The Effect of Pulp Pad Dryness in Determining Brightness using Non-Standard Fast Drying Methods

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In integrated pulp and paper mills a rapid pulp brightness determination method is needed at the pulp mill for quality and process control. In this study, the effect of dryness on the brightness reading of pulp pads has been studied. The results showed that in comparison with that from the TAPPI standard test procedure, the brightness was significantly lower when the pulp pad dryness was lower than 50%, implying that at pulp mills, the pulp pads should be dried quickly to a dryness of about 50% or higher in order to give rapid, yet reproducible brightness results. For this purpose, a forced hot air dryer was designed to dry the pulp pads to 50 to 60% dryness in about 15 minutes. The pulp pads which were dried with the forced hot air dryer had similar brightness readings to those prepared and dried by following the TAPPI standard method. Alternatively, a microwave oven can be used for the same purpose, and the pulp pads can be dried to about 50% dryness in 2.5 minutes.

Keywords: Pulp brightness; Rapid measurement; Pulp dryness; Rapid drying method

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INTRODUCTION

The brightness of pulp is defined as the diffusive reflectance of blue light from a pad of pulp sheets, using a defined spectral band of light having a nominal wavelength of 457 nm (Holik 2006)). The pulp brightness is one of the most important quality parameters, and it is also critical for controlling the chemical dosages in the bleach plant (Paul and Rowat 2011; Robinson *et al.* 1974; Van Fleet 1998). In the TAPPI test method (TAPPI Test Methods, T218 sp-02), pulp pads need to be prepared and air-dried under the conditions of 23 $^{\circ}$C and 50% relative humidity for at least 24 h. For process monitoring and control purpose at the pulp mill, online pulp brightness sensors have been widely used for real-time process control purposes (Paul and Rowat 2011; Robinson *et al.* 1974; Van Fleet 1998). Additionally, laboratory testing is often carried out by technicians; for example, in some mills, the manual brightness testing is done every hour in the bleach plant. In these cases, it is critical to measure the pulp brightness quickly, and it is not practical for pulp mills to follow the TAPPI method, due to the time delay to complete the testing. As a result, pulp mills have developed some in-house procedures for a quick method to make pulp pads and measure brightness. This can vary from one mill to another. For example, a Büchner funnel and vacuum suction method is typically used to make brightness pads, and then some mills measure brightness on wet pulp pads, some

may use the pressed pulp pad, and some may use speedy driers to dry the pulp pads to various dryness.

Pulp moisture content is an important factor in brightness measurement. The dryness in pulp pads prepared by the vacuum suction method can vary from 15 to 35%, which can cause significant variation to the measured brightness value. On the other hand, when the pulp pad is dried using a hot press or an oven, there is also the possibility for brightness reversion due to overheating the pulp pad (TAPPI Test Methods, T218 sp-02; Granström *et al.* 2002; Tran 2002; Granström *et al.* 2001; Jahan *et al.* 2010a,b). Therefore, pulp mills that do not have an automated system for making brightness pads and measuring brightness and rely on manual testing have to understand the influence of pulp pad dryness on the measured brightness. Otherwise, there will be variations in the brightness values induced by the variation in the testing method between technicians.

In a paper published by Zhang *et al.* (2010), it was reported that the moisture content of the pulp pad is a major factor affecting the brightness measurement, especially at moisture content lower than 60%. By pressing the wet pulp pad onto a glass plate, a rapid method for pulp brightness determination was reported by the same authors (Zhang *et al*. 2010), which gave a good reproducibility in brightness measurement for the wet pulp pad.

This study was undertaken to demonstrate and validate a quick method for brightness measurement for process control purposes and/or to validate the brightness before sending pulp to paper machines. Especially when brightness is measured on a wet pulp pad, the influence of moisture is a big factor for the brightness reading. This work will also serve to support the notion that due to the changes in personnel at the pulp mills, the training is usually conducted informally by passing information from word of mouth. Thus, procedures and practice may have altered, resulting in variation in the brightness measurement values. For bleach plants that rely heavily on manual testing for making brightness pads, it is critical to accurately measure the brightness, but also in a timely manner in order to decrease the bleaching costs while maintaining the product quality.

The objectives of this project were: 1) to investigate the effect of moisture content on the brightness reading of wet pulp pads, 2) to determine the pulp brightness using non-standard drying methods, such as forced air fan, microwave so that a quick brightness measurement can be made. The hypothesis is that the dryness variation of the pulp pad causes the variation in brightness testing. A forced hot air dryer was designed, an approach that allowed the wet pulp pad to dry to about 50% dryness in about 15 min, and this dried pulp pad showed similar brightness to that of the air-dried pulp pad following the TAPPI standard method. Alternatively, a microwave oven can be used to reduce the drying time, but a study must be conducted in the mill to determine the optimum time setting depending on the power rating of the microwave to reach the optimum dryness. A standard test method should always be used as a reference for comparing and developing the quick testing method.

