

# An Effective Method to Produce High Quality Fiber Fines

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## ABSTRACT

This work demonstrates that a pulp, which is almost pure fines, can be effectively produced in a laboratory by intense refining, having properties comparable to fines collected by the conventional method of classification and sedimentation. The properties of these fines made at different refining levels were studied by comparing the fines with the classified old corrugated container (OCC) fines and classified virgin pulp fines. The experimental results show that the quality of manufactured fines is slightly better than classified virgin fines and is much better than classified OCC fines in improving the mechanical strength properties of handsheets. This work shows that mechanical properties of sheets made from OCC pulp can be improved by adding clean manufactured fines.

## KEYWORDS

Fines, Never dried fines additions, OCC, Strength properties

## INTRODUCTION

It has been recognized for a long time that fines significantly influence the wet end chemistry and operation as well as the mechanical strength properties of paper for two major reasons. First, since the swelling ability of fines is about twice as large as that of fibers (1), fines can absorb more water

and are more flexible than fibers. Thus, fines easily enter bonding areas, fill voids and "glue" fibers together. Large interfaces among air, water and fines lead to a higher Campbell pressure and significantly increase relative bonded area and bonding strength, resulting in higher mechanical properties (breaking length, burst index, ring crush index and Scott bonding). This has been demonstrated by Gartshore (2), Corson (3), Fjerdingen and Houem (4) and Zhang et. al. (5). Second, since the surface area of fines is 4.5-6.5 times greater than that of fibers (1), fines can adsorb much more chemical additives than fibers. Although fibers and fines have similar chemical components, the difference in physical/chemical behavior between fines and fibers results from the high adsorptivity of fines. A small quantity of fines with a large adsorptive potential may dominate wet end chemistry and manufacturing operations. Therefore, the production of paper and ultimate quality are determined largely by interactions among fines, fibers, and additives through colloidal chemical forces, dependent on the quality and concentration of fines, and fines retention (6-12, 16).

Currently, the recycled paper industry faces several problems. Two important problems are mechanical strength loss and low machine runnability due to an accumulation of recycled fines. Fines are generated as a result of refining secondary pulp to develop strength properties. These problems are generally attributed to a reduction in the swelling ability and bonding ability of recycled fines and fibers due to their hornification and chemical contamination. In particular, some chemicals, such as starches, wet and dry strength agents, sizing agents, retention aids and fillers, used during manufacturing of the original paper, become a liability in the recycling process. These chemically contaminated and recycled fines accumulate in the whitewater, interfere with chemical additives, increase cationic

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demand, and reduce the water removal capacity in the forming, pressing and drying sections. Also, these fines may deposit on the felts, press rolls and drying cans diminishing the productivity of the paper machine. Efforts to solve these productivity problems are currently the subject of numerous research efforts.

In a laboratory, fines are usually separated from pulp using a fiber classifier. Pulp is classified through a 200 mesh screen collecting the fines in the filtrate, which is concentrated by decanting clarified water after sedimentation by gravity for 48 hours (Waterhouse and Omori (13), Richardson (14), Retulainen et al. (15), Zhang et al. (5)). This classification. In addition, a large amount of filtrate has to be collected and settled. If the Clark

proach of adding manufactured fines is explored in this investigation. Practical and economical issues need to be addressed as this new approach is shown to be effective.

## EXPERIMENTAL

### (1) Pulps

Clean old corrugated containers (OCC) were obtained from a paper recycling mill. The pulp was soaked in distilled water overnight, then disintegrated in a slush maker for 20 minutes at a temperature of 85° C and a pH value of 10, adjusted

All the fines in this report refer to pulp that has

- f) Refining was stopped for 30 minutes and an additional 50 ml de-ionized water was required after each 25,000 revolutions to prevent the PFI mill from overheating.

*Overheating of the sample during the refining process required that the refining process be interrupted at intervals to let the mill cool and to adjust the consistency to counter the evaporation that occurred during the interval.*

The fines production versus refining level is shown in Figure 1. From this figure, it can be seen that the fines concentration reaches 95%, when the refining level is above 120,000 revolutions. These fines were used later without further separation. Hence, the manufactured fines described in this report are actually pulps rich in fines. Using this technique, it takes about three hours (including the cooling time incorporated in the refining process) to produce 30 grams pulp that has about 95% fines.

