Grinding of a PFI Mill: a comparison between two PFI mills by evaluation of Eucalyptus pulp physical properties

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Grinding of a PFI Mill: a comparison between two PFI mills by evaluation of *Eucalyptus* pulp physical properties

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The traditional methods for cellulose pulp evaluation require a transformation into laboratory hand sheets in conjunction with drainability tests. In this evaluation, as a previous step, the pulp undergoes a treatment of the fibers by a laboratory refining procedure, which simulates the process made at paper mills.
The PFI mill method is still the most used in laboratories, as it provides a uniform treatment of pulp giving more homogeneity in the refined fibers and uses a small quantity of sample. The PFI mill traditionally used in the Forest Projects Department of the Technological Laboratory of Uruguay (LATU) provides robustness and confidence along with control charts and historical data already well established. This confidence is based on inter and extra reference analysis. Recently, our laboratory has acquired a new PFI mill.
The objective of this study was to achieve a similar beating effect of the new PFI mill as the effect of the one habitually used, in order to have interchangeable mills. The adjustments were made over the new mill by using mixtures of silicon carbide powder. To evaluate the beating effect a reference Eucalyptus pulp was refined. After each adjustment a refining was made and the Canadian Standard Freeness (CSF) measured. When the CSF reached the approximate desired value, hand sheets were made to determine the physical properties. Finally, when the results were comparable to those of the long-established mill, several refinings were made to evaluate their stability. The results proved that both mills were equivalent, thus concluding that the grinding procedure was successful allowing an optimized indistinct use of them.

Keywords: PFI mill, Eucalyptus bleached pulp, Canadian Standard Freeness, Physical pulp properties.

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INTRODUCTION

The laboratory refining process is done to predict the usability of the pulp, although it is usually operated differently to the industrial process. Nevertheless, it is one of the most important procedures to characterize the cellulose pulps.

The industrial refining or beating of the pulps is a mechanical treatment over the cellulosic fibers in order to achieve their optimal characteristics for the final use. The refining produces internal and external fibrillation, fines production and shortening of the fibers. As a consequence of this, there are also changes in the flexibility, specific volume and mechanical resistance of the fibers (Smook, 1990). Besides, the refining process diminishes the pulp drainability by increasing the water uptake of the fibers. In the case of the laboratory refining the consequences over the fibers are similar, but it is used to characterize the pulp by determining the development of certain properties like drainage, physical properties, *etc.* (Hiltunen, 2000)

Several aspects affect the variability of the laboratory refining process. Among these, the equipment and beating procedure are the most important. The most common used laboratory is the PFI mill, with other common mills being the Valley, Jokro and Voith mills (Hiltunen, 2000).

In the case of the PFI mill the consistency of the refining is 10 % while industrial refining consistency is around 2 % to 5 %. One of the advantages of the PFI mill is the small amount of pulp needed for the refining process (Hiltunen, 2000)

In the Forest Department of the Technological Laboratory of Uruguay (LATU) we have a significant experience using a PFI mill. Several years of measurements and controls inside our laboratory using a stable reference pulp, and the participation in different rounds of worldwide interlaboratory comparisons has made of our PFI refining a quite well established and controlled process. Therefore, it is well known that even between PFI mills there are important variations.

Moreover, the increase in the demand of laboratory testing due to the installation in Uruguay of different pulp mills has presented the necessity of acquiring a PFI mill. Also, the extra PFI would allow the continuous delivery of the service even if any setback presents.

In consequence, the recently acquired PFI mill has been taken to the same refining level of the established mill to allow an indistinct use and to give comparable results. This study presents the procedure made to grind the PFI mill and the evaluation of the properties affected by the refining process.

