary study has proved that there is significant potential for cyclone fractionation in this process. This will lead to energy savings due to less intensive main line refining. In addition, the product quality will be improved due to fewer thick walled fibres and less fines in the final pulp. Fewer fines will lead to better dewatering.

RECOMMENDATION FOR FUTURE WORK

Following the encouraging results obtained in the preliminary study, it is recommended that a detailed study to be conducted. The following approach is proposed:

- **Phase two**: Establishing the extent to which pulp quality is affected under the current mill practices. Pulp quality from each refining stage to be evaluated through fractionating the pulps from primary and secondary refining in the Hydrocyclone. This work will provide a better understanding on the effect on pulp quality.

- **Phase three**: Optimising pulp quality and energy efficiency at the mills. After establishing the extent to which pulp quality are affected under the current mill practices, the focus should be on exploring the potential of using the combination of screens and Hydrocylone in the mill fractionation process. Depending on the phase one findings, the screen trials may focus on removing shives and any other bigger particles from the first main line refiner pulps. Then the screen accepts will further fractionated in the Hydrocylone to remove out the thick walled and unfibrillated fibres. This approach may enable stoppage of the secondary refiner, installing of screens and Hydrocylone fractionation units after the first main line refiner for industrial application.

- The study should to be accomplished by simulation of mill application through performing fibre and energy balance. We believe this work will provide vital information which will assist the mills in deciding on possible investment opportunities to improve product quality and energy efficiency.

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