### (3) Drainage time test

In general, this test followed TAPPI standard T221. However, the standard and the formula used in the calculation of drainage time are for the handsheets with a basis weight of 60 g/m<sup>2</sup>. The test is inaccurate when the pulp has a high freeness. For example, when the pulp has a freeness of 700 CSF, the drainage time is 4 s. When the pulp is refined to a freeness of 650 CSF, the drainage time is 4.1 s. The increase of only 0.1 s may be within an experimental error if the test is carried out manually. In the present experiment, the handsheets with a basis weight of 150 g/m<sup>2</sup> were used to simulate paperboard. For the same change in freeness from 700 to 650 CSF, the difference in drainage time for these two pulps was 1.2 s, an order of magnitude higher



**Figure 1.** Effect of PFI mill revolutions on fines production (200 mesh).

than the test for 60 g/m<sup>2</sup> sheets. The effect of grammage on drainage time for the OCC pulp is illustrated in Figure 2. It can be seen that the higher the grammage, the greater the difference between the drainage time of pulps. In the testing, the temperature was controlled at 20 ± 0.5 °C and the basis weight was controlled at 150 ± 1.5 g.

### (4) Swelling level test

The technique of solute exclusion is used to test the swelling ability of pulp and fibers [1, 8]. The swelling ability of fines is determined using the additive rule:

$$F_p = (1 - C_{200}) * F_f + C_{200} * F_{200} \quad (1)$$

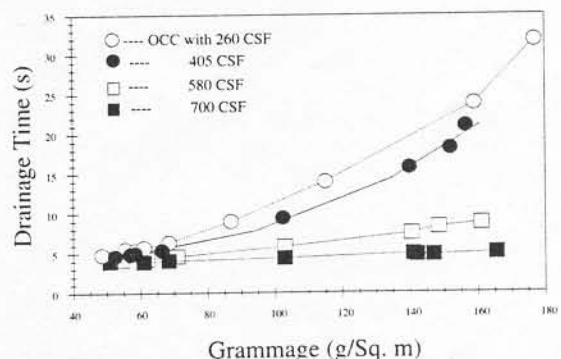
Where,  $F_p$ ,  $F_f$  and  $F_{200}$  were the swelling levels of pulp, fibers and 200-mesh fines, respectively.  $C_{200}$  is the fines fraction in the pulp. To test the swelling level of manufactured fines, the fines are added to the long fiber. The swelling level of the mixed pulp and of the long fiber allows the swelling level of fines to be calculated.

### (5) Retention aids

Cationic polyacrylamide from AXE or Astro X101 cationic starch from Penford Products Co. are used as a retention aid. The starches are cooked at 1% concentration and at a temperature of 95 °C for 25 minutes. During cooking, the starches are stirred continuously. A dosage level at a concentration of 15 lb/ton (0.75 %) for starch or a concentration of 0.75 lb/ton for polyacrylamide is used.

### (6) Handsheets

All handsheets were made in a British handsheet mold and air-dried.



**Figure 2.** The dependence of drainage time on the grammage of OCC sheets.

## RESULTS AND DISCUSSION

### 1. Comparison between manufactured fines and classified virgin fines

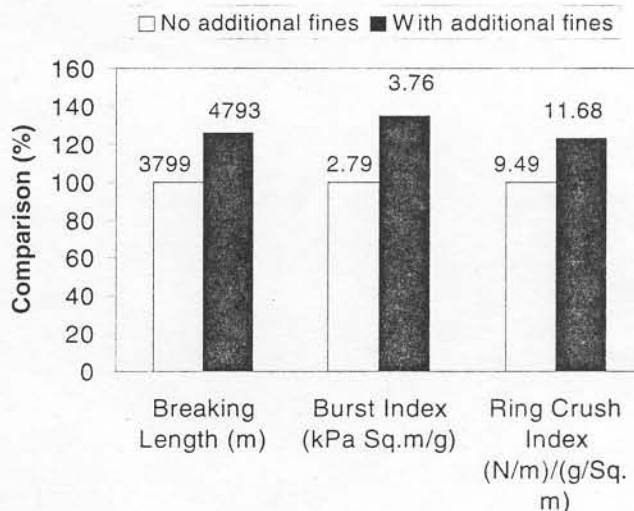
Virgin unbleached never-dried Kraft pulp from pine refined to 7,000 rev. in a PFI mill contained 15.3% classified fines. Handsheets were made from this pulp. Long fibers were also separated from the same pulp. Then manufactured fines, refined to 150,000 rev., were added to the long fibers at a fines concentration of 15.3%. This procedure replaced the classified fines in the pulp with the manufactured virgin fines. Handsheets were made and tested for mechanical properties.

