

The Myth of Commodity Pulps

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ABSTRACT

Most people who work with pulp are familiar with the concept of commodity pulps and can probably supply most of the acronyms, like NBSK, NBHK, SBSK, SBHK, DIP, and BCTMP. As many of these labels illustrate, the commodity, Northern Bleached Softwood Kraft (NBSK), for example, is defined by a region, level of bleaching, wood type, and pulping process. Recently the New York Board of Trade (NYBOT) began trading NBSK pulp futures. This commodity is described in the press releases as being of a commercially accepted “prime” grade of a specific moisture content, dirt count and brightness. All of this information suggests that NBSK is a commodity, but is this “commodity pulp” truly a commodity? This presentation delves into this question by looking at the similarities and differences of a cross-section of market NBSK pulps available around the world.

The testing results of 16 NBSK market pulps, ranging across the northern hemisphere from Coastal British Columbia to Siberia, are compared to show that major differences exist in many key properties of this commodity pulp. These differences are translated into both likely paper performance outcomes and their economic impact. The major role that fiber morphology plays in these differences and the reason for the trends in the data will be highlighted. The presentation will examine, additionally, the connection between traditional paper industry pulp analysis and commodity pulp.

INTRODUCTION

Recently the New York Board of Trade (NYBOT) [1] began trading pulp futures in the form of 20 metric ton lots of Northern Bleached Softwood Kraft (NBSK) pulp. Even though only a small percentage of these contracts will be delivered in the form of pulp, this process assumes that there is a definable commodity, NBSK. This is possible because market pulps are classified into various categories based on the type of fiber, pulping process and degree of bleaching. This commodity is described as being of a commercially accepted “prime” grade of a specific moisture content, dirt count and brightness. All of this information suggests that NBSK is a commodity, but is this “commodity pulp” truly a commodity? Are the NBSK market pulps substantially indistinguishable one from another? Or are there significant opportunities to benefit pulp producer and papermaker by being selective in the selling and use of these pulps. What does the data on a broad range of NBSK market pulps suggest? This question can be examined by analyzing the database of “The World of Market Pulp CD Book” [2].

NATURE OF THE DATA USED IN THIS PAPER

The data used in this paper are taken primarily from the “The World of Market Pulp CD Book”. The development of this book was supported, in part, by a grant from the Center for Paper Business and Industry Studies (CPBIS) in Atlanta, Georgia. One of the goals of this project was to develop a database of the properties of a representative cross-section of the market pulps available in the world. Sixty pulps were selected as being representative of all the major pulp types; accounting for different fiber sources, processes and principal uses. A major effort was made to assure that the pulp samples were representative of pulps produced by the major suppliers in each category. Pulp suppliers were extremely helpful in achieving this outcome. The PFI beater curves, handsheet preparation and testing and chemicals analyzes were completed on all the pulps at Integrated Paper Services in Appleton, Wisconsin. All the fiber morphology, Britt Jar fines and Scanning Electron Micrographs (SEM) work were carried out at the

Institute of Paper Science and Technology in Atlanta, Georgia. The pulps were collected and tested, using TAPPI and other standardized procedures, by skilled personnel in a reasonably short time.

RANGE OF PROPERTIES IN THE NBSK MARKET PULP CATEGORY

There are sixteen NBSK market pulps covering a geographic range from the Pacific Coast of Canada to Siberia in this data set. Two special pulps, a “sawdust” and a flash-dried market pulp, are excluded from this analysis. To set the stage for a more detailed analysis, the following descriptions of the range of properties in this fourteen pulp data set are presented. First there are handsheet property and refining energy comparisons made at a common level of tensile strength development. The second are a sampling of key fiber morphology measurement comparisons.

Examples of major property differences at the same moderately high level of tensile breaking length (8.5 km):

- Refining energy is as much as 75 % less for the best pulp
- Tear values can be as much as 49 % higher
- Bulk nearly 10 % higher
- Freeness 67 % higher
- Scattering coefficient 30 % higher for the highest versus the lowest.

Major differences also exist in fiber morphology:

- Fiber strength is 25.9 % higher for the strongest fiber NBSK pulps compared to the lowest.
- Longest average fiber length pulp can be 37 % longer than the shortest.
- Coarseness (mass of fiber per unit length, mg/m) of the finest fiber pulp is 32 % lower than the coarsest.
- Ratio of coarseness to fiber length (C/Lw), a key predictor of reinforcement potential, is nearly 50 % better for the lowest ratio compared to the highest.

These comparisons suggest that this representative sample of NBSK market pulps is not sufficiently similar to seamlessly replace any one of these pulps with any other NBSK. So how does this information square with our experience and practice? It’s clear that many pulp producers, sellers, buyers and papermakers subscribe to this commodity view of pulp categories and commonly sell and buy these as if they were interchangeable. It’s also clear that many pulp producers, sellers, buyers and papermakers are very selective to the point of using only one NBSK pulp for particular grades and processes. Why this disparity in practice? Part of the explanation for our tendency to treat pulps as commodities is our “typical” evaluation process [3].

ROLE OF THE EVALUATION PROCESS IN SUSTAINING COMMODITY PULPS

This typical process is illustrated by looking at how an “Average” and four representative individual NBSK pulp beater curves would be evaluated. The “Average” pulp was constructed by numerically averaging the handsheet and pulp testing results at each PFI refining level for the fourteen pulps in the database. In Fig. 1 we have a common first analysis step of plotting freeness versus refining level and making our evaluation at specified freeness levels (350 ml and 550 ml, for example). Pulp #11 would be most desirable (it took the least energy to target freeness levels). Pulp #3 would be least desirable because it took the most energy. We might also look at tensile strength versus refining, as shown in Fig. 5, but because we’re focused on comparisons based on freeness we would probably analyze tensile strength, tear and opacity (scattering coefficient) versus freeness as in Figs. 2, 3 and 4. From Fig. 5 we should have concluded that Pulp #3 had the lowest tensile strength potential. When we plot against freeness the picture gets confusing. In Fig. 2, Pulp #3 had the lowest tensile at 350 ml, but Pulp #11 was lowest at 550 ml. Things get more confusing in Fig. 3 because Pulp #3 is clearly the best for tear and Pulps #11 and #14 are the worst. Relative performance reverses again in Fig. 4 where Pulp #11 has the best scattering coefficient and Pulps #3 and #10 are the worst at 550 ml and 350 ml, respectively. If the analysis stopped at this point, there would very little clarity added to the “Which pulp should we buy?” decision.

