Impact of High Power Ultrasound Treatment on Fiber Morphology and Effect of Hyper-Washing on Pulp and Paper Properties

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ABSTRACT

The pulp suspension is treated with high power ultrasound in order to evaluate the influence of ultrasound to fiber morphology and compared with conventional refining process, Jokro mill refining. The changes in fiber morphology are evaluated using a correlation analysis between the results obtained from automatic optical fiber analyses and selected suspension and paper properties. In doing so, already generated data material is also resorted. The effect of hyper-washing is also evaluated. The influence of high power ultrasound on fiber morphology (length of fibers, fibrillation, curl, wall thickness, and width), pulp properties (drainage resistance, water retention value) and paper properties (thickness, tensile strength, tear growth resistance) are discussed. The fibrillation of fibers and the thickness of paper sheets are seen to be increased with the ultrasound treatment of pulp suspensions. The amounts of small fibers are largely reduced after hyper-wash. Thickness also increases with hyper wash. However no significant changes are seen on other pulp and paper properties.

Key words: *ultrasound, cavitation, hyper-wash, fibrillation.*

Introduction

Ultrasound (US) is widely used in many industries and has wide range of industrial applications such as disintegration of biological, non-destructive testing or ultrasonic cleaning. When fluids or suspensions are treated with ultrasound, it causes different effects, among which the most important and exciting phenomenon is acoustic cavitation. Due to inadequate technology and equipment, the ultrasound technology is not employed in paper industries. With the progress in ultrasound technology, high power ultrasound technology evolved and, which can transmit high energy for different industrial applications.

Ultrasound causes modifications of fiber morphology which are beneficial to the papermaking process. The chemical composition of fiber is not modified by ultrasound treatment and the fibers retain their natural chemical characteristics. Physical changes include fibrillation of fibers without breaking them. This may be particularly useful with recycled pulps in which fibers have a previous history of mechanical refining. There is evidence that treatment with ultrasound reverses hornification (1-9), which is a big problem with recycled pulps, restoring the plasticity and strength of fibers which is lost during earlier processing. Overall, ultrasound has many potential applications in the paper manufacturing industry provided

