MORPHOLOGICAL COMPOSITION OF WEB-BREAK INDUCING SHIVES IN COMMERICAL NEWSPRINT PULP

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ABSTRACT

Web-breaks during paper production cause a serious inconvenience in production process and increase cost of production. Earlier studies indicate that web breaks occur at tensions far below the ultimate tensile strength values determined by tensile testing in the laboratory. It was also reported that most of the web-breaks were caused by shives (bundle of unseparated fibers).

In this paper the result of an investigation on the morphological composition of shives in commercial newsprint pulp as a whole and those causing web-breaks is presented. It was found that 93% of the shives were earlywood and only 7% latewood. It was also determined that latewood shives are the main causes of web-break. More than 90% of the web-break inducing shives were found to be latewood shives.

INTRODUCTION

In softwood there are two morphologically different types of fibers known as earlywood (springwood) and latewood (summerwood) fibers . Fig. 1 and Fig. 2 are images of the cross-sections of typical earlywood and latewood fibers respectively taken by Scanning Electron Microscope. Earlywood fibers are short and have thin fiber walls whereas latewood fibers are stiff, longer and stronger and have thick walls [2]. Their proportions in soft wood differ depending upon factors which influence growth of wood.

The earlywood and latewood regions of pulpwood respond differently to repeated compressive and shear forces, which are believed to be the cause of fatigue failure of the wood chips in a disc refiner. Disc refining process takes place in two stages. In the first stage, known as separation, chips are reduced into smaller wood particles: shives and fibers. In the second stage, known as fiber development, the separated fibers and fiber segments are further refined to produce papermaking pulp [4].

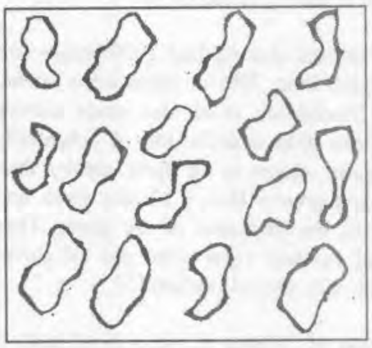

Figure 1 Crsoss-section of disintegrated earlywood fibers *(Edited, Scanning Electron Microscope Image)*

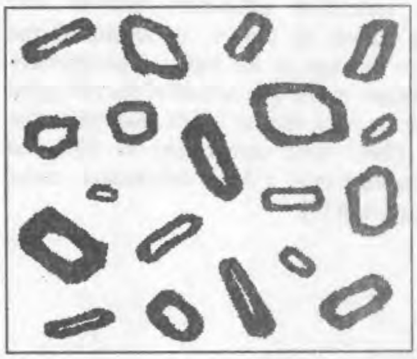

Figure 2 Crsoss-section of disintegrated latewood fibers *(Edited, Scanning Electron Microscope Image)*

Though in commercial newsprint pulp processing most of the fibers are separated, a small amount (≈1%) of shive (*bundle of unseparated fibers*) will usually be found in the final product. This small amount of shive however affects the quality of the pulp considerably. Both the producer and consumer of the pulp are affected by this problem. One of the major problems caused by shives is web break. Sears et al reported that web breaks occur at tensions far below the ultimate tensile strength values determined by tensile testing in the laboratory[7]. More than 3200 breaks were investigated and in more than 98.5 % of theses breaks shives were found. They also observed that the shives were poorly bonded to the surrounding fibers. Those shives of approximately cross machine orientation, length between 3-4 mm and thickness equal to a considerable fraction of the web thickness were reported to constitute weak spots at which stress concentration, development of cracks and web failure may occur [7].

Adams and Westlund also studied 2000 breaks and showed that more than 70% of them were caused by shives[1]. MacMillan et al also made similar studies and came with a definition of potentially harmful newsprint shives to be those greater than 3.5 mm long and greater than 0.12 mm wide, and approaching half the thickness of the paper. They also mentioned in their report that not all shives cause break but only a small portion [5].