EXPERIMENTAL

Materials

A semi bleached (D_0Eop) softwood kraft pulp (never-dried), and market bleached kraft pulp samples (both softwood and hardwood) were used in the study.

Preparation of Pulp Pads

The semibleached pulp was used without further treatment. The market bleached kraft dry pulp sheets were soaked in deionized water at room temperature for 4 h and then disintegrated for 15,000 revolutions in a British standard disintegrator. Pulp pads were prepared by filtration on a Büchner funnel with a 200-mesh screen, by following the TAPPI Test Method T218 sp-02.

Drying of the Pulp Pads

Four different drying methods were used to dry the prepared pulp pads:

1) The pulp pads were dried in an air-conditioned room at 23 °C and 50% relative humidity for 24 h (TAPPI standard method T218 sp-02).
2) The pulp pads were dried for 0.5 to 5 hours in an air-conditioned room at 23 °C and 50% relative humidity, with a fan to increase air flow (TAPPI standard method T218 sp-02).
3) The pulp pads were dried in a newly developed forced hot air pulp pad dryer for 5 to 25 min.
4) The pulp pads were dried in a 1500 W microwave oven for 20 to 450 seconds.

Forced Hot-Air Fan Dryer

The design of the forced hot air dryer for pulp pads is shown in Fig. 1. It consisted of a fan, an electric heating element, and a sample holder. The fan had a capacity to generate about 2 cubic meters of air flow per minute. The heating element provided 1500 W of heating capacity. In the sample holder there were two levels of screen, so two pulp pads could be processed at the same time. The pulp pads were secured on the screen with clips. When this forced air fan dryer was turned on, the temperature in the tunnel would increase from room temperature to about 60 °C in 2 min. The electric power to the pulp pad dryer was controlled by a timer, which could be set from 1 to 60 min.

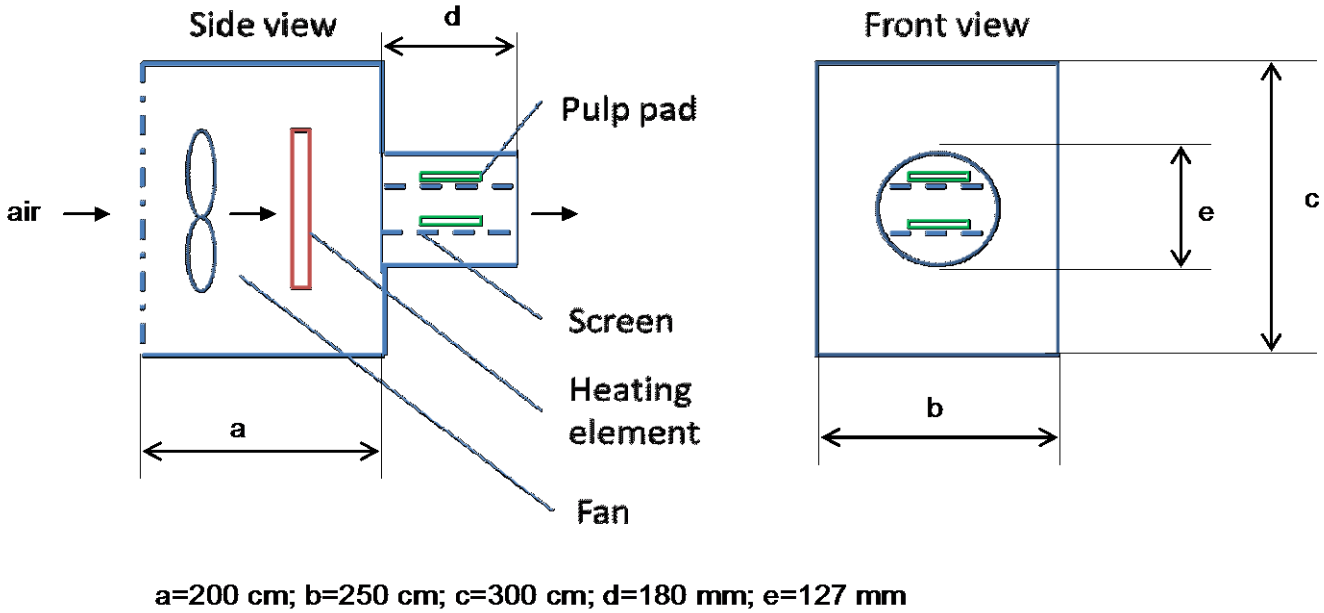

Fig. 1. Schematic of the forced hot-air fan dryer

Testing of the Pulp Pad Brightness

After drying, the brightness of the pulp pads was tested immediately on an Elrepho spectrophotometer according to the TAPPI standard method (T525 om-92).