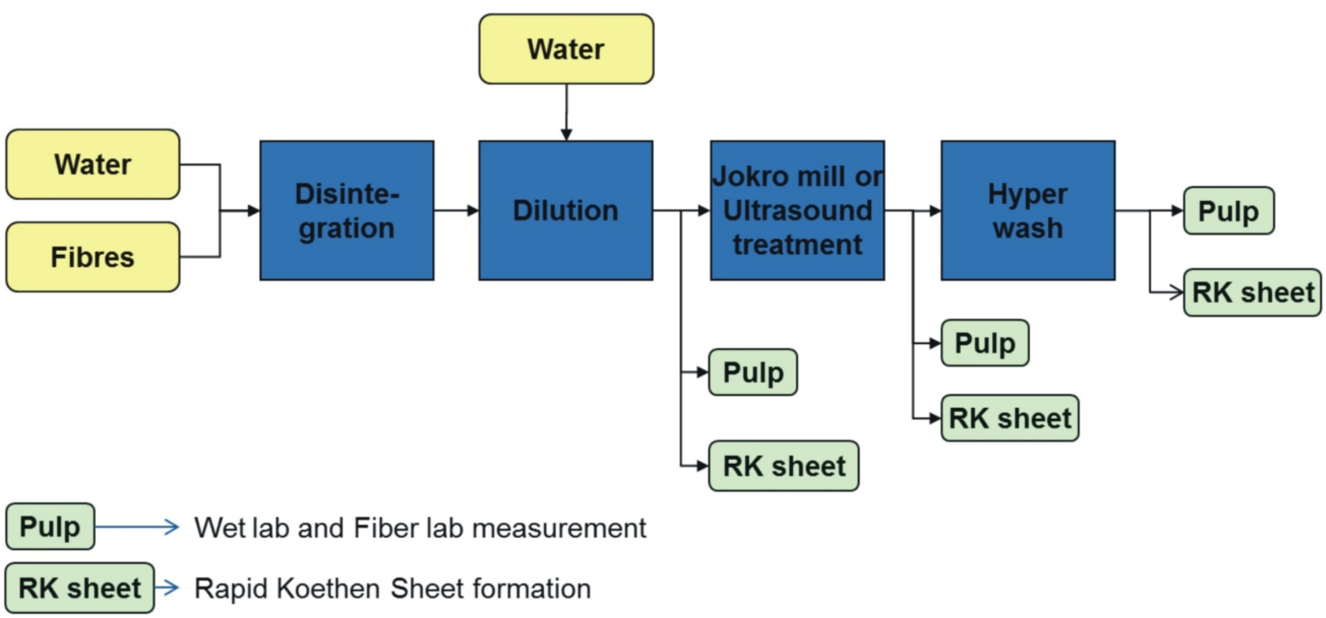

Figure 1 : Flow chart of methodology

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that US generators can be sufficiently scaled up and energy issues resolved (10-16). Refining in stock preparation, similar to pulp selection has a major impact on the quality of the paper subsequently produced. The aim of refining is to improve the strength values and to increase the volume of the paper to be made. In view of the importance of refining for the papermaking process, and the sharp increase in energy costs have induced papermakers to search for possibilities of significantly reducing the specific energy requirements of refining by the use of new technologies such as ultrasound.

Experimental

Materials and Methodology

In this work recovered paper pulp of grade 1.02 is used as a sample represented as AP below in results and discussion, which contains mixed papers and boards of various qualities (sorted) containing a maximum of 40% of newspapers and magazines. The sample is soaked in water overnight. Then the pulp suspension is disintegrated for 10 minutes at 3000 rotations per minute (rpm) in a standard pulp disintegrator (30 g of pulp in 2 liters). After disintegration, pulp is transferred to batch chest and diluted with water up to 8 - 10 liters. The pulp is either refined in Jokro mill or treated with ultrasound. A small amount of pulp is taken for wet lab measurements (mainly drainage resistance and water retention value) and for fiber lab measurements. A part of pulp is used for Rapid Koethen Sheet (RK sheet) formation of grammage 75 g/m^2 to measure the paper properties (mainly thickness, tensile strength, tear strength and apparent sheet density). The flowchart of the methodology is shown in back page:

Each time small amount of pulp was taken for wet lab measurements, fiber lab measurements and RK sheet formation. After this, the pulp was hyper-washed in Haindl-Mcnett classifier. The Haindl-McNett classifier is a laboratory device used to assess fiber size distribution. It consists of a series of tanks, typically four or five mounted in cascade and each tank has a progressively smaller screen mesh. At the beginning of the process, a prescribed amount of pulp is poured into the first tank, then a continuous water flow passes through series of tanks and an agitated pulp suspension is fractionated according to fiber/particle size. At the end of the process the desired fractions are collected at the bottom of the respective tank.

Wet lab measurements

The °SR and Water retention value (WRV) of each pulp sample is measured following standard ISO 5267-1:1999 and Merkblatt IV/33/57 respectively. Suspension with 5 gm dry mass from the batch chest is filled into a freeness mug. Then the suspension is dewatered using a filter paper and the pulp is removed from the filter paper and further divided into two parts of same weight. Then after centrifugation for 15 minutes at 3000 rpm, the pulp cakes are weighed and dried in the oven until dry mass is reached and the weight is taken down. Water retention value is determined.

Dry lab measurements

All tests are carried out at 23°C ±1°C and 50 ±2% relative humidity as per TAPPI standard. The paper properties are measured in dry lab using following standards:

- Thickness (ISO/DIS 534:2010)
- Tensile strength (ISO1924-2:2008)
- Tear resistance (DIN 53115)
- Apparent sheet density (ISO/DIS 534:2010)

Kajaani fiber lab measurements

A beaker containing the sample is placed in the sample unit. The analyzer gets mixed with the sample after the start command and it dilutes the sample to the correct consistency for measurement. The sample is then sucked in, so that it flows through the capillary. Length measurement optics (with Laser and Xenon light sources) monitors its passage through the capillary. When the fiber reaches the centre, the Xenon lamp flashes, the two cameras, length and cross-sectional cameras simultaneously capture an image of the same fiber. The cameras have different field of view and different resolution. The length camera has a resolution of 10µm. The cross-section camera has a resolution of 0.15µm and a smaller field of view that in most cases is too small to see the full fiber length. The image is then processed by the software, and results such as fiber length, fiber width, curl, cell wall thickness, cross sectional area, fiber volume index and fibrillation are calculated.

Results & Discussion

Based on the laboratory experiments various pulp properties are evaluated. These are interpreted in the following figures. In the figures, the values from three different processes are compared.