The composition of shives in news print pulp is believed to depend on the relative tendency of the two types fibers to separte easily by the forces in the disc refiner. This tendency to separate easily is known as separation efficiency. Salmén and Dumail, as shown in Fig. 3, demonstrated the difference in response to the repeated compressive and shear forces in the disc refiner of the two types of fibers by showing that at stress level when the earlywood fibers were compressed to 50% the latewood reached only a 5 % deformation under cyclic compression [6].

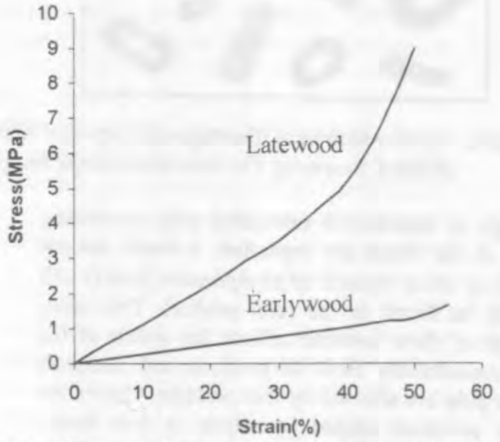

Figure 3 Stress and strain curves for latewood and earlywood samples compressed at 150^0C in ethylene glycol *(From Salmen and Dumai [13])*

Hickey and Rudie also showed that there is a preferential energy absorption by earlywood fibers in cyclic compression [3]. They expressed this by showing that the temperature increase due to cyclic compression of the earlywood portion of the wood was considerably greater than the latewood portion as shown in Fig. 4. They also showed that most of the compression (strain) is absorbed by the earlywood portion of the wood. Due to these different responses to cyclic compression of the two kinds of fibers it is expected that the earlywood and latewood regions of the wood may have different separation efficiency. Therefore it is highly probable that the morphological composition of the shives is different from the original composition of the fibers in the pulp.

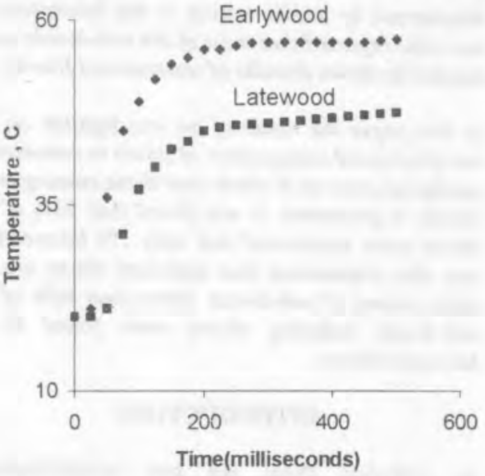

Figure 4 Temperature record of the samples tested at room temperature and 15Hz *(From Hickey and Rudie[13])*

Though there is a strong evidence that shives are the main cause of web-break there is only little information about the morphological composition of these shives. This paper focuses on determining the morphological composition of shives in commercial newsprint pulp as a whole and those that trigger web break. The main questions the author tries to answer in this paper are:

- What is the morphological composition (early wood-latewood composition) of shives in commercial newsprint pulp?
- What is the morphological composition of those shives that cause web-break during paper production? Is any one of the the two types of fibers dominant?

Why does only a small portion of the shives cause web-break?

EXPERIMANTAL PROCEDURE

The objective of the experiment is to determine the cross-sectional measurements, lumen perimeter, lumen area, and filled area of:

- Disintegrated fibers in the web-break analysis pulp
- Shives in the web-break analysis pulp
- Web-break inducing shives in the analysis pulp

Disintegrated Fibers in the Analysis Paper

A sample of newsprint pulp was used to produce paper under standard laboratory condition for web-break analysis. Part of this test paper was disintegrated according SCAN -C 18 : 65. A sample of the fibers was suspended in water at low consistency and bundles of paralleled fibers were prepared using a special grid. These bundles of parallel fibers were freeze dried, embedded in epoxy and cured. These preparates were then ground and polished perpendicular to the fiber axes. They were carbon coated and digitized, and binarized electron micrograph were taken by Scanning Electron Microscope (SEM). All micrographs had magnification of 250×.