EXPERIMENTAL

Materials And Methods

Beating effect evaluation

To evaluate the beating effect, a reference Eucalyptus pulp was refined using each one of the PFI mills, according to ISO 5264-2. The pulp was a Kraft ECF-bleached. Refinings were made using two PFI mills Kumagai Riki Kogyo:

PFI A: The habitually used, requires the manual application (by a lever) of the load of weight responsible for the beating. (Figure 1)

PFI B: The new PFI beater, works automatically, using a pneumatic load and a predetermined digital revolution counter. (Figure 1)

The number of roll revolutions used for the study was 4000. After each adjustment a refining of pulp was carried out and the Canadian Standard Freeness (CSF) was measured (ISO 5267-2).

Figure 1. Left: PFI A; Right: PFI B

Grinding process

After the first beating effect evaluation, it was concluded that the new PFI beats less than the other one. As the objective was to achieve a similar beating effect between both PFI by doing adjustments on the new one only, it was necessary to carry out a grinding procedure. First, the direction of the beater housing was reversed; in order to obtain a clockwise rotation. Then, a fine-grinding procedure was performed. The beater was charged with a mixture prepared with 15 g of silicon carbide powder passing through a 45 µm aperture, 50 mL of soluble oil (Hummer) and 50 mL of water, while the roll revolutions were set on 5000. Before cleaning the equipment carefully (including one refining with pulp) the beater housing was returned to the anticlockwise direction of rotation. A beating effect evaluation was done immediately, showing that a rough-grinding procedure was necessary. The steps for it were the same previously followed, using a similar mixture but this time the silicon carbide powder used passed through a 90 µm aperture. The fine-grinding procedure was repeated again and some rough edges were removed using an abrasive file. The evaluation performed at this stage was an evidence for a similar beating effect reached between both PFI mills.

Checking the stability

When the results were comparable to those of the long-established mill, several refinings were made to evaluate their stability. The drainage capacity was studied again by Canadian Standard Freeness (CSF), Schopper-Riegler (SR, ISO 5267-1), and Water Retention Value determinations (WRV, ISO 23714); while the physical and optical properties studied on hand sheets were done according to ISO 5270 and ISO 2470.

Visual evaluation

The refined pulp was observed using a Nikon Eclipse E 800 microscope with the image analyzer Image Pro Plus. To do this, small amounts (less than one gram) of the pulp were diluted in deionized water. From this dilution a drop was taken and observed over the microscope slide. Several sub-samples were prepared.

RESULTS AND DISCUSSION

Figures 1 to 8 show the behavior of the PFI B for the different properties studied. In every plot it is represented the control limits as they were established for the PFI A and the control limits calculated for the PFI B. In the case of Figures 1 to 3, the 'wet' properties are plotted, *i.e.* the CSF, the SR and the WRV. For the three properties it can be seen (and statistical tests applied proved) that there are no significant differences for both mills. However, the average values and the control limits show an analogue trend, meaning that the beating effect may be less for the PFI B than for the PFI A. Although this could be corrected by applying another round of a grinding procedure, there are some other aspects that were considered to decide not to do it. In particular, the participation of our department in several interlaboratories (Innventia, 2008 to 2013) has proved that refinings made by different PFIs around the globe have a high dispersion. Therefore, the comparability achieved between our two PFI mills should be qualified as quite acceptable. Also, it must be noted that the grinding procedure is a somehow destructive method, since the metal parts of the PFI are affected. In this case, if another grinding round had been applied, different standardized dimensions in the equipment could be affected.

