Effects of Fines on the Fiber Length and Coarseness Values Measured by the Fiber Quality Analyzer (FQA)

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ABSTRACT

Instruments for optical fiber measurements, such as the Fiber Quality Analyzer (FQA), are widely used to measure various properties of pulp samples. For the evaluation of market pulps, the pulp properties of interest are fiber length, coarseness, and fines content. Fiber length and coarseness are often used to determine which pulps are suitable for producing particular products. The objectives of this research are 1) comparison of fines content as measured by the FQA and Britt Jar (TAPPI test method T261), and 2) determination of the relationship between the fines content and the fiber length/coarseness measurements. Over 40 samples bleached kraft and chemithermomechanical market pulps were evaluated for fines content, fiber length, and coarseness using the FQA and Britt Jar methods. The FQA measurements were performed on whole pulp samples and fine free samples to provide length weighted fines percentages, length weighted length and coarseness measurements, while the Britt Jar measurements provided a mass percentage of fines. The aforementioned values for multiple samples in each category allow for a unique comparison of fines' effects on fiber length and coarseness values. Fines affect the length weighted length and coarseness values for different grades of pulps.

INTRODUCTION

Recently, WOMP LLC has published a database book entitled "The World of Market Pulp" [1] which covers 60 of the most representative market pulps from all over the world. The main objective of this book is to provide technical data of market pulps to assist in the selection of raw materials for various paper products. In the course of the database development, fiber properties of 60 market pulps were measured by a Fiber Quality Analyzer (FQA) instrument. For the evaluation of market pulps, the pulp properties of interest are fines content, fiber length, and coarseness. Both fiber length and coarseness are often used to determine which pulps are suitable for producing particular products.

The objectives of this research are 1) comparison of fines content as measured by the Britt Jar and FQA methods, and 2) determination of the relationship between the fines content and the fiber length/coarseness measurements. The following 6 categories of pulps were selected for the analysis: northern bleached softwood kraft, southern bleached softwood kraft, northern bleached hardwood kraft, southern bleached hardwood kraft, eucalyptus bleached kraft, and chemithermomechanical pulp. Between 4 and 16 samples of each market pulp category were evaluated.

Fines are small particles that exist in all types of pulp. Chemical pulps contain fines that include 1) ray cells and axial parenchyma cells originating in wood; 2) fiber fragments from the wood chipping process; and 3) damaged fiber fragments from cooking and bleaching. Mechanical pulps contain fines that primarily consist of cut fiber fragments and pieces of peeled-off cell wall layers.

The most widely used method for fines content measurement is TAPPI Test Method T261 [2]. This procedure consists of using a Britt Jar with a screen to separate the fines from long fibers. The screen for fines content measurement is a 200-mesh screen with a 14.5% open area and 76.2μm hole diameter. The fines are filtered and weighed after separation. The final percent fines ($\%F_m$) is expressed as a mass percentage.

Fiber quality analyzers are also used to measure fines content. There are two FQA fines measurements. The first and least-often used measurement is the percent arithmetic fines content. This is simply the percentage of particles that exist in a sample that are smaller than the specified maximum fine length. Since this number does not agree well with paper properties or mass percentages, it is not commonly used. The more commonly used number is the length-weighted percent fines content. This is the percentage of the total length of all measurable fines divided by the total length of all measurable fines and fibers. Both methods are dependent upon the user specifying the maximum length of the fines. The maximum length is generally set to 0.2 mm.

The ease and quickness of FQA measurements contribute to their popularity. Although the FQA manual contains a procedure for completing FQA measurements, the sample preparation procedures for FQA measurements vary widely. There are no standard operating procedures with respect to fines content (use of whole pulp vs. fine free pulp). Fines are rarely removed prior to regular FQA testing and few efforts have been made to investigate fines' contribution to length and coarseness measurements. By using data collected from over 60 market pulps varying in type, location and pulping procedure, meaningful conclusions can be made concerning optical measurement reliability and dependency on pulp type.