These are given as under:
AP-0 = Disintegrated recovered pulp (without any treatment)
AP-U = Ultrasound treated recovered pulp
AP-J = Jokro mill refined recovered pulp

Wet lab results

Drainage resistance (°SR)

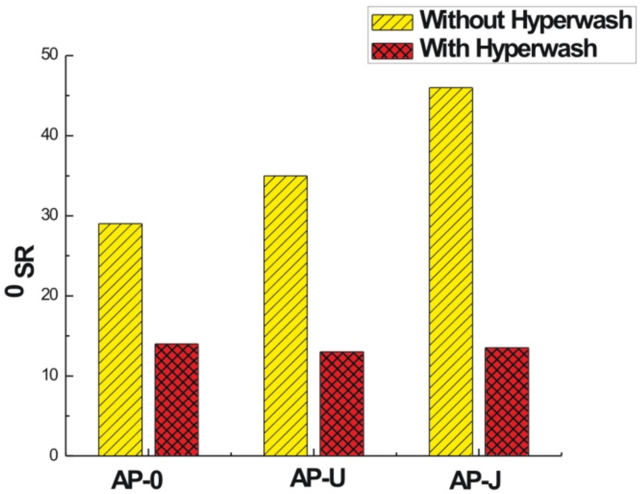

Figure 2: °SR (drainage resistance) values of RK sheet

From the figure, we can see that value of SR of recovered pulp with Jokro mill refining (without hyper-wash) is higher than the ultrasound treated recovered pulp (without hyper-wash). In contrast, hyper-wash shows almost similar value of SR for all the treatments. The hyper-washed pulps have much less value of SR than without the hyper-wash.

Water Retention Value (WRV)

Water retention value of Jokro mill treated recovered pulp

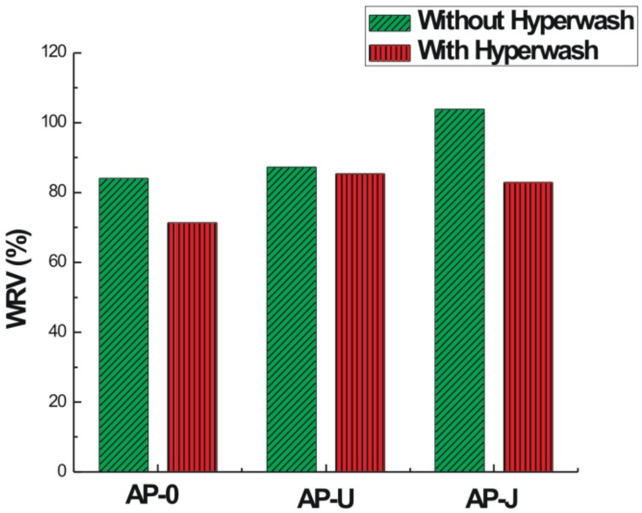

Figure 3: WRV values of RK sheet

(without hyper-wash) is higher than ultrasound treated recovered pulp (without hyper-wash). With hyper-wash shows little variation in WRV.

Dry lab results

Thickness

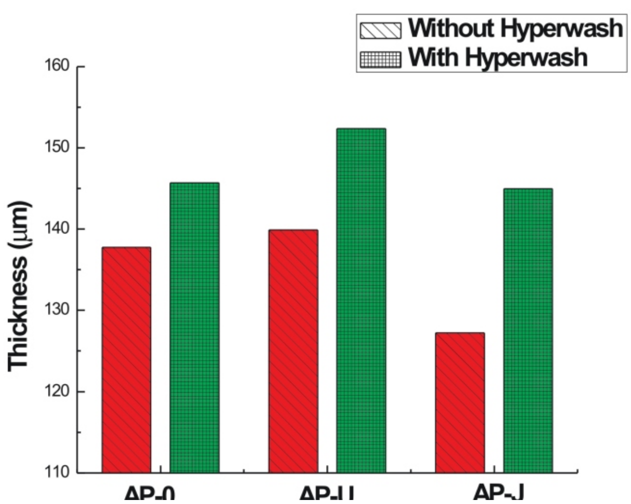

Figure 4: Thickness values of RK sheet

Thickness of RK sheet of recovered pulp with hyper-wash for both ultrasound and Jokro mill is much higher than without hyper-wash. Ultrasound treated recovered pulp sheets shows more thickness than Jokro mill.