How do we get clarity and take advantage of the wide range in performance and characteristics of NBSK pulps? The first step is to recognize several key facts: (1) Papermakers don't sell freeness, but they do sell tensile strength; (2) The freeness test has major repeatability differences throughout its range and, because it's a dependent property, it's poorly suited as an x-axis reference; and (3) All paper is a compromise where its performance is determined by the balance of key properties. Selecting the best pulp for a particular product and process requires that we understand what the key pulp attributes are and how to get the best balance.

HOW TO TAKE ADVANTAGE OF THE RANGE OF PROPERTIES OF NBSK MARKET PULP

A more detailed approach to evaluating market pulp is presented in references [2, 3], but the key elements are: (1) Recognize that fiber morphology determines paper structure; (2) A testing framework based on Page's Equation [4] and standardized testing of key attributes that relate to product performance; and (3) Approach the ranking process from the most to the least important attribute, weighing each in light of the papermaking system capability, existing practice and the product requirements.

A key application for many NBSK market pulps is as reinforcing fiber in mixture with shorter chemical and mechanical pulps. NBSK pulps contribute reinforcement by providing a strong coherent network of long, slender and strong fiber that increases the fracture toughness of the paper. Traditionally tear values have been used to measure this property, but as Uesaka, et. al. have demonstrated tear values don't correlate well with web runnability, while the combination of tensile and stretch correlates much better [5]. Seth has shown that the combination of tensile and stretch can be used to estimate the fracture toughness of handsheets [6]. Fiber morphology characteristics, such as fiber length (L_w), fiber coarseness (C) and especially the ratio of coarseness to length (C/L_w), are important descriptors of the reinforcement potential of NBSK pulps [2, 3].

With the preceding outline as a guide, let's look at how we might evaluate the same five pulps presented in Figs. 1-5, starting with Figs. 5 and 6. The nature of the "Average" pulp was described above. The other four pulps were chosen to cover most of the range of data seen in the database and also illustrate some of the unique properties of individual NBSK pulps. In Fig. 5, we see Pulp #3 has the lowest tensile strength through all refining levels. Pulp #11 starts out with the highest tensile level but is eventually overtaken by Pulps #10 and #14, however, Pulp #14 declines to the level of the average pulp at 9000 revs. Depending on the level of refining and strength needed any of these pulps might perform satisfactorily.

To go to the next level of evaluation, as an illustration, let's assume that we need our selected NBSK pulp to develop a tensile breaking length of 8.5 km. We begin the next step of evaluation by plotting key handsheet properties against tensile strength as shown in Figs. 6 through 10. Pulp # 16 has been restricted to just Figs. 7 and 8 to avoid cluttering the other graphs. Each of these property values are obtained by interpolation and summarized in Table I. Interpolated refining levels are obtained similarly from Fig. 5. What is the implication of the data in Table I?

IMPACT OF SELECTING THE MOST DESIRABLE VERSUS LEAST DESIRABLE PULP

The data in Table I are the basis for the broad range of property values presented early in this paper, so let's look at the highlighted extremes to quantify the economic and performance impact of selecting the most desirable versus least desirable pulp. The NBSK market pulp is assumed to be 35 % of the fiber furnish.

- **Refining energy:** An estimate of the net refining energy required by Pulp #3 is 200 kWh/t. Pulp #11 would only require 49 kWh/t to reach the 8.5 km tensile. At an electrical rate of \$0.06/kWh that would result in a savings of \$9.06/t of NBSK refined.
- **Drainage rate/paper machine speed:** Pulp #14 has a freeness that's 218 ml higher than Pulp #3. That's approximately 76 ml faster drainage on the paper machine. That should provide a substantial opportunity to increase machine speed and productivity.
- **Sheet bending stiffness:** The 10 % higher bulk of Pulp #16, compared to Pulp # 11 could translate into 10 % higher sheet bending stiffness.
- **Fracture toughness:** The 42 % higher stretch of Pulp #14 versus Pulp #16 could translate into approximately 8 % higher fracture toughness and improved paper machine and converting runnability.

- **Opacity:** The 30.2 % higher scattering coefficient of Pulp #10 might result in 10.5 % higher sheet opacity than Pulp #3. This could result in lower pigment costs or reduced basis weight to meet product targets.

These comparisons suggest that there are many, in some cases significant, opportunities to reduce costs and improve performance by choosing the most desirable instead of the least desirable pulp. Which pulp would be the “best” depends on the specifics of the products and processes in question.

There is a second set of pulp characteristics, listed in Table II, that are fiber morphology, fiber strength and brightness related. Fiber morphology determines the type of fiber network structure that will be realized in the paper. While refining, other process unit operations and additives can alter the paper’s performance, it is the size and shape of the individual fibers that are the principal controllers of paper structure. Fiber strength controls the maximum strength that a given paper can realize. Most of the characteristics listed don’t lend themselves to the quantification possible from Table I, but here are some of the important implications for selecting NBSK market pulps.