ANALYSIS OF FIBER PROPERTIES BY FQA

The OpTest Laboratory's Fiber Quality Analyzer (FQA) is the optical device used to measure the fiber length, coarseness, and length weighted percent fines for this essay. The FQA uses circular polarized light to project images of the fibers in the sample to gain information concerning fiber length and contour. As the fiber suspension joins the water sheaths and passes through the optics box, the digital camera takes pictures of the fiber projections [3].

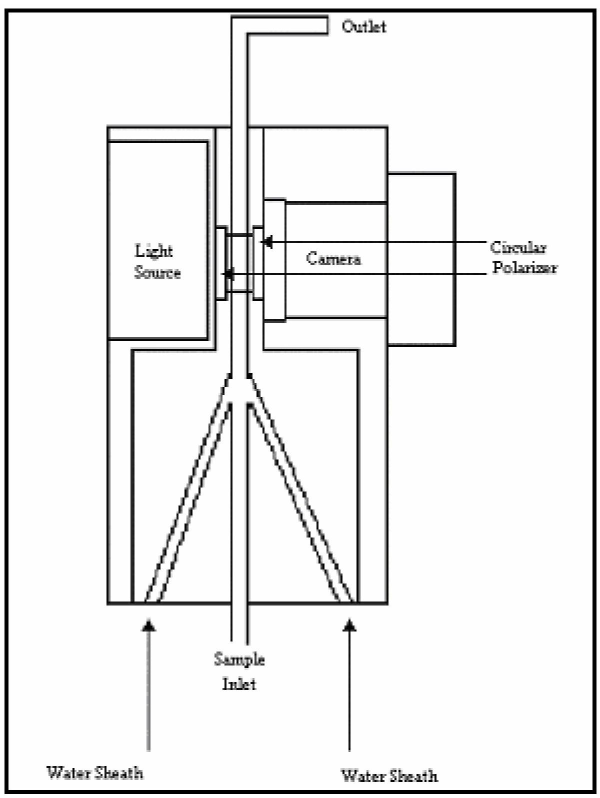

Figure 1: Flow cell configuration of FQA

If the particles present in the pulp sample are not sufficiently birefringent, due to chemical composition or physical dimensions, they will not register as being present in the sample. Fibers are not consistent throughout their length in width and cell wall thickness. If a certain length from the end of a fiber is not projected, then the population length will be misrepresented. This misrepresentation becomes increasingly relevant as the fiber length average decreases.

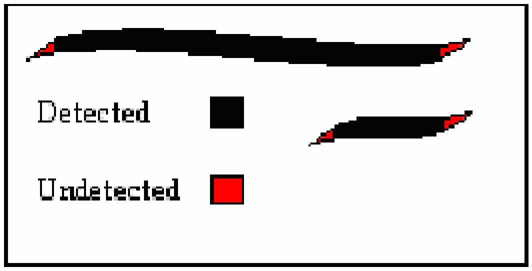

Figure 2: Fiber detection representation

Although the same amount of each fiber in Figure 2 (above) is undetected, the undetected amount of the shorter fiber represents a higher percentage of that fiber. Therefore, fiber populations consisting largely of smaller misrepresented fibers will have skewed fiber length averages and coarseness values. Less coarse fibers or fibers with thin cell walls could also contribute to lower length averages and misrepresented coarsenesses.

Some fines may not be detected at all. Fines are typically defined as particles that pass through a 200-mesh Britt Jar and are usually quantified as a mass percentage. The FQA's optical evaluation of fines depends on user settings. The user sets the maximum length for fines and all particles detected at or lower than the maximum length are considered fines. This criterion is often changed depending on the results of interest. However, a maximum fine length of 0.2 mm is most common. The minimum length that is detected is 0.072 mm. Some pulps are composed of over 20% fines by mass, as determined by Britt Jar fractionation. A significant portion of these fines can contribute to the sample's mass without contributing to the total length (undetected by the FQA), thus affecting the coarseness values.