The images were edited to remove dirt and broken fiber parts. They were, then analyzed by image analyzing software (Kontron Vidas) and the cross sectional measurements: lumen perimeter, lumen area and filled area were taken.

Total Shives in Rupture Analysis Paper

Another sample of the above mentioned newsprint paper was disintegrated according SCAN -C 18 : 65. The shives in the pulp were separated from the fiber by Summerville shive separator. The separated shives were suspended in water at low consistency and bundles of paralleled shives were prepared using a special grid. These bundles of parallel shives were freeze dried, embedded in epoxy and cured. These preparates were then ground and polished perpendicular to the fiber axes. The images were prepared for measurement in the same procedure as the previous. The images were edited to remove dirt, single and broken fibers. The shives were split in to single fibers on the image. Then the images were analyzed by image analyzing software (Kontron Vidas) and cross sectional measurements were taken.

Web-Break inducing Shives

Web-break inducing shives were identified *(appear as bumps in strained paper)* for the fracture load strains of 30.5 Tensile Index (kNm / kg) at 75% relative humidity. The identified cites were carefully marked and the middle of the shive length was marked. The shive was carefully removed, cut at the center and they were then embedded in epoxy and cured. The cross-sectional images of the shives and necessary measurements were taken in the same procedure as before.

CLASSIFICATION METHOD

Image analyzer software is used to measure the lumen perimeter, lumen area and filled area of the edited images of the Scanning Electron Microscope. A characteristic size, which can be calculated from the measured data, was defined to classify the fibers as earlywood and latewood. Since a fiber can be earlywood or latewood regardless of its shape (whether collapsed or not) the characteristic size should be able to predict the morphology irrespective of the fiber shape. To accommodate this, the characteristic size is defined for one common shape and a circular cross-section of the same fiber perimeter and lumen perimeter as the original fiber was chosen.

The characteristic size z is then defined for the circular cross section as the ratio between the wall area and filled area (lumen area + fiber wall area). The characteristic size varies between 0 and 1; higher values show latewood fibers and lower values show earlywood fibers. Fig. 5 shows some typical earlywood and latewood fibers and the corresponding z vales and lumen perimeter. The parameter z is calculated from cross sectional measurements by the following formula *(See Appendix for Derivation)*.

$$Z = 1 - \left(\frac{P_l}{P_f} \right)^2$$

p_l = lumen perimeter,
p_f = fiber perimeter,
z – characteristic size

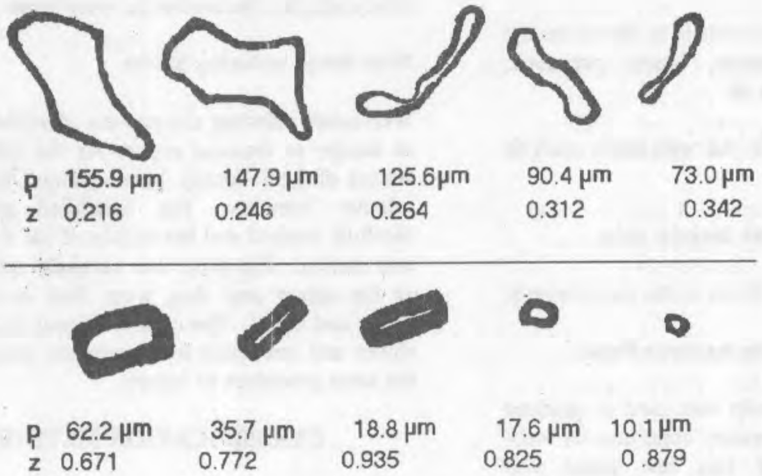

Figure 5 Typical earlywood and latewood fibers with corresponding lumen perimeter (P_1) and characteristic size z.

The characteristic size z was tested for many samples and proved to be very effective, and accurate in characterizing fibers as earlywood and latewood.