It is evident from Table 1 that the ring crush index and burst index of the sheet with manufactured fines are the same as those of sheet with classified fines. The breaking length of the former sheet is slightly higher than the latter. It is noted that the pulp with manufactured fines has a lower drainage time than that with classified fines although the two pulps have the same fines concentration. If drainage times for both pulps are adjusted to be the same by adding more manufactured fines to the sheet, the sheet with manufactured fines will be expected to have better mechanical properties. Therefore, the quality of manufactured fines is comparable to or slightly better than virgin classified fines.

The better quality of manufactured fines is also reflected in swelling ability. It is observed that the swelling level of manufactured fines refined to 120,000 revolutions is 7.9 g/g, compared to 5.5 g/g for the classified virgin fines. The results are reproducible. Both values obtained in the experiment are slightly different from those in reference (1), where the Na ion exchange in sample preparation was used (10). These results are not surprising as manufactured fines also contain 5% well fibrillated fibers.

### 2. The effect of additional manufactured fines on the OCC handsheets.

Figure 3 compares mechanical properties of sheets prepared from washed and refined OCC pulp with 4.3% additional manufactured fines (filled bars) and unwashed OCC pulp containing 4.5% fines (open bars). In this figure, the manufactured fines were produced by beating never-dried virgin Kraft pulp to 120,000 revolutions, and the washed OCC pulp was beaten to 3,000 revolutions and contained 4.5% fines. When the manufactured fines were added to the beaten OCC pulp, the breaking length was increased by 26%, burst index by 35% and ring crush by 23%. It was expected that the additional fines could improve the mechanical strength of sheet since the original OCC pulp had a low concentration of fines at 4.5%. However, it was surprising that the



**Figure 3.** The breaking length, burst index and ring crush index of the OCC handsheets with 4.3% additional manufactured fines (filled bars) compared with those of the OCC sheet without additional fines (open bars). The OCC pulp was beaten to 3,000 revolutions and had an initial fines concentration of 4.5%. All data for the sheet without additional fines are scaled to 100%.

**Table 1.** A comparison between the handsheets with fines replaced by the manufactured fines and those without fines replacement.

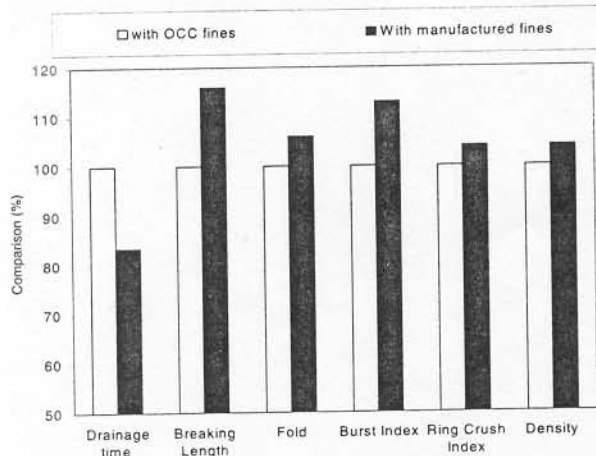
Sample	Description	Drainage time (s)	Burst (PSI)	Ring Crush (lb)	Breaking Length (m)	Ring Crush Index (Nm/g)	Burst Index (Kpa. M <sup>2</sup> /g)
Original fines	Virgin pulp refined to 7000 rev. + polymer	14.24	147.4	85.3	7688	14.6	5.9
Replaced fines	Long fiber + 15.4% manufactured fines + polymer	12.25	142.6	82.2	7878	14.5	5.9

improvements in mechanical strength were so remarkable.