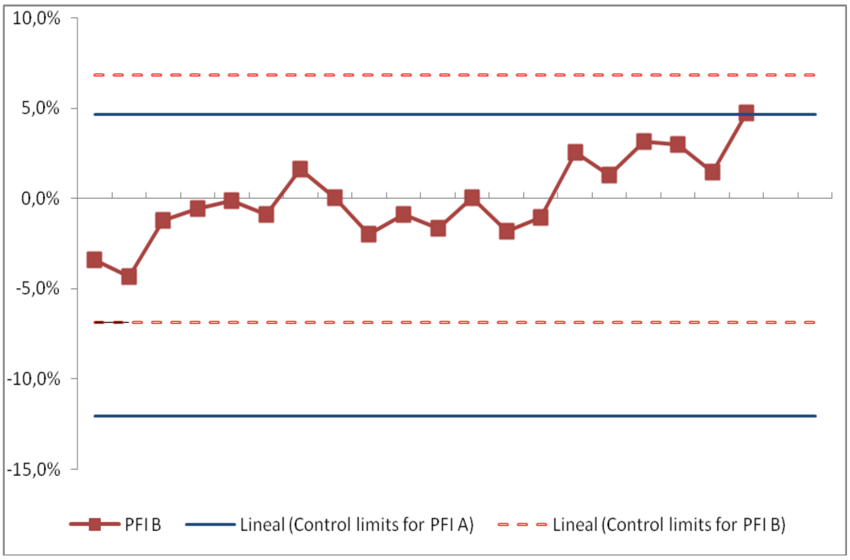

Figure 2. Canadian Standard Freeness evaluation. The 0.0 % represents the average of the measurements made with the PFI B.

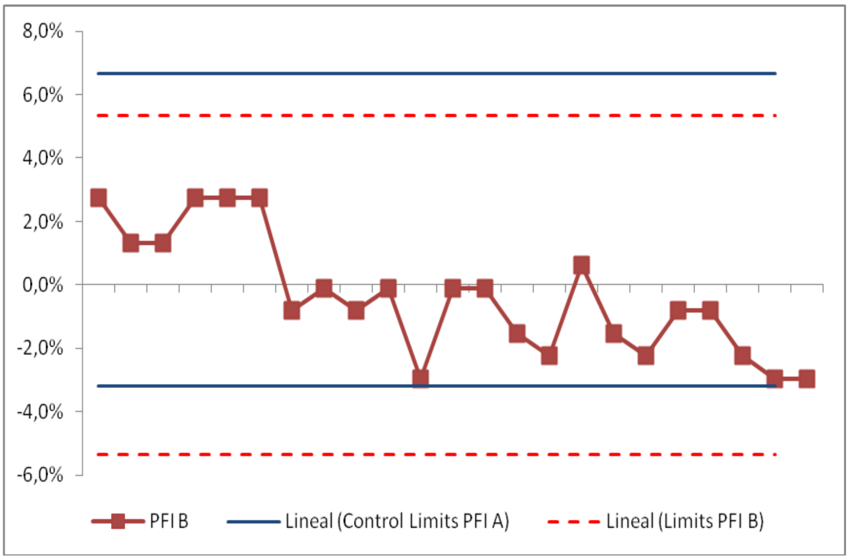

Figure 3. Schopper-Riegler evaluation. The 0.0 % represents the average of the measurements made with the PFI B.

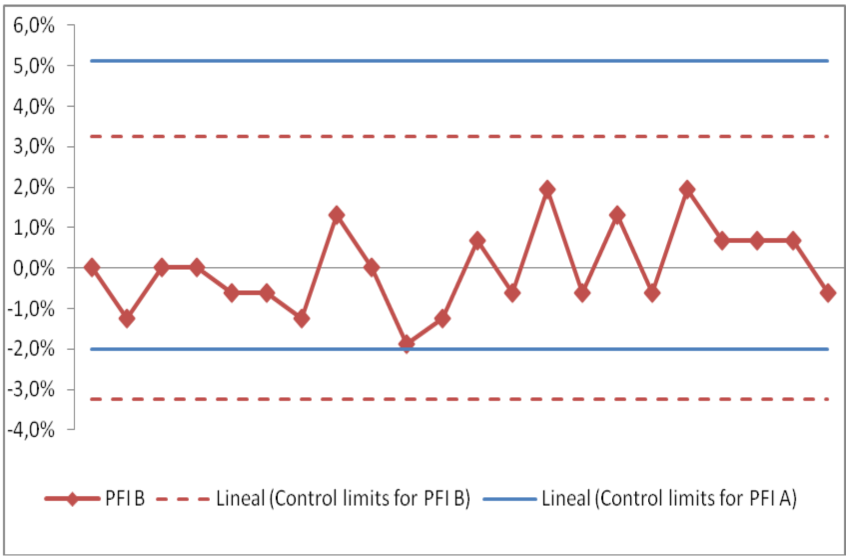

Figure 4. Water Retention Value evaluation. The 0.0 % represents the average of the measurements made with the PFI B.