The distribution of z in the whole fiber population represents the two types of fibers and is represented by the sum of two normal (Gaussian) distribution curves, as shown in Fig. 6., one representing the eralywood and the other the latewood. This distribution is easily found by a curve fitting software called Peakfit which finds the best peak-fit curve with a given curve type (e.g. Gaussian) by iteration (Fig. 6). The program generates two sets of curves. At the top the total distribution curve, which is the sum of the two normal curves, is drawn. At the bottom the two normal curves constituting the upper curve are drawn. It also indicates the mean value of the two normal curves as shown in Fig. 6. The left normal-curve with a small mean z value (0.336) is the distribution for earlywood fibers and the right one with a larger mean z value (0.672) is the distribution for latewood fibers. The areas under the two left and right curves represent the fractions of the earlywood and latewood fibers and are automatically generated by the program in a separate table.

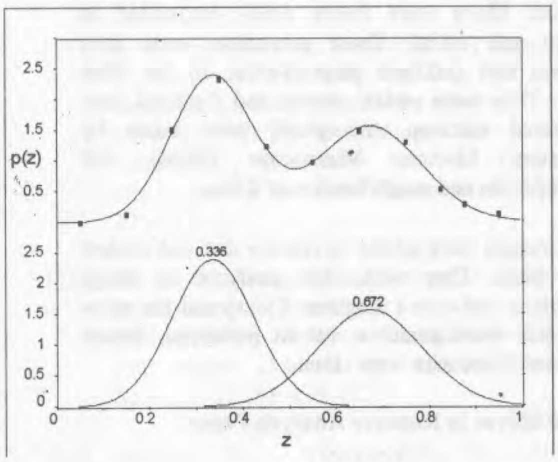

Figure 6 Distribution of earlywood and latewood fibers

This method of determining the composition of fibers is used throughout this paper to determine the morphological composition of the disintegrated fibers, the fibers in the shives, and the web-break inducing shives.

RESULT AND DISCUSSION

Morphological Composition of the Disintegrated Fibers

The morphological distribution of the disintegrated (separated) fibers in the web-break analysis pulp, as represented by the distribution of the characteristic size z, is as indicated in Fig. 7. The purpose of this distribution is to estimate the morphological composition of the fibers in the original newsprint pulp. Since the shive is very small (≈1%) as compared to the disintegrated fiber we can estimate the composition of the whole fiber population from the composition of the disintegrated fibers.

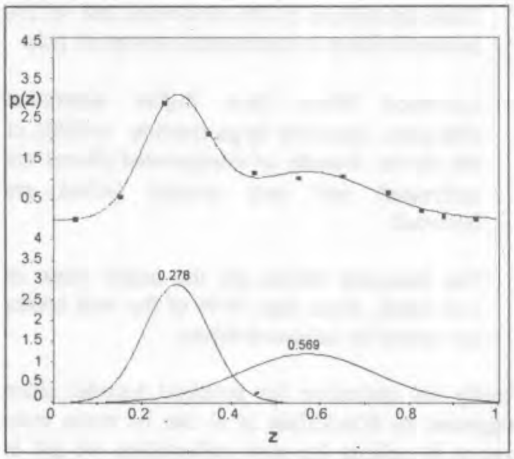

Figure 7 Distribution of z for fibers in the shives as a whole.

As discussed earlier the left curve at the bottom with mean z = 0.278 represents the distribution of the earlywood and the right curve with mean z = 0.569 represents the late wood. The percentage distribution of the early wood and late wood fibers in the whole population is determined from the area covered by the respective curves representing the two population. It was found that 53.8 number % of the disintegrated portion are earlywood fibers and 46.2 number % are latewood fibers. Hence we can take this as approximate fractions of the whole fiber and shive population..

Morphological Composition of the Whole Shive in the Sample

The distribution of z for the fibers in the shive was obtained as shown in Fig. 8. This gives us the morphological distribution of the whole shive population (Web break inducing and non web-break inducing shives). It was found that 93.0 % of the total shive found in the paper were earlywood shives and only 7% were latewood shives. As it can be observed from Fig. 9 earlywood shives are composed of fibesr with thinner fiber walls than latewood fibers shown in Fig. 11.