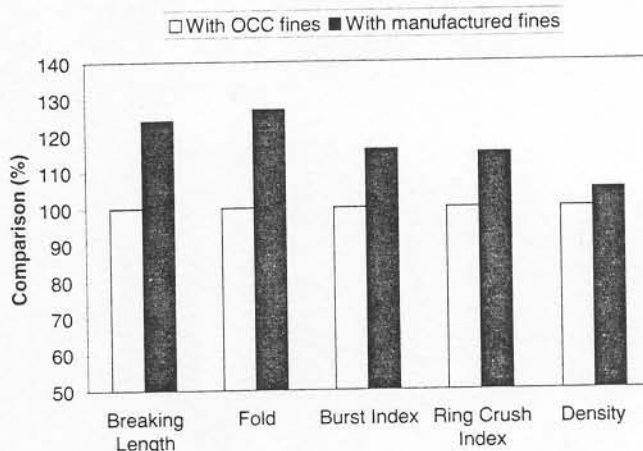
### 3. A comparison between manufactured fines and classified OCC fines

Figure 4 compares the drainage time, mechanical properties and densities of sheets, when 10% manufactured unbleached Kraft fines and 10% classified OCC pulp fines, respectively, are added to OCC long fibers. These long fibers are separated from OCC pulp beaten to 267 CSF in a Valley Beater and collected following the procedure described in the experimental section. It can be seen from the figure that the paper containing manufactured fines (filled bars) had better mechanical properties and higher density than that containing the classified OCC fines. It is interesting that the pulp with manufactured fines had a drainage time of 14.69 s, which was about 3 s faster than the pulp with classified OCC fines. The freeness was 40 CSF higher than the former pulp.

When the OCC pulp, with manufactured fines, was adjusted by fines addition to have the same drainage time as the pulp with the classified OCC fines, 13.5% manufactured fines must be added to the OCC long fibers. The mechanical properties of the resulting sheet are shown in Figure 5. For comparison, the data for the sheet with classified fines in Figure 4 are re-plotted in Figure 5. In this case, the breaking length, fold, burst index, ring crush index and density are respectively 23.5%, 27%,



**Figure 4.** A comparison of pulp and paper properties of handsheets made with manufactured fines and classified fines. Manufactured fines from beating never-dried virgin Kraft pulp to 120,000 revolutions (filled bars) and classified fines (open bars) were respectively added to the long OCC fibers. In the two groups of sheets, the fines concentrations are the same.



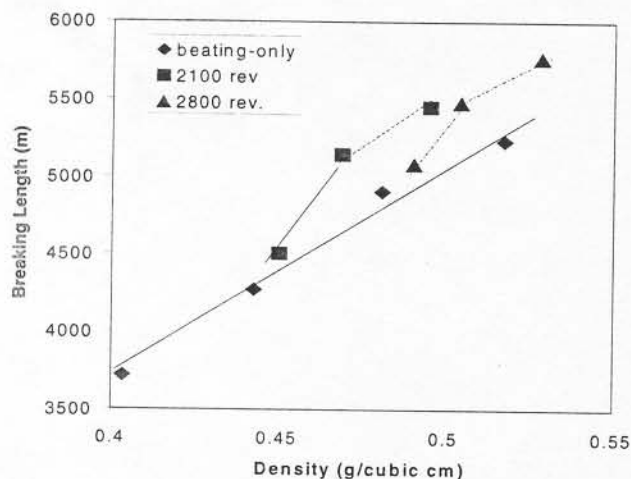
**Figure 5.** A comparison of paper properties of handsheets made with manufactured fines and classified fines. The same fines as in Figure 4 are added to the OCC long fibers, resulting in the same drainage time in the final pulps. For this purpose, 13.5% manufactured fines and 10% classified fines are required, respectively. Much better mechanical properties in the paper with manufactured fines are obtained.

16.3%, 14.9% and 5.4% higher for the sheet with manufactured fines than for the sheet with classified fines.

4. The comparison of handsheets prepared from washed OCC pulp with additional manufactured fines and refined OCC pulp.

Figure 6 shows the relationship between the breaking length and the density of handsheets produced with the addition of manufactured virgin fines (solid squares and triangles) and for handsheets produced at different refining levels (solid diamonds). For the fines addition sequence, OCC pulp was first refined to 2,100 revolutions (solid squares) and 2,800 revolutions (triangles), respectively, in the PFI mill. The manufactured fines refined to 125,000 revolutions were added to the 2,100 revolutions OCC pulp at levels of 4%, 8% and 11%, and to the 2,800 revolutions OCC pulp at levels of 3%, 6% and 8%. Cationic starch was used as retention aid in these handsheets at an 0.75% addition level.