EXPERIMENTAL PROCEDURE

The three tests performed on each pulp include two versions of a FQA and a Britt Jar fines test. A detailed procedure for each test is included in *The World of Market Pulps* [1] and the abbreviated version is as follows. The first FQA method is a whole pulp test. A 0.5 gram sample is diluted to the required consistency range for FQA testing. The second version is a fine-free FQA test. The 0.5 gram sample is first fractionated 10 times using a Britt Jar equipped with a 200-mesh screen and later diluted to an adequate consistency range. The final test is a Britt Jar fines test. A 3.0 gram sample is fractionated 10 times using a Britt Jar equipped with a 200-mesh screen. The filtrate and supernatant were then filtered and weighted to obtain a percent mass of fines. The above three tests were performed on northern bleached softwood kraft, southern bleached softwood kraft, northern bleached hardwood kraft, southern bleached hardwood kraft, bleached eucalyptus kraft and chemithermomechanical pulp.

RESULTS

Comparison of Britt Jar Fines and FQA Length Weighted Fines

The whole pulp and fine-free FQA testing allows an interesting means of investigating the fines' effect on the length-weighted average length and coarseness. As mentioned in the introduction, the length-weighted fines content is not a mass percentage. A specific correlation between the length-weighted fines and percent mass fines is not expected. The deviation between the Britt Jar fines and FQA length-weighted fines has not been investigated on such a large population of pulp samples. Figure 3 shows the comparison between FQA length-weighted fines and Britt Jar fines.