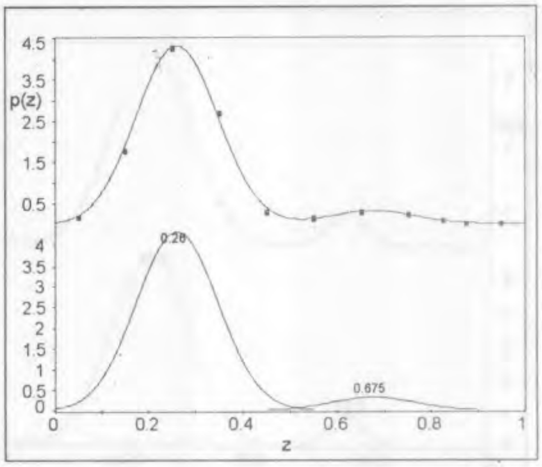

Figure 8 Distribution of earlywood and latewood fibers in the web-break inducing shives

As it was indicated from the previous result around 46.2% of the whole fiber population was latewood fibers. Since only 7% are found in the shive we can determine that the separation efficiency of the latewood fiber is high and only few are found in form of unseparated bundle (shive).

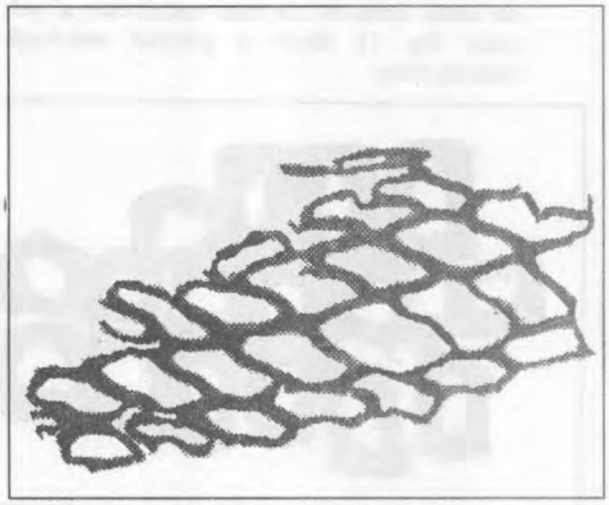

Figure 9 Crossection of an earlywood shive *(Edited, SEM image)*

Morphological Composition of the Web-Break inducing Shives

Thirty cross-sectional images of web-break inducing shives were studied. The distribution of the mean value of z of each web-break inducing shive was found to be as shown in Fig. 10.

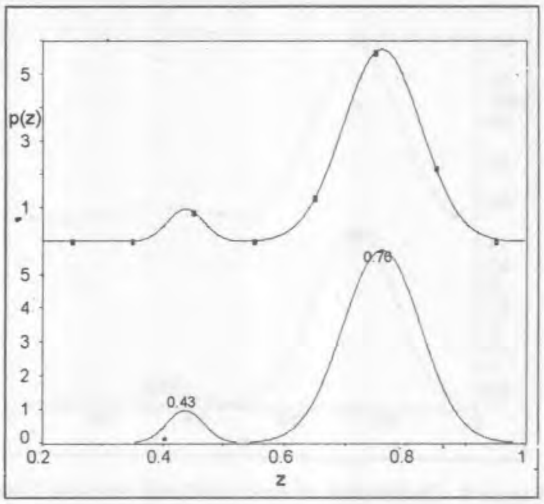

Figure 10 Distribution of earlywood and latewood fibers in web-break inducing shives

Analysi of the distribution represented by Fig. 10, using peak-fit, gives that 92.3% of the web break initiating shives are late wood which corresponds to 27 of the 30 web-break inducing shives under the test. It is therefore evident from this result that late wood shives are the main contributors of web break. Fig. 11 shows a potential web-break inducing shive.