- **Fiber length:** In general, longer fibers make stronger paper so Pulp # 3 would be much more desirable than Pulp #11. The preferred measure of average fiber length is the length-weighted measure which puts more emphasis on the contribution of the larger fiber than a straight average of all fiber lengths (L_w).
- **Fiber coarseness:** Coarseness is defined as the average weight per unit of length of the fiber. Lower coarseness fibers produce finer structures and so we would choose Pulp #11 over Pulp #3.
- **Population:** There are typically millions of fibers per gram of pulp. Population incorporates the impact of both length and coarseness and the higher its value, the finer the paper structure. On that basis we would prefer Pulp #11 over Pulp #3. The impact on the paper structure can be understood by realizing that for every three fibers in Pulp #3 there will be five fibers in Pulp #11.
- **Britt Jar fines:** Northern softwoods are composed primarily of long fibers called tracheids, but there are small parenchyma cells that contribute little to paper performance. A low “fines” level is better because it maximizes the amount of long fiber available. We can quantify the fines impact by assuming that they have zero value and that NBSK pulp is priced at \$600/t. Pulp #11 has the lowest fines and would have a fiber value of 96.66 % of \$600, or \$580/t. Pulp #16, with the highest fines level of 4.64%, would have a fiber value of \$572/t; a difference of \$8/t. Fines may actually have a negative value, so this is probably a conservative estimate of economic impact.
- **Ratio of fiber coarseness to length (C/L_w):** This ratio is among the most important measures of the ability of an NBSK pulp to provide efficient reinforcement. The lower this value the higher the efficiency. On that basis we would chose Pulp #10. Its value is nearly 50 % better than Pulp #16. The economic implication depends on the particulars of a given situation, but the most efficient NBSK pulps can perform their reinforcement function at lower percentages of the fiber furnish. This permits improvements in formation and surfaces, and the use of higher levels of lower-cost, short fiber pulps.
- **Fiber length distribution (L_w/L_n):** This parameter is the ratio of the average weight-weighted (L_w) and numerical (L_n) fiber length values. The higher its value the broader the distribution of fiber lengths. Narrow length distributions are more efficient. We would expect Pulp #10 to be a better performer than Pulp #3.
- **Formation:** Long fibers are more difficult to form into paper than short fibers. An equation and set of operating conditions have been developed around a “Crowding Number, (N)” concept [7]. A fiber concentration, describing the ease or difficulty of forming a fiber furnish, is presented in Table II. The lower this value the more difficult the forming will be. On that basis we would choose Pulp #16 over Pulp #14.
- **Fiber strength:** Zero-span testing can be used to estimate the average strength of individual fibers. For most applications higher strength is better. Pulps #10 & #14 would be preferred over Pulp #11. Most of the NBSK market pulps have relatively high fiber strengths, but as the value for the “average” pulp suggests there are some pulps that are significantly lower than those shown in Table II [2].
- **Brightness:** These values are reasonably close, but choosing Pulp #10 over Pulp #11 could provide some economic and product performance advantages.

An overall view of the data in Table II leads to the conclusion that Pulp #10 would be the most desirable pulp and Pulp #16 would probably be the least desirable. The data in Table I are reasonably consistent with that conclusion,

but there may specific circumstance, such as refining capacity or paper machine capacity limitations, that would alter the conclusions that I've drawn. The value of this selection process is that both paper and fiber properties are considered and, as a result, a much clearer view of why you would choose a particular pulp emerges.

One major question that cannot be answered with this data and analysis is the question of how stable the pulp source is over time. Do I get the same desirable pulp bale-to-bale, shipment-to-shipment and season-to-season? This information may be best obtained by reviewing the producers control chart data, along with testing over time.

CONCLUSIONS

1. The range of important property and fiber morphology values for a representative group of the NBSK market pulps suggests that this pulp category cannot be considered a "commodity".
2. Depending on the particular paper grade and process capabilities, it should be possible to make significant improvements in product performance and cost by selecting the best NBSK from the "commodity" pulps available in the marketplace.
3. A systematic, fundamentals based approach, that utilizes both handsheet property and fiber morphology measurements, can provide clarity to the pulp selection process.

ACKNOWLEDGEMENTS

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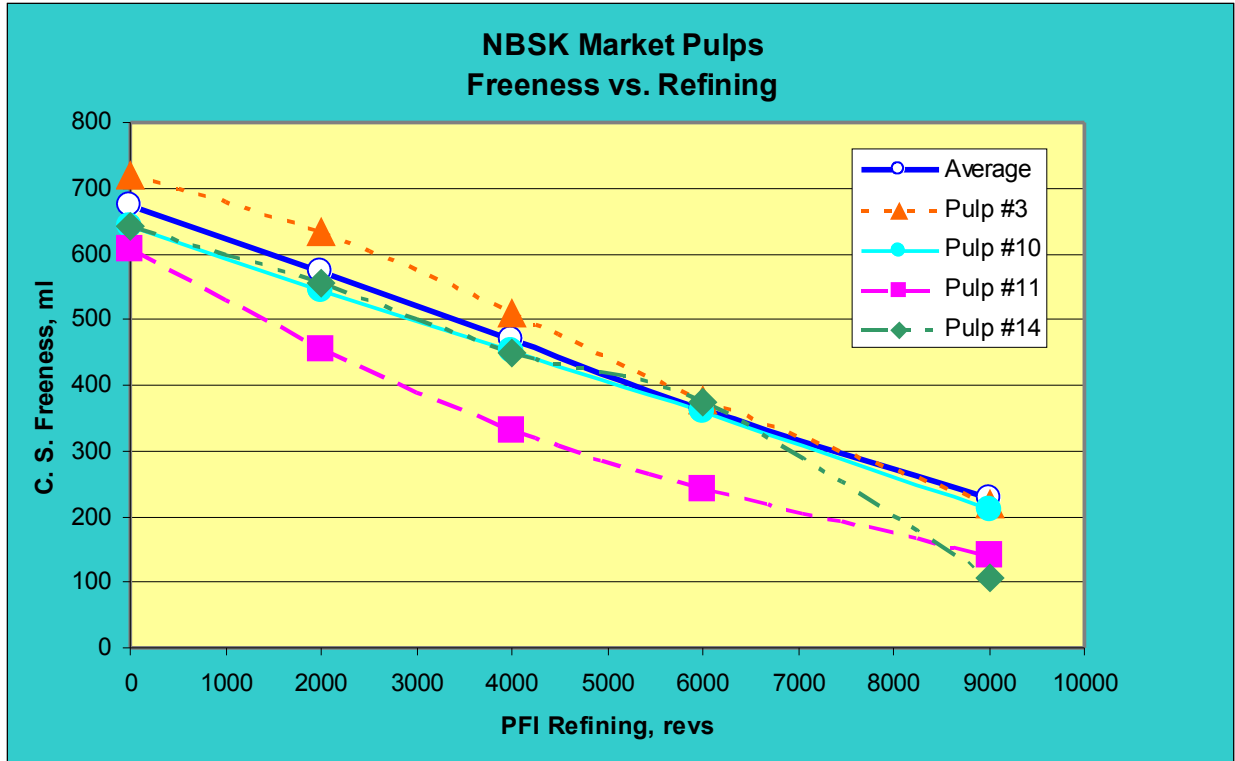