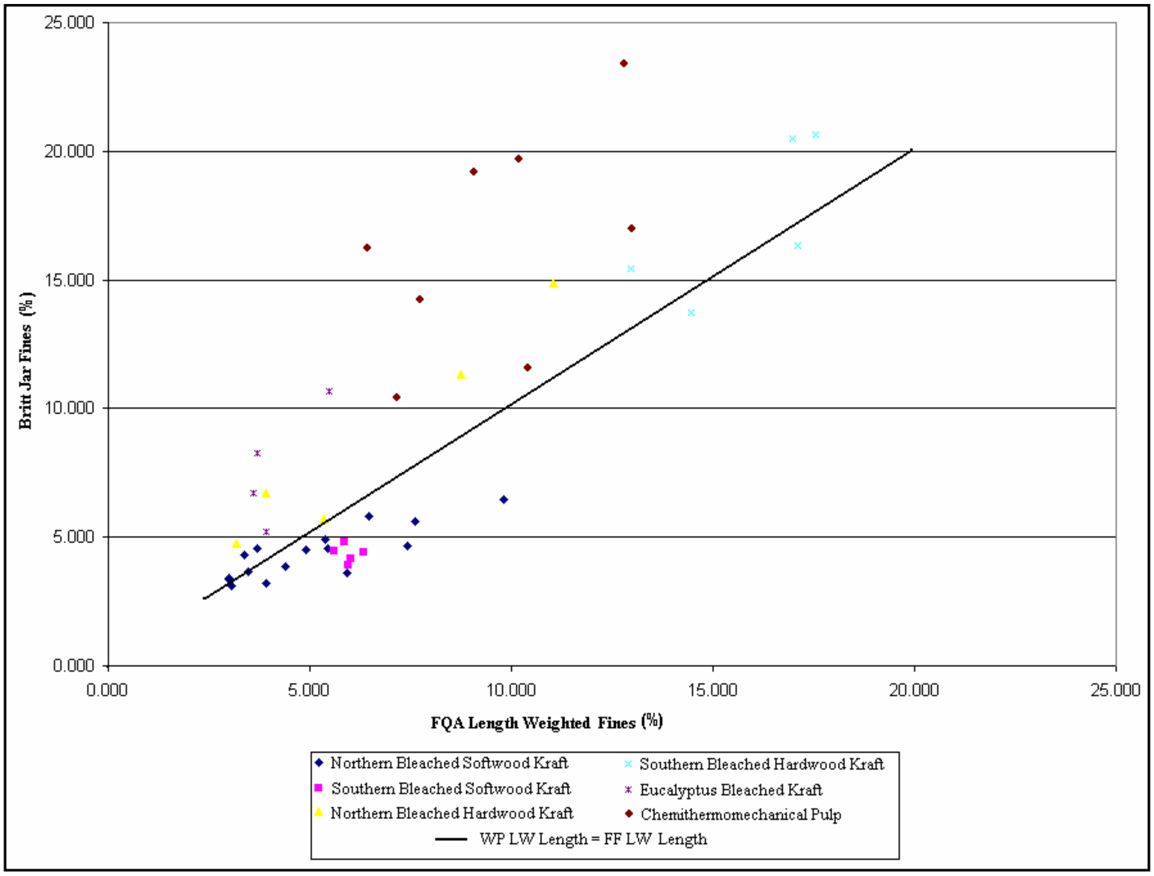

Figure 3: Fine Measurement Comparison

The basic agreement between increased FQA length-weighted percent fines and increasing Britt Jar fines in Figure 3 is as obvious as the futility of attempting to quantify it. The deviation between the two can be determined by observing the data points' location in relation to the theoretical solid black line. At approximately equal lengths of length-weighted percent fines, softwoods often have the lowest mass percent fines followed by hardwoods, eucalyptus and chemithermomechanical pulp. One can speculate as to the reasons for this trend, such as typical fiber lengths, fine structure, etc. The variety of pulp characteristics within categories would complicate such a discussion and is not as important as the general expectation of mass percent fine levels at comparable length-weighted fines.

Effect of Fines on Fiber Length Measurement

Effect of fines content on the fiber length measurement by FQA was evaluated comparing fiber length of whole pulp and that of fines free pulp.

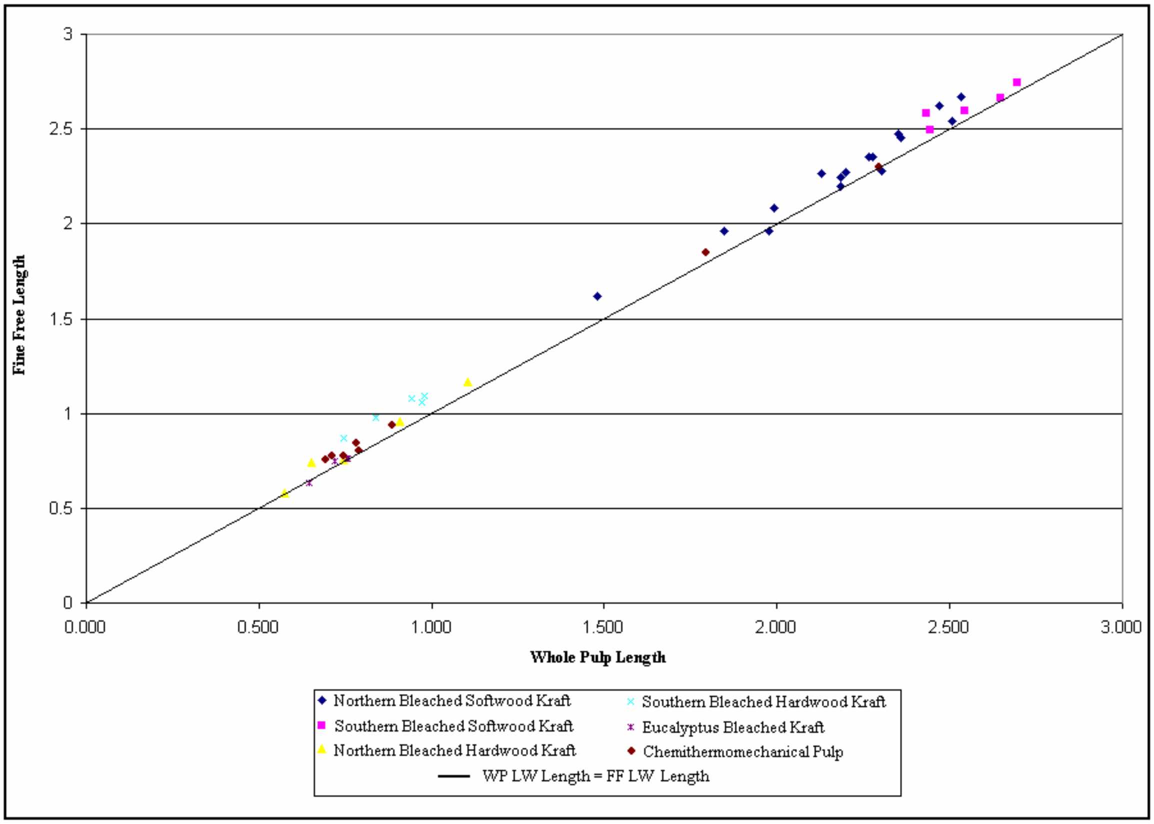

Figure 4: Length-weighted Length Comparison

Figure 4 shows that the fines do not affect the length-weighted length measurements to a large degree when looking at the entire range of pulps tested. The overall trend is that fine-free samples have a larger length-weighted length than whole pulp samples. This is intuitive, as a large number of short particles are removed from the fine-free samples. A more detailed investigation of length measurements offers additional information concerning the percent difference between the whole pulp and fine-free samples. A more detailed investigation of length measurements offers additional information concerning the percent difference between the whole pulp and fine-free pulp fiber length. First, additional terms must be introduced and defined.

L_{WP}: FQA length-weighted fiber length of whole pulp
L_{FF}: FQA length-weighted fiber length of fine-free pulp
% dL: Percent difference of whole pulp length and fine-free length
$\% dL = (L_{WP} - L_{FF}) / L_{FF} * 100\%$

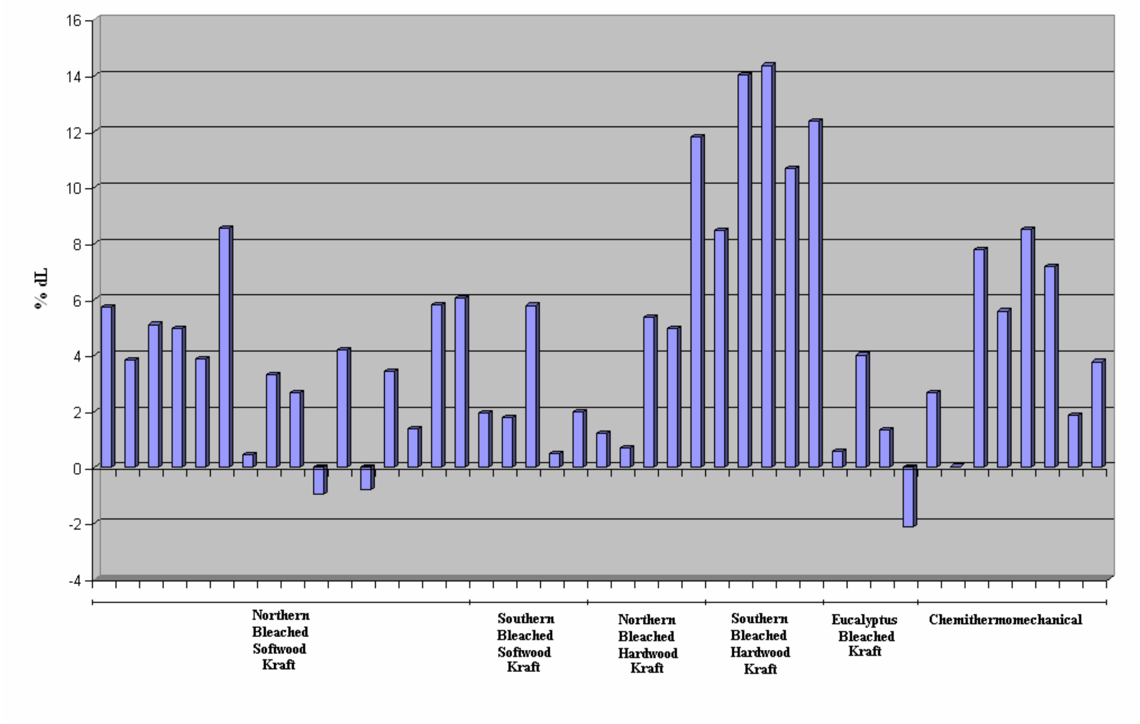

Figure 5: Pulp grade dependency of length measurements

Figure 5 shows the length weighted fiber length dependency on fines by pulp type. All of the length percent differentials are less than 10%, except for the hardwood pulps. The hardwood pulp length values differ by about twice as much as the other pulp samples. However, the %dL does not exceed 15% for any sample. Therefore, any hardwood sample that requires a very accurate length measurement should be checked by also testing a fine-free sample.

Fines Effect on Coarseness Measurement

The final conclusion or observation concerning fines and small fiber detection of FQA testing concerns the coarseness measurement. Coarseness measurements can differ greatly depending on fines content in some pulp samples. An accurate coarseness measurement requires accurate mass and dimension measurements. The fines effect on the coarseness measurement will be investigate in a similar manner to that of the length-weighted length measurement. By comparing the whole pulp and fine-free coarseness measurements, some observations and practical suggestions can be made.

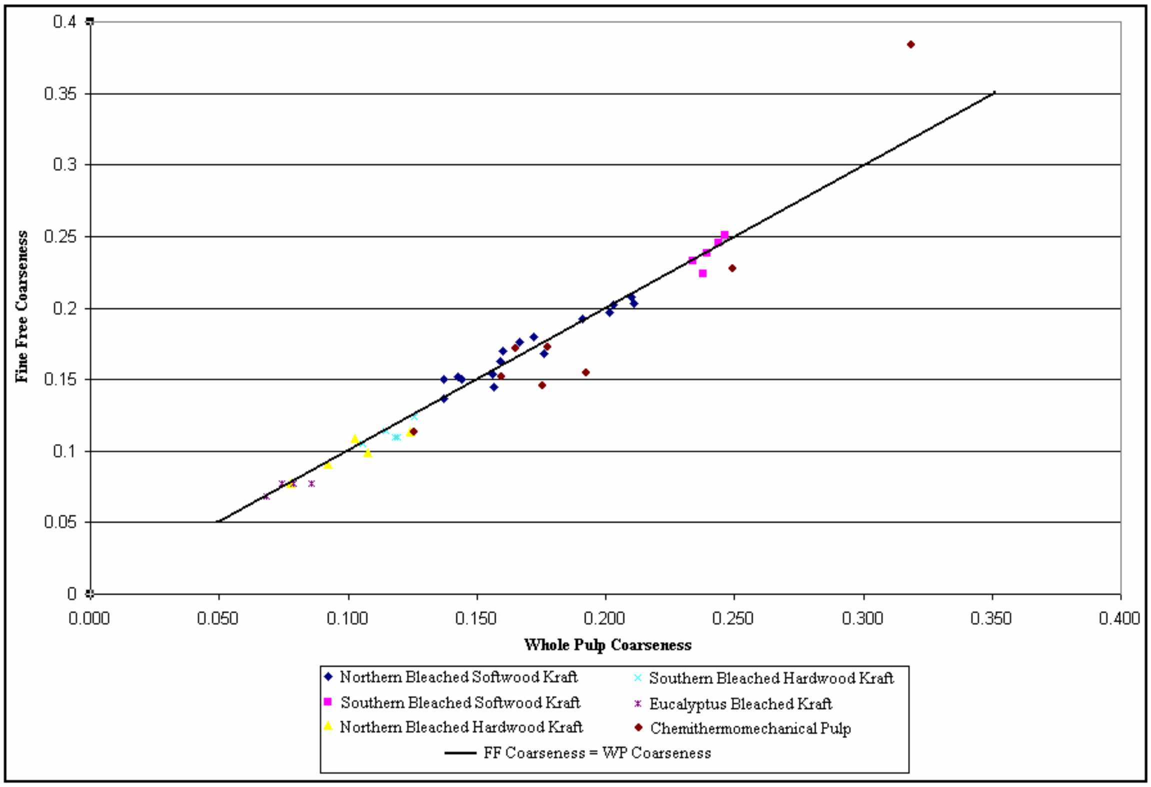

Figure 6: Coarseness Comparison

Figure 6 shows the general similarity between the whole pulp and fine-free pulp coarseness measurements. For most pulps, removing fines prior to coarseness measurements is not necessary. However, the chemithermomechanical pulps deviate significantly, due to the large fines content. To show the relative magnitude of the deviations that fines cause in coarseness, we must introduce and define a few terms.

C_{FF}: Coarseness of fine-free pulp
C_{WP}: Coarseness of whole pulp
%dC: Percent difference of fine-free pulp and whole pulp coarseness

$$\%dC = (C_{FF} - C_{WP}) / C_{FF} * 100\%$$

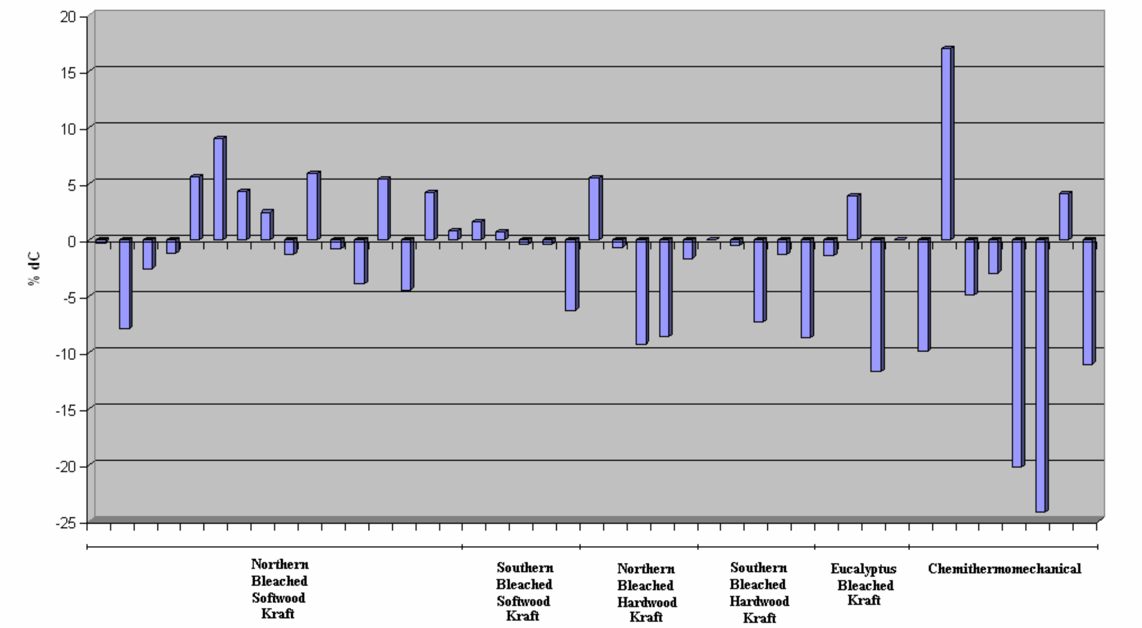

Figure 7: Pulp grade dependency of coarseness measurements

Figure 7 shows the dependency of coarseness on the fines with respect to pulp type. None of the hardwood or softwood samples have coarsenesses that differ up to 10%. One of the four eucalyptus pulp samples has a 10% difference in coarseness. Five of the eight chemithermomechanical pulp samples differ by greater than 10% and three samples differ by greater than 15%. The difference in coarseness values of chemithermomechanical pulps is greater than differences that can be attributed to number of samples and repeatability issues. The fines are clearly responsible for these differences and should be removed prior to coarseness testing if an accurate fiber coarseness is to be obtained.

CONCLUSIONS

This investigation of fines and their contribution to length and coarseness measurements yields three main conclusions. First, the mass percentage of fines as determined by Britt Jar fractionation cannot be predicted by the FQA length-weighted fines percentage. Second, the FQA length-weighted length measurement is not significantly affected by the fines content of pulp samples regardless of pulp type. Finally, fines should be removed prior to testing chemithermomechanical pulp for coarseness values.

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