Testing of the Pulp Pad Dryness

The moisture content of the pulp pads was determined according to the TAPPI method (T55). After measuring the brightness, the weight (W_1) of the pulp pads were taken immediately to 0.001 accuracy, and then dried to constant weight (W_2) in an oven at 105 °C. The dryness of the pulp pads was calculated as W_2/W_1*100%.

Experimental Errors

For each trial, 3 replicates were conducted, and the average was reported. The relative standard deviation of the brightness and dryness of three replicate trials was below 5%.

RESULTS AND DISCUSSION

Effect of Pulp Dryness on Brightness

In order to determine the effect of pulp pad dryness on brightness, pulp pads were made with the fully bleached pulp and dried using a fan for different time periods at 23 °C and 50% relative humidity. Table 1 shows the results.

Table 1. Effect of Pulp Dryness on the Pulp Brightness (Fully Bleached Softwood Kraft Pulp. Brightness pulp pad drying conditions: 23 °C, 50% RH, Forced Air)

Time (hour : min)	Dryness (%)	Brightness (%, ISO)
0	27.1	87.3
0:28	33.5	87.4
1:21	40.9	88.4
1:50	49.9	89.5
2:15	56.7	89.5
2:43	65.0	89.6
3:16	75.8	89.9
3:52	83.6	89.8
4:25	88.8	89.9
5:04	91.5	89.8
24*	93.5	89.6

* TAPPI standard test method (T218 sp-02)

It can be seen in Table 1 that the pulp pad dryness had a pronounced effect on the brightness: a much lower brightness was obtained at lower pulp pad dryness. However, when the pulp pad dryness was increased to 50% or higher, the measured pulp brightness became stable. Zhang *et al.* (2010) also observed similar moisture effects on the brightness testing of different pulps. At a dryness lower than 50%, the excess amount of water filled up the voids and thus decreased the light scattering coefficient of the pulp sheets, as the refractive index difference between cellulose and water is smaller than that between cellulose and air. As a result, the brightness reading of the pulp pad was lower. The effect of light scattering coefficient on brightness can be described by the well-known Kubelka-Munk equation, as summarized in a recent review article (Hubbe *et al.* 2008).

The results in Table 1 also show that when the pulp pads were dried to 50% solids or higher, the brightness reading was very similar to that obtained by the TAPPI standard method (dried for 24 h without a fan at 23 °C and 50% relative humidity).Another advantage of drying the pulp pads to 50% or higher dryness was the improved repeatability of brightness testing. A forced hot air pulp pad dryer was therefore developed to quickly dry the pulp pads to 50% dryness or higher in a short time.

Drying with the Forced Hot-Air Dryer

Semi-bleached pulp samples (Samples #1 and #2) were used. Figure 2 shows that pulp pad dryness increased as the drying time increased in the forced hot air fan dryer. Pulp pad dryness reached 50% within 15 min in the forced hot air dryer versus 1.5 h using a fan. The corresponding brightness measurements are shown in Fig. 3. It can be found that the brightness was significantly affected by the pulp pad dryness. For example, for Samples #1 and #2, the brightness reading was 71% ISO at 23% pulp dryness and 75% ISO at 42% pulp dryness.

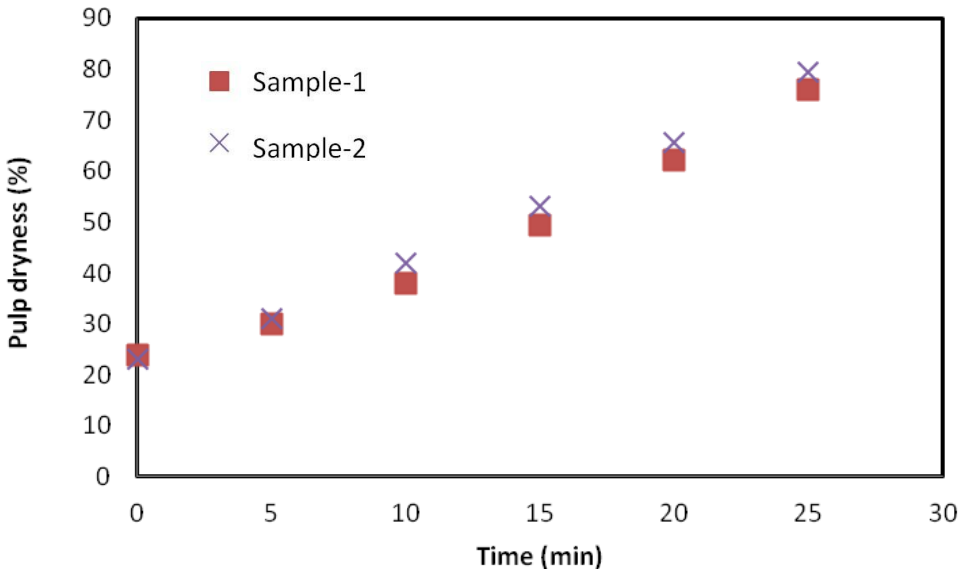

Fig. 2. The drying process of the pulp pads in the forced hot air dryer (Sample-1 and Sample-2 were two different semi- bleached softwood kraft pulps from the D_0Eop stage.)