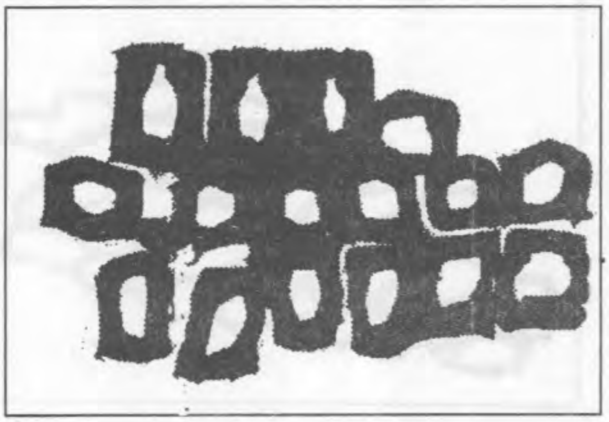

Figure 11 Cross-section of a latewood shive *(Edited, SEM image)*

The result also indicates why only minute part of the shive causes web break. Because of their higher separation efficiency late wood shives are found only as small fraction of the whole shive (only 7%). Out of these small fraction again only those that have shive length greater than 3.5 mm are the potentially harmful. And out these only those that have cross-machine orientation are harmful. Therefore it is reasonable to expect only minute fraction of the shives in the pulp to be the web-break inducing shives.

CONCLUSION

From this study the following conclusions can be made:

- There are around 53.8% earlywood and 46.2% latewood fibers in commercial newsprint pulp.
- Latewood fibers have higher separation efficiency, therefore large fraction (≈93%) of the shives *(bundle of unseparated fibers)* are earlywood and only around (≈7%) are latewood.
- The latewood shives are the major cause of web-break. More than 90% of the web breaks are caused by latewood shives.

Finally the definition for potential harmful shive suggested by MacMillan et al can be made more precise by adding the new information we get in this paper. Potentially harmful shives are those **late wood shive** that are 3.5 mm long and 1.5 mm wide and have cross machine orientation.

RECCOMENDATION

Web-break during paper production, and printing causes a serious inconvenience in the production process and incurs a significant amount on the production cost. Most the web-break is now known to be caused by latewood shives. Hence future studies should focus on reducing the amount of the latewood shives in the pulp.

REFERENCES

[1] Adams, J.R. and Westlund, K.B., " Off-Line Testing For Newsprint Runnability", Printing and Graphic Arts Conferance, 1982

[2] Hattula,T, Mannströ, "Wood Structure as a Limiting Factor in Mechanical Pulping", Int. Mech. Pulp. Conf., 1981.

[3] Hicky*, K.L. and Rudi.A.W, "Preferntial Energy Absorption by Earlywood by cyclic compression", Int. Mech. Pulp. Conf. (poster) 1993.

[4] Law, K.N., Yang*, K.C., and Valade, "Fiber Development in Thermo Mechanical Pulping : Comparison Between Black Spruce And Jack Pine", 83rd Annual Meeting , Technical Section Cppa.

[5] MacMillan, F.A., Farell, W.R. and Booth, K.G., "Shives in News Print: Their Direction,Measurements and Effects on Paper", Fifth. Intl. Mech. Pulp. Conf., 1964.

[6] SalmeN, L., Dumail, J.F., Uhmeier, J.F., Compression Behavior of Wood in Mechanical Pulping, Int. Mech. Pulp. Conf.1997.

[7] Sears, G.R., Tyler, R.F., and Denzer C.W., " Shives in Newsprint: The role of Shives in Paper Web Breaks", Fifth. Intl. Mech. Pulp. Conf., 1964.

APEENDIX

Derivation of Z

All parameters are referred to a circular cross section of the same lumen and fiber perimeter.

$$Z = \frac{Wall\ \ area}{filled\ \ area}$$

But

$$filled\ area = lumen\ area + fiber\ wall\ area$$

Hence

$$Z = \frac{filled\ \ area\ - lumen\ \ area}{filled\ \ area}$$

Taking the equivalent circular measurements

$$Z = \frac{\pi\,(R_f)^2 - \pi\,(R_l)^2}{\pi\,(R_f)^2}$$

$$Z = 1 - \left(\frac{R\,l}{R\,f}\right)^2,$$

Where R_l and R_f are the radius of the lumen and the fiber respectively

Therefore

$$Z = 1 - \left(\frac{P\,l}{P\,f}\right)^2$$

Z= Characteristic Size

P_l= *Lumen perimeter*

P_f= *Fiber perimeter*