In addition to this, not all the properties behave in the same manner. Although tensile index (Figure 4) has the same tendency as the properties previously discussed, in the case of the tear index (Figure 5) the plot control parameters are almost the same. A modification of the beating effect that could make a more similar behavior for other properties will be clearly detrimental in the case of the tear index.

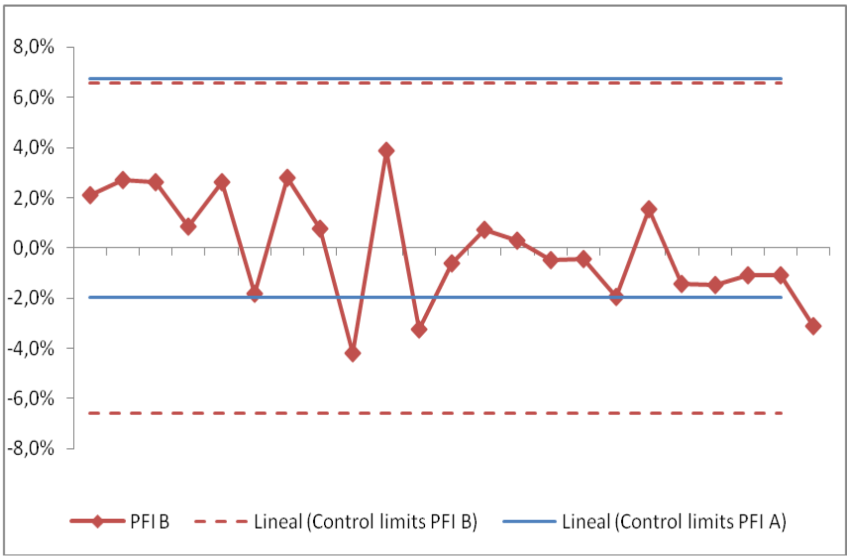

Figure 5. Tensile Index evaluation. The 0.0 % represents the average of the measurements made with the PFI B.

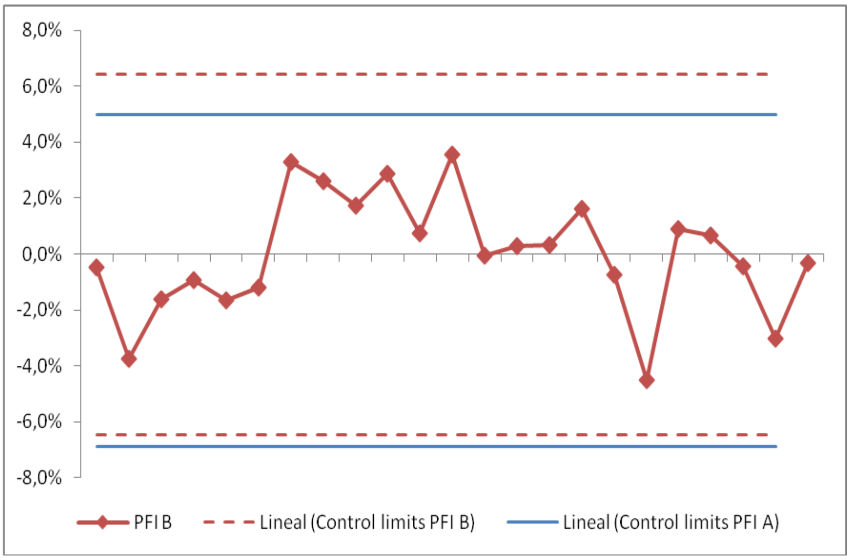

Figure 6. Tear Index evaluation. The 0.0 % represents the average of the measurements made with the PFI B.

Another point that could be interest to corroborate with further studies is the stabilization of the PFI B mill measurements (Figures 