Figure 1. NBSK Market Pulps: Freeness vs. Refining

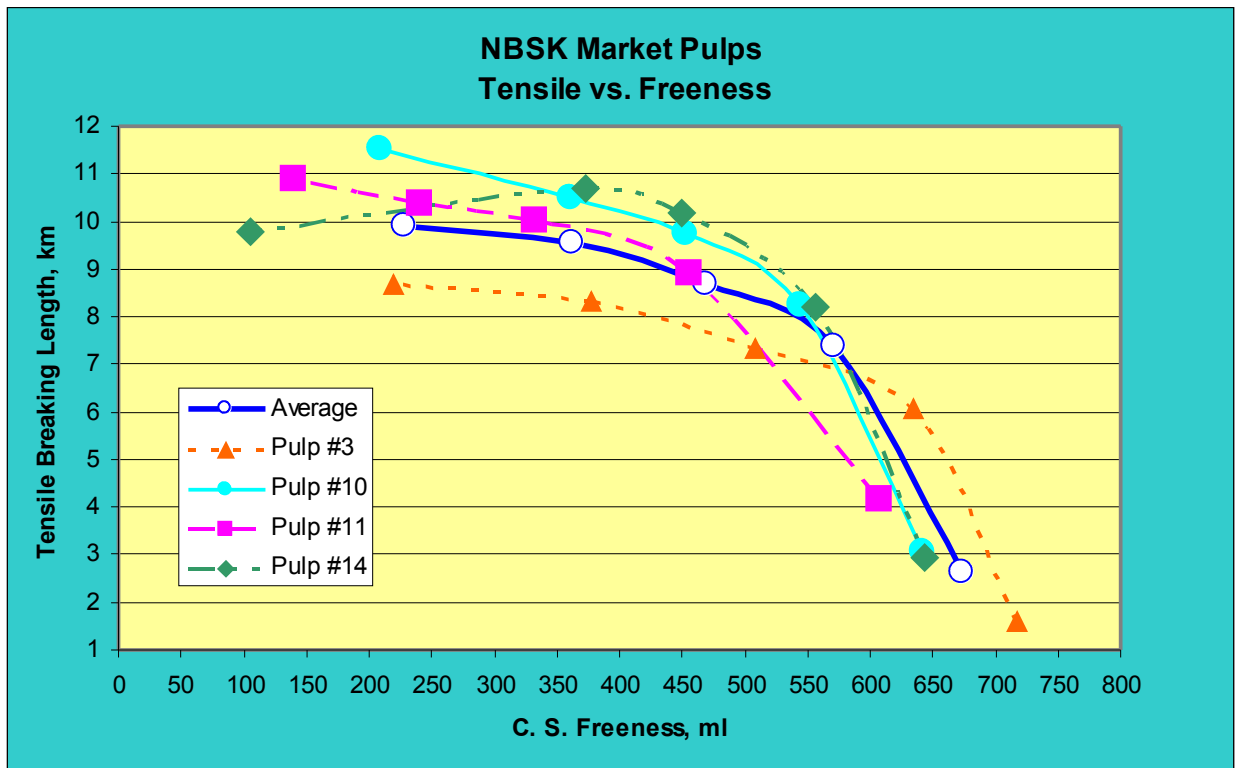


Figure 2. NBSK Market Pulps: Tensile vs. Freeness

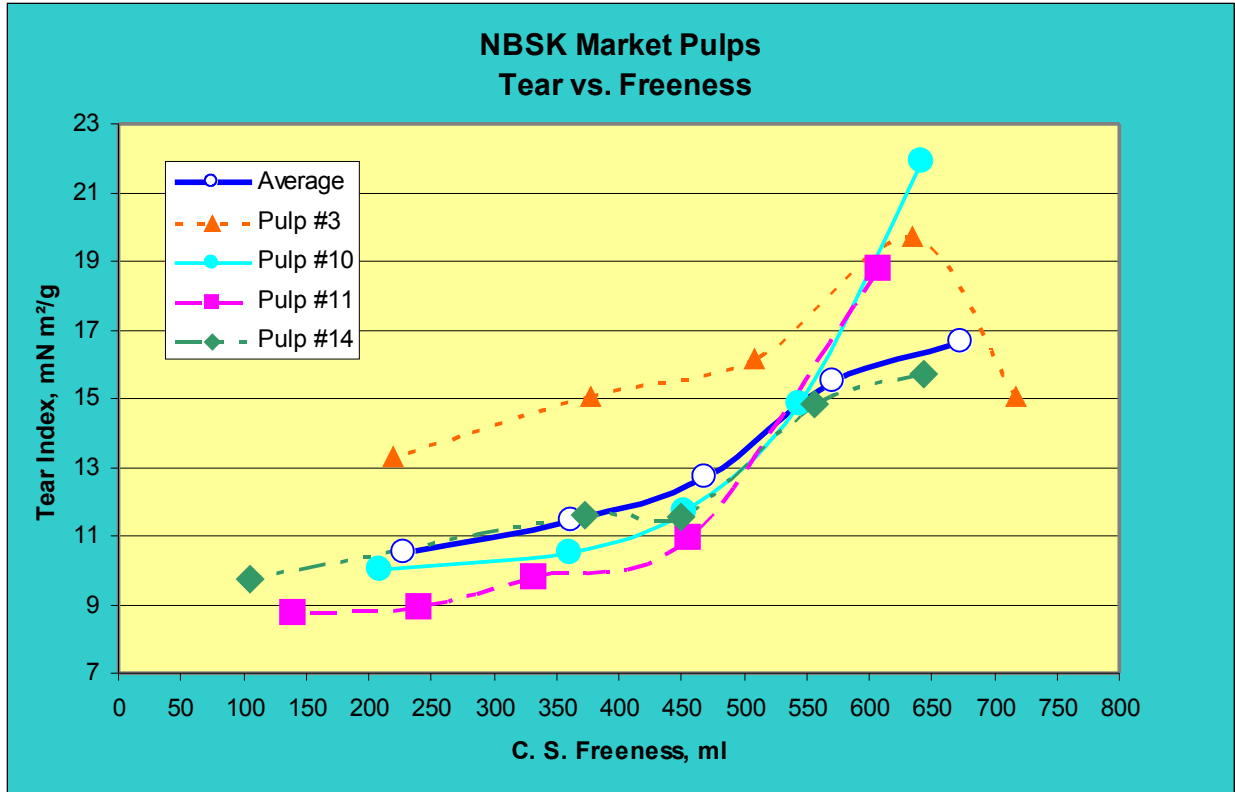


Figure 3. NBSK Market Pulp: Tear vs. Freeness

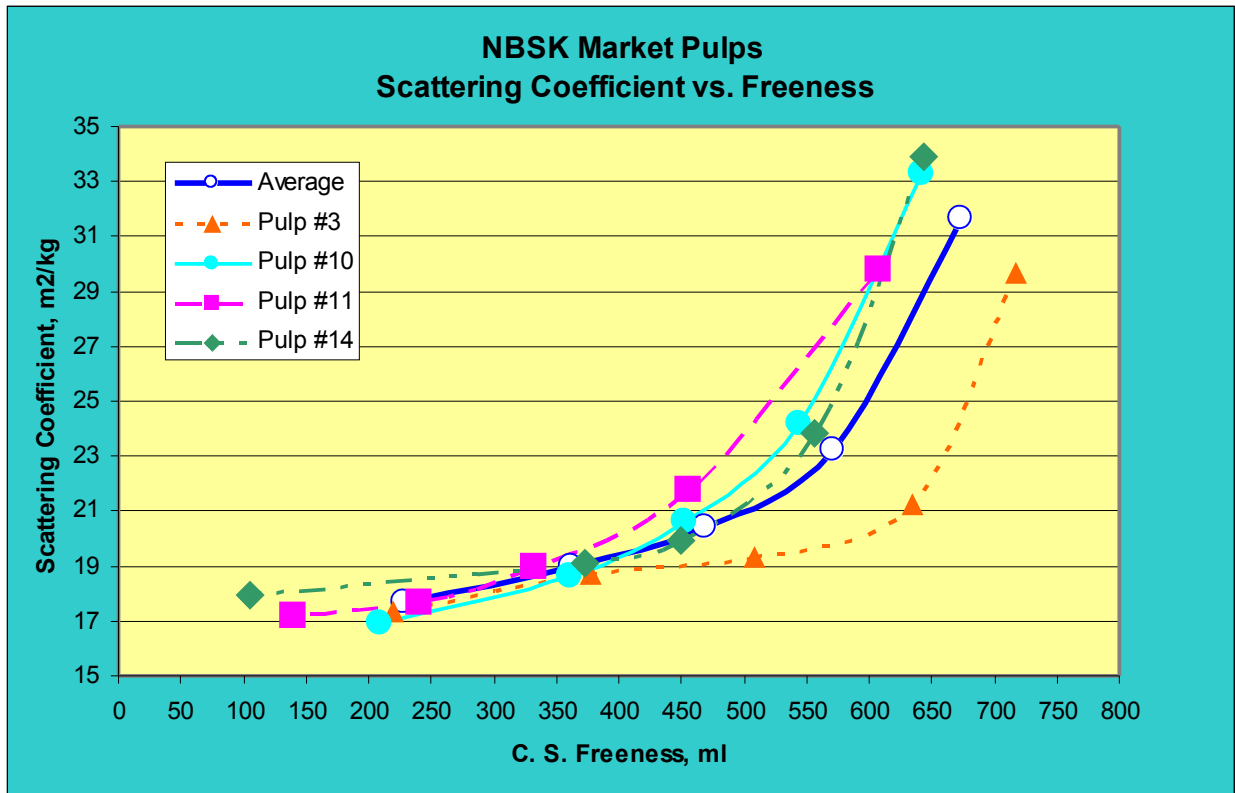


Figure 4. NBSK Market Pulp: Scattering Coefficient vs. Freeness

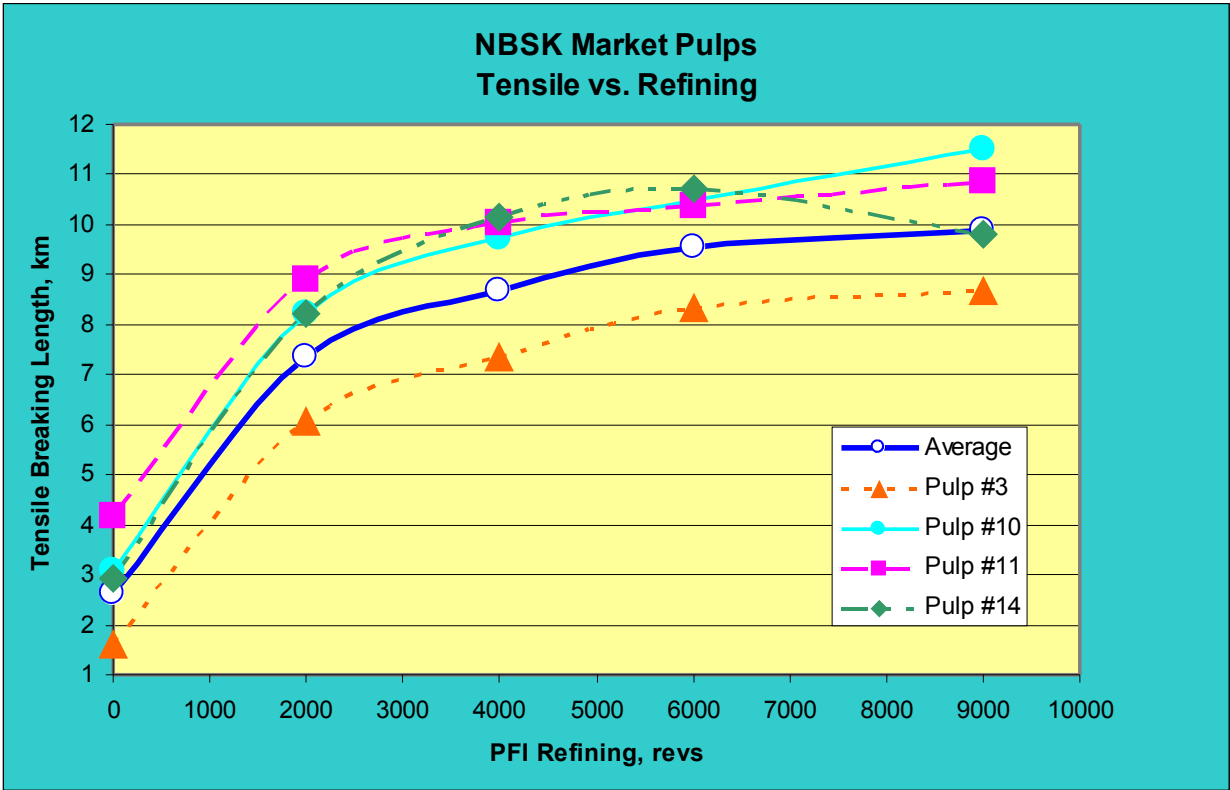


Figure 5. NBSK Market Pulp: Tensile vs. Refining

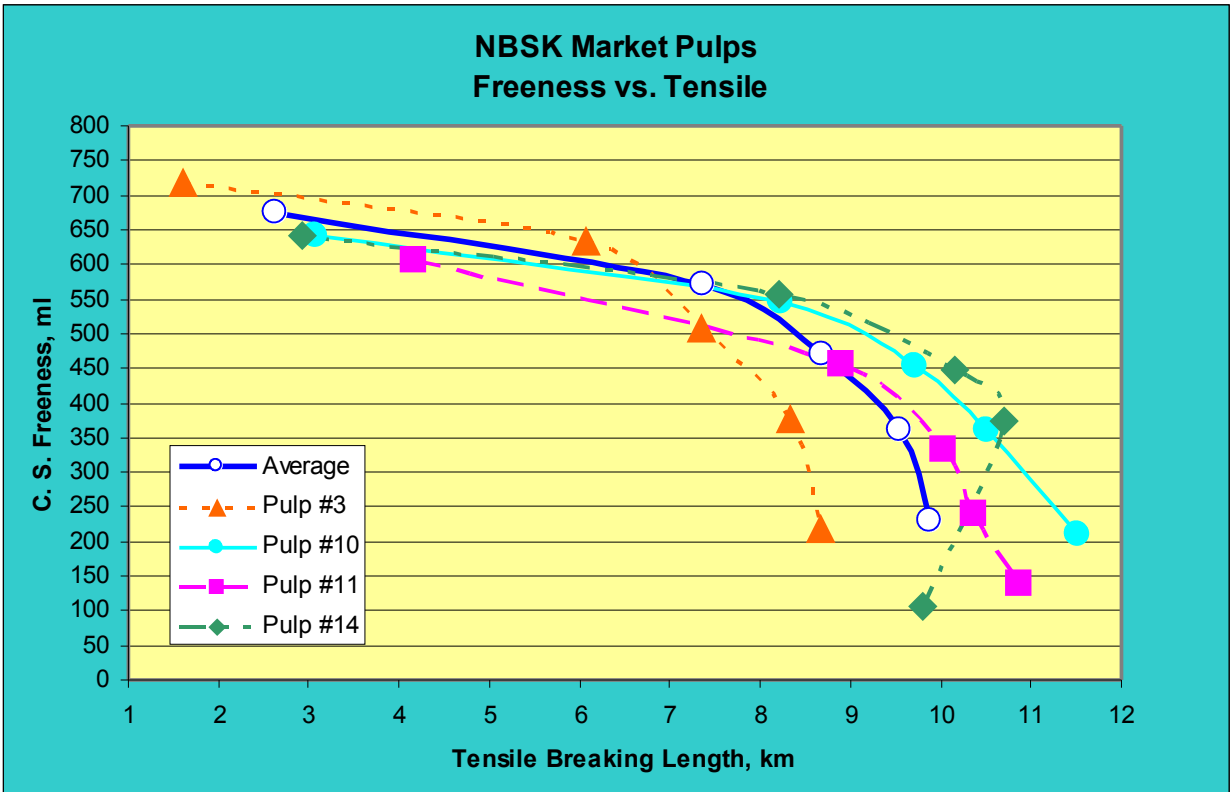