Density

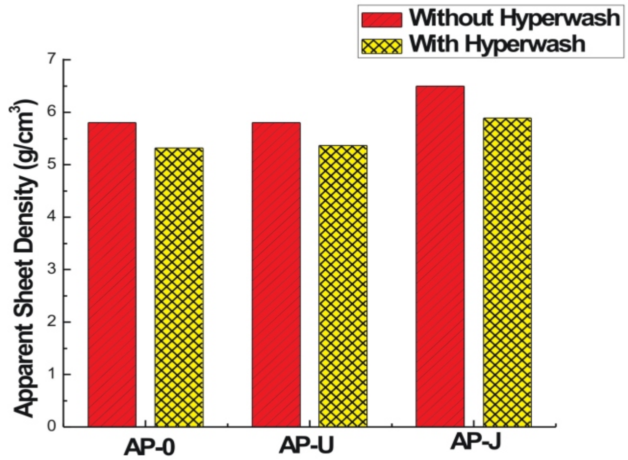

Figure 5: Apparent sheet density of RK sheet

Without hyper-wash shows little higher sheet density than with hyper-wash. Jokro mill sheet density is higher than the ultrasound.

Tensile strength

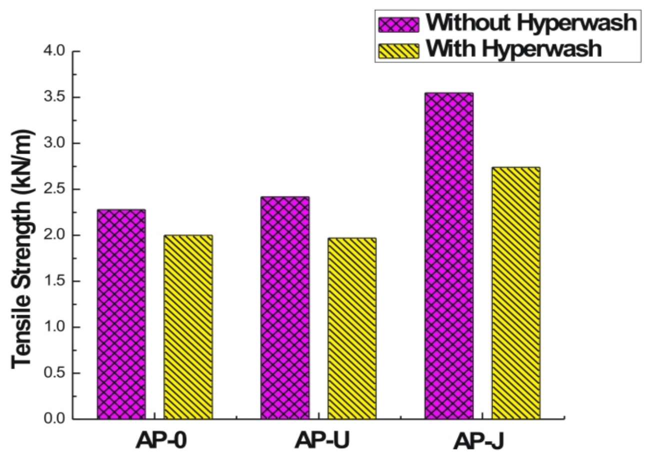

Figure 6: Tensile strength of RK sheet

With hyper-wash shows less tensile strength for both treatments than without hyper-wash. Tensile strength of Jokro mill is higher than the ultrasound.

Tear Resistance

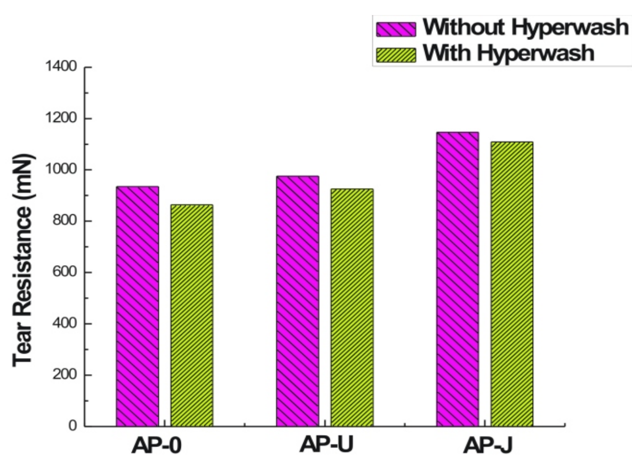

Figure 7: Tear resistance of RK sheet

Tear strength without hyper-wash for both the treatment is higher than with hyper-wash. Jokro mill shows higher tear growth resistance than ultrasound.

Fiber lab measurements

Fibrillation

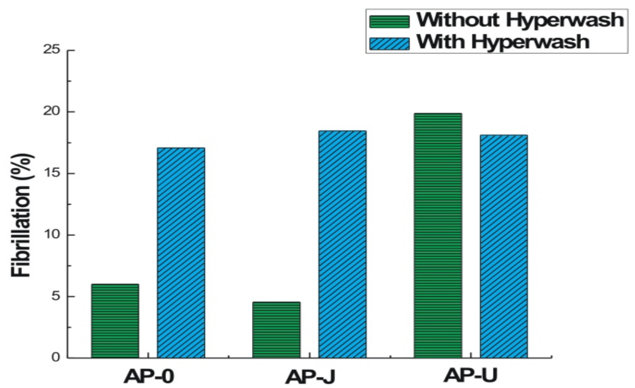

Figure 8: Fibrillation of the pulp

Fibrillation of hyper-washed disintegrated and Jokro mill treated pulp is much higher than unwashed pulp. But fibrillation of both hyper-washed and unwashed ultrasound treated pulp is similar.