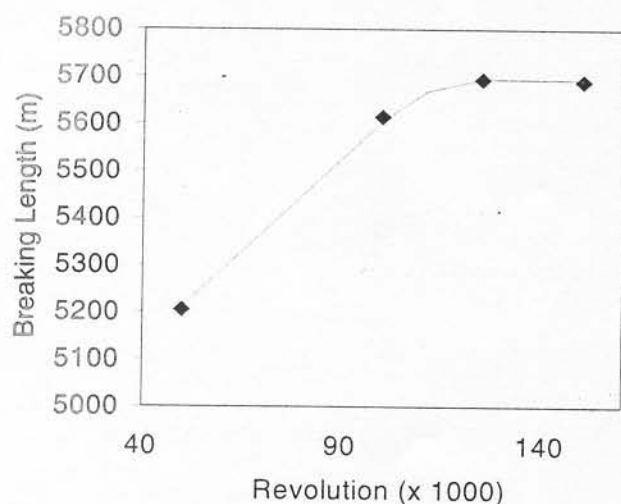
The addition of manufactured fines produces greater strength than additional refining of the OCC when both the sheets have the same density. For example, when the densities of sheets are between 0.51 and 0.53 g/cm<sup>3</sup>, the breaking length of the sheet with additional manufactured fines is about 8% greater than that of the refined only sheet



**Figure 6.** Effect of fines addition and refining on sheet strength as a function of sheet density. For the fines addition curve, OCC pulp was respectively refined to 2,100 revolutions (solid squares) and 2,800 revolutions (triangles). Then manufactured fines refined to 125,000 revolutions were added to the 2,100 revolutions OCC pulp at levels of 4%, 8% and 11%, and to the 2,800 revolutions OCC pulp at level of 3%, 6% and 8%. Cationic starch retention aid concentration in these handsheets was 0.75%.

(beating curve). This indicates that the pulp with additional manufactured fines has a better bonding ability.

Figure 7 illustrates the effect of refining levels used to manufacture fines on breaking length. The handsheets were produced by the addition of 10%



**Figure 7.** Effect of refining level (used to produce the virgin fines) on breaking length. The pulp contains 10% manufactured fines and 90% long fibers classified from OCC pulp. Polyacrylamide was added at 0.75 lb/ton.

manufactured fines to OCC long fibers. Cationic polyacrylamide was used as a retention aid at a concentration level of 0.75 lb/ton.

As shown in this figure, the breaking length is related to the levels of refining used for manufacturing fines. The breaking length increases with the levels of refining up to 125,000 revolutions. Above this level, no further improvement in breaking length is observed. The breaking length of the sheet made with the 50,000 revolution virgin fines is about 5,200 m and that of the sheet made with the 125,000-revolution fines is 5,700 m. The dependence of burst index and ring crush index on refining levels is similar to that of breaking length.

There is no doubt that increased refining produces more fines (Figure 1). Moreover, fines quality is improved with the refining level. If the fines are separated from slightly beaten pulp, most fines come from the primary layer or the S1 layer of fiber cell walls. If pulp is heavily refined, the origin of the fines is from deeper in the cell wall, the S layer, and show a better bonding ability (15). This explains the dependence of mechanical strength on refining levels shown in Figure 7. Perhaps, this is also one of the reasons why the manufactured fines are more effective than the classified fines.

## CONCLUSIONS

It has been demonstrated that fines concentrations as high as 95% can be manufactured effectively by intensive refining of pulp in a PFI mill. This manufacturing process is much more efficient than the conventional process of classification followed by sedimentation. The quality of manufactured virgin fines is slightly better than classified virgin fines, and much better than classified OCC fines. The possible applications of the manufactured fines in recycling processes have been shown through the following experiments:

- 1) The OCC pulp with 4.3% manufactured fines improves mechanical strength by about 30%, compared with that with classified fines.
- 2) The breaking length is 16% higher for the sheet with manufactured virgin fines than for the sheet with classified fines. This value is increased to 23.5% when fines content is adjusted so that both pulp have the same drainage time.
- 3) The comparison between a beating curve and the curve with additional manufactured virgin fines shows that

additional manufactured fines improve sheet strength more than does the pulp that has been refined only.

This work demonstrates an effective technique for producing a large quantity of high quality fines that can be used for increasing the strength properties of OCC pulp.

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