Figure 6. NBSK Market Pulp: Freeness vs. Tensile

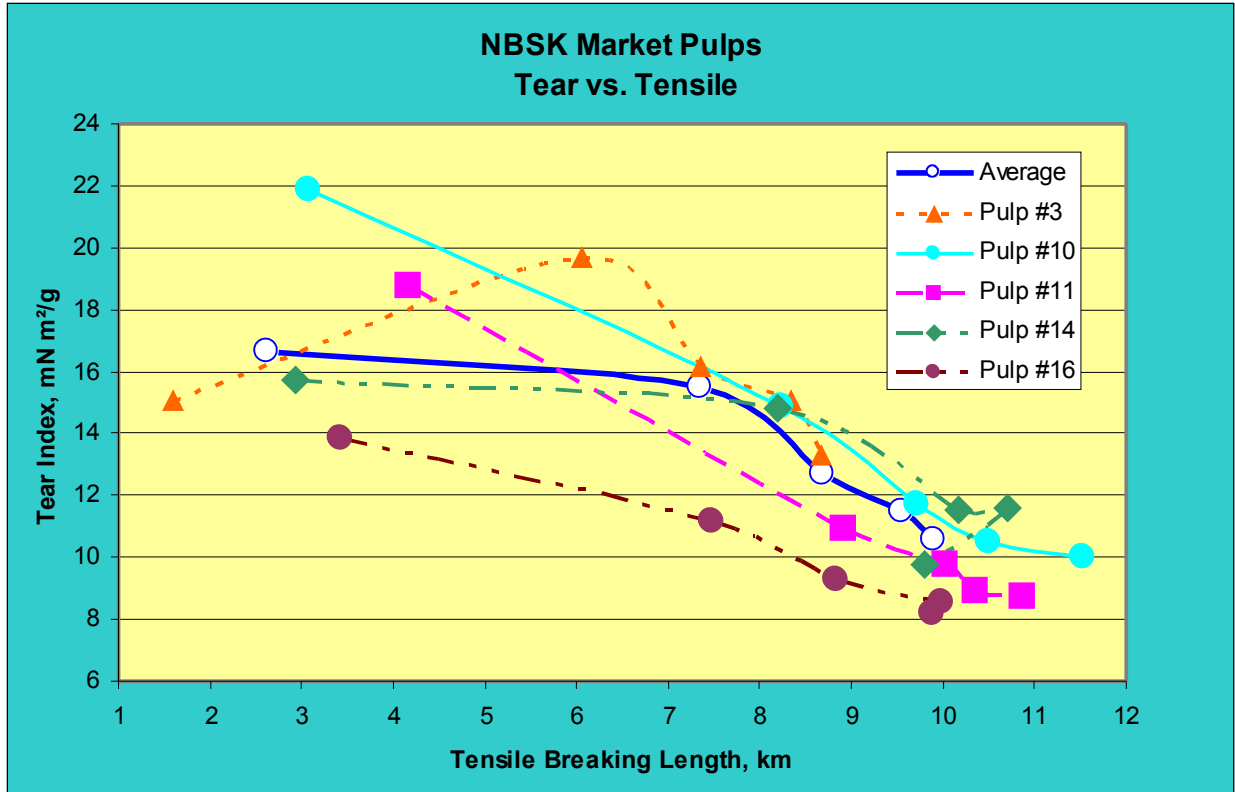


Figure 7. NBSK Market Pulps: Tear vs. Tensile

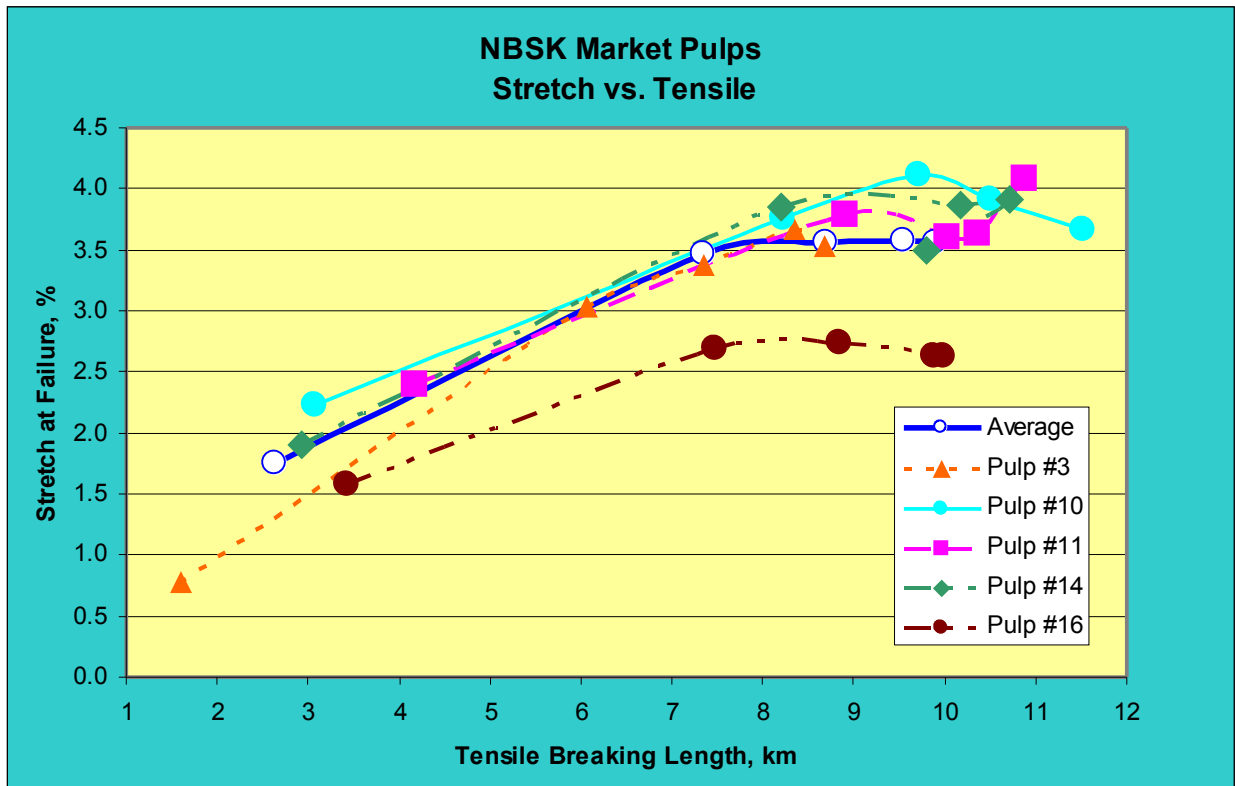


Figure 8. NBSK Market Pulps: Stretch vs. Tensile

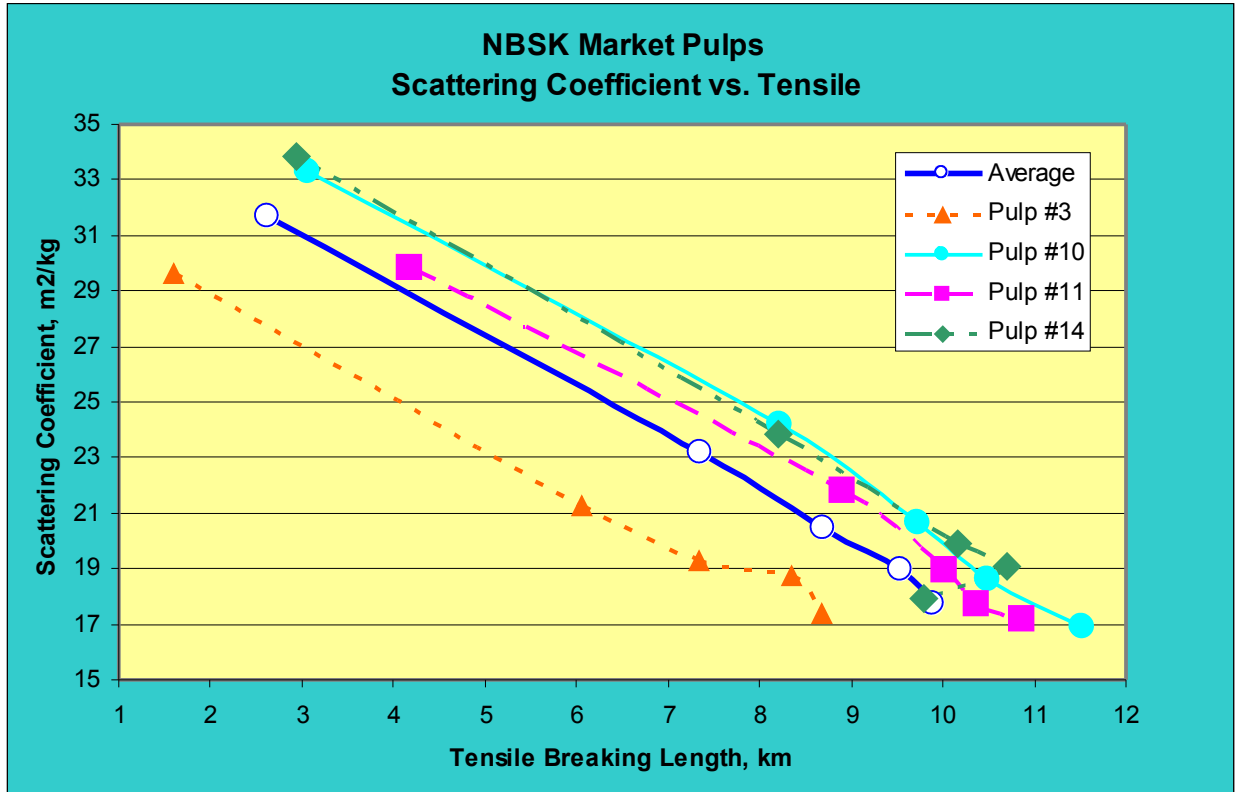


Figure 9. NBSK Market Pulps: Scattering Coefficient vs. Tensile

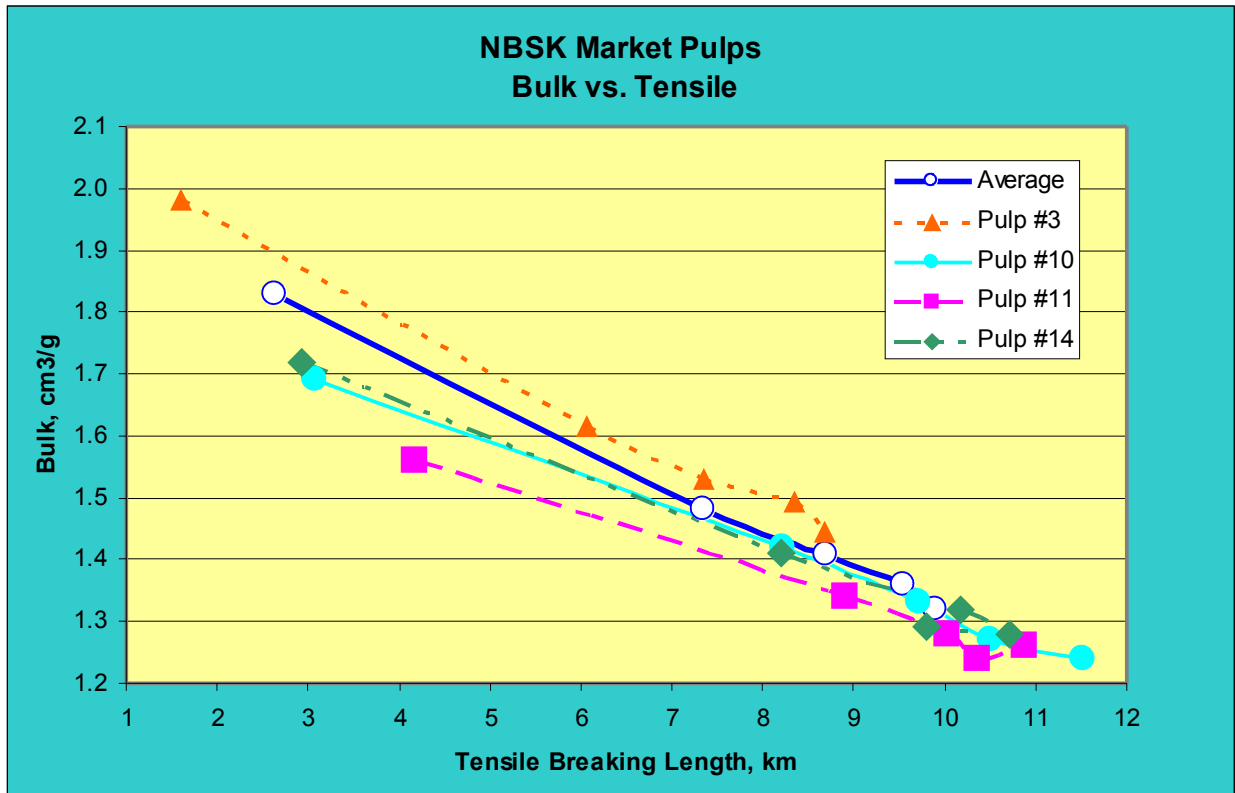


Figure 10. NBSK Market Pulps: Bulk vs. Tensile

TABLE I. Reinforcement Application: Moderately High Development Level from Refined Pulp Perspective