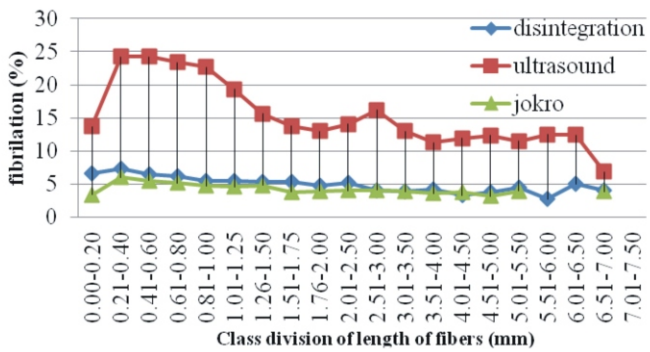

Figure 9: Fibrillation of disintegrated, ultrasound and Jokro mill treated pulp (without hyper-wash)

Fibrillation of recovered paper pulp treated with ultrasound shows very high fibrillation than recovered paper pulp refined in Jokro mill.

Average length of fibers

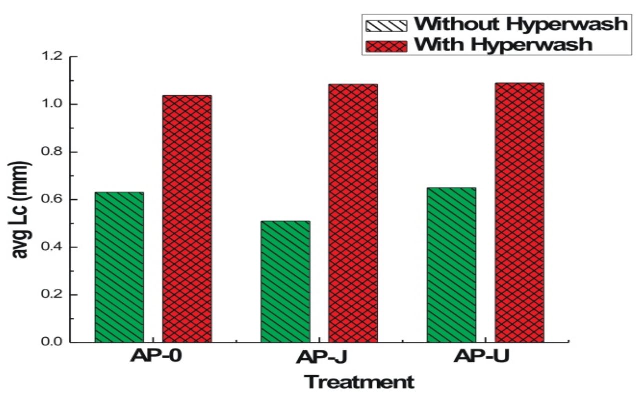

Figure 10: Average length of fibers

The average length of fibers of ultrasound treated pulp is similar to that of disintegrated pulp (without hyper-wash). The average length of fibers of pulp with hyper-wash is much higher almost double that of the unwashed pulp.

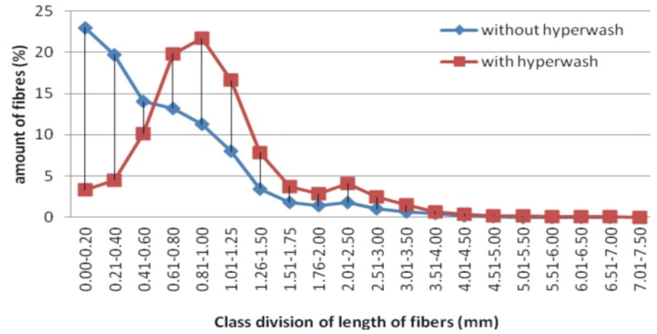

Figure 11: Fiber size distribution

From the above figure we can see that number of fibers of length smaller than 0.6 mm is more in unwashed pulp than hyper-washed pulp. This division of fibers according to fiber length is common in disintegrated pulp, ultrasound treated pulp and pulp refined in Jokro mill. Thus amount of fines is very little in hyper-washed pulp than unwashed pulp.

Width

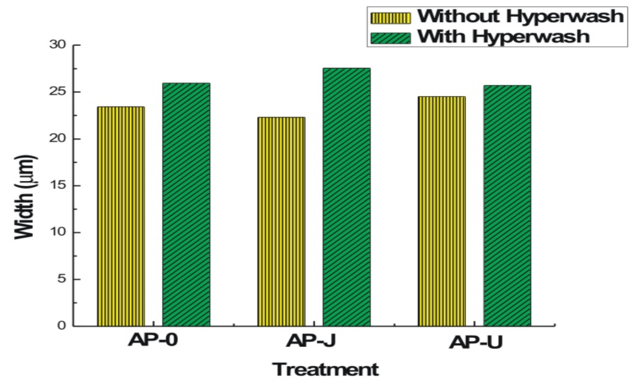

Figure 12: Width of fibers in the pulp

Width of ultrasound treated pulp without hyper-wash is higher than Jokro mill treated pulp. The hyper-washed pulp Jokro mill treated pulp has higher width than the hyper-washed ultrasound treated pulp.