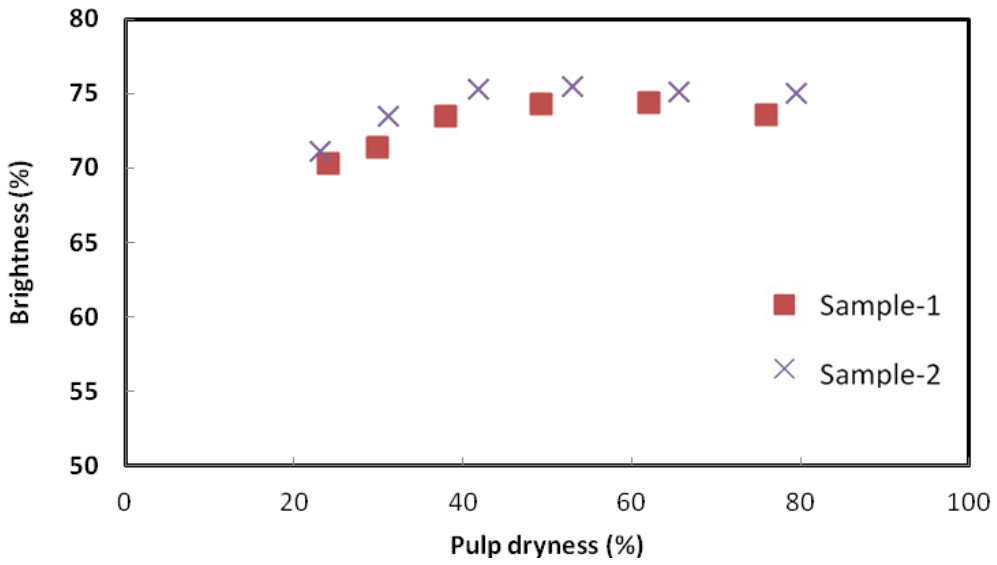

Fig. 3. Effect of drying in the forced hot air dryer on the brightness reading (Sample-1 and Sample-2 were two different semi- bleached softwood kraft pulps from the D_0Eop stage.)

Drying in a Microwave Oven

A microwave oven also was used for drying the wet pulp pads. Table 2 shows the results. It took 140 seconds (approximately 2.3 min) in the microwave oven, for the pulp pad dryness to increase from 23% to about 50%, while the brightness increased from about 83% to 91% ISO, which was very similar to the TAPPI standard method (24 h air drying without fan at 23 °C and 50% relative humidity)..

Table 2. Effect of Pulp Dryness using a Microwave Oven on the Pulp Brightness (Fully Bleached Hardwood Kraft Pulp)

Time (s)	Dryness (%)	Brightness (%, ISO)
0	22.9	83.0
20	26.6	84.8
40	30.5	86.9
60	34.3	88.2
80	37.5	89.5
100	40.9	89.9
140	49.0	91.2
200	63.8	91.6
220	69.0	91.3
280	81.3	91.6
300	85.1	91.2
330	90.6	90.7
Overnight*	94.0	90.8

* TAPPI method, (T218 sp-02), air-dried overnight (24 h) at 23°C, 50% RH, without fan

By increasing the drying time from 140 to 330 seconds, the dryness of the pulp pads increased from 50% to about 85%, but the brightness reading remained essentially unchanged. These results support the conclusion that the brightness of pulp pads is stable when the pulp pad dryness is 50% or higher. Though the optimum time in our study was 2.5 min, this time may vary for each mill, depending on the type of microwave oven used and the brightness pad preparation method, *etc*. Each mill would need to do a similar study as presented in this paper to determine the optimum time setting required, depending on the power rating of the microwave and the brightness pad preparation method, to reach the optimum dryness

CONCLUSIONS

Brightness readings of pulp pads were found to be greatly affected by their moisture contents. A 50% pulp pad dryness was determined to be the breakeven point. Below 50% dryness, the brightness reading was strongly affected by the pulp dryness; at 50% or higher pulp dryness, the brightness reading was essentially independent of the dryness. To improve the accuracy of fast pulp brightness testing at pulp mills, it is recommended that a standard procedure should be followed in preparing and drying the pulp pads to at least 50% dryness prior to measuring the brightness. In this study it was shown that a forced hot air dryer, or alternatively a microwave oven, can be used to quickly dry the pulp pad to 50 to 60% dryness.

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