Refined Pulp Attribute at: 8.5 km Tensile Breaking Length	NBSK Market Pulps					
	Average	Pulp #3	Pulp #10	Pulp #11	Pulp #14	Pulp #16
Refining properties:						
PFI, revolutions	3672	7140	2202	1752	2202	3279
Drainage properties:						
C.S. Freeness, ml	488	327	534	475	545	480
Handsheet properties:						
Bulk, cm ³ /g	1.42	1.48	1.41	1.36	1.39	1.49
Tear Index, mN*m ² /g	13.2	14.5	14.5	11.7	14.6	9.8
Stretch, %	3.55	3.66	3.83	3.71	3.91	2.75
Optical properties:						
Scattering Coefficient, m ² /kg	20.8	18.2	23.7	22.5	23.3	21.8

Green = most desirable; Red = least desirable

TABLE II. Reinforcement Application: Moderately High Development Level from Fiber Perspective

Unrefined Pulp Attribute	NBSK Market Pulps					
	Average	Pulp #3	Pulp #10	Pulp #11	Pulp #14	Pulp #16
Fiber morphology: Optest FQA, Britt Jar						
Fiber length (Avg. length-weighted), mm	2.24	2.53	2.3	1.99	2.51	2.13
Fiber Coarseness (Avg.), mg / m	0.172	0.202	0.143	0.137	0.176	0.191
Population (Fines free), fibers x 10 ⁶ /g	3.94	3.19	4.29	5.24	3.65	3.82
Britt Jar Fines, %	4.21	4.58	3.34	4.49	4.56	4.64
Coarseness/Length, C/Lw	0.077	0.08	0.062	0.069	0.07	0.09
Length Distribution (Fines free), Lz/Ln	1.89	2.09	1.79	1.83	1.89	2.06
Formation (Gel Point Concentration), %	0.101	0.088	0.093	0.101	0.084	0.12
Fiber strength: Pulmac						
Zero Span, km	13.1	13.7	14.2	13.5	14.2	13.9
Optical properties:						
Brightness (ISO), %	87.8	88.9	89.2	88	89.1	89.0

Green = most desirable; Red = least desirable