Cell Wall Thickness

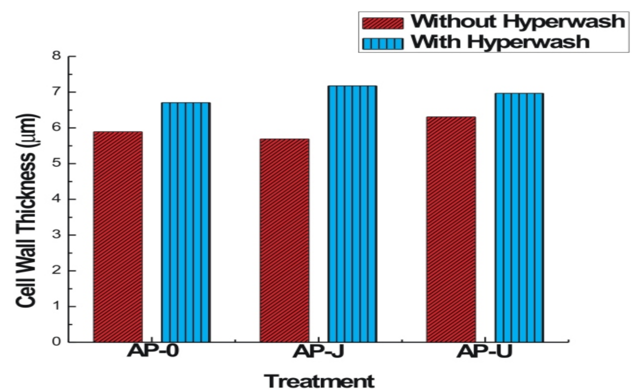

Figure 13: Cell wall thickness of fibers in the pulp

Cell wall thickness of ultrasound treated pulp without hyper-wash is higher than Jokro mill treated pulp. The hyper-washed pulp Jokro mill treated pulp has higher wall thickness than the hyper-washed ultrasound treated pulp.

Curl

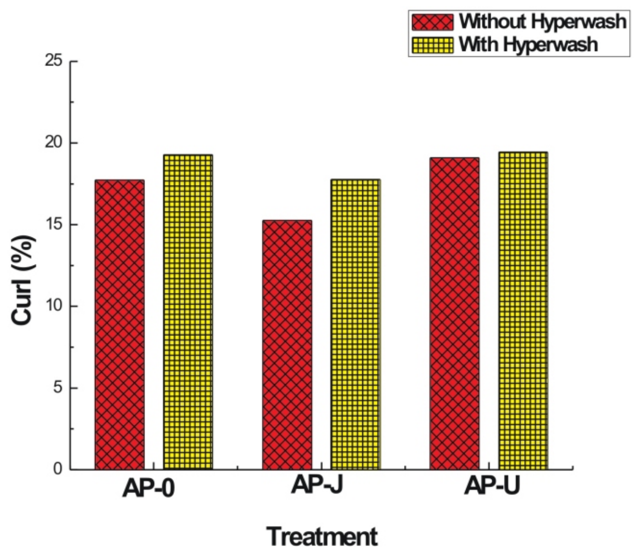

Figure 14: Curl of the fibers in the pulp

Curl of ultrasound treated pulp without hyper-wash is higher than Jokro mill treated pulp. The hyper-washed pulp Jokro mill treated pulps have better curl than the hyper-washed ultrasound treated pulp.

Conclusion

In the field of pulp preparation, ultrasound causes modifications to fiber morphology which are beneficial to the papermaking process. Ultrasound causes physical changes like fibrillation of fibers without breaking them. The average length of fibers remains the same with ultrasound treatment, thus length of fibers is not hampered with the ultrasound treatment**.** But the average length of fibers of ultrasound treated pulp compared to the average length of fibers of Jokro mill treated fiber is higher. The width of the fibers, the cell wall thickness of the fibers, the curl percentage also increases with ultrasound treatment.

Ultrasound shows great impact on the fibrillation for all the classes of length of fibers. Amount of fibrillation of fibers increases by more than double of what is achieved by Jokro mill treatment. Although for ultrasound shows no significant differences in fibrillation with Jokro mill refining with hyper-wash. The thickness of the paper sheets also increases with ultrasound treatment.

Impact of hyper-wash

The amount of fibers, with length less than 0.60 µm, is reduced by hyper-washing for both ultrasound treated recovered paper pulp and Jokro mill refined recovered paper pulp. Thus fines are greatly reduced.

The curl, fiber width and the wall thickness of fibers increase for long fibers with hyper-wash. Hyper-washing also has an effect on the thickness of the paper sheets as the thickness increases with hyper washing of pulp.

Hyper-wash also affects the fibrillation; particularly for Jokro mill refined recovered paper pulp and only disintegration of recovered paper pulp. The fibrillation is quite high with hyper-washing for Jokro mill refined recovered paper pulp and without any treatment (with just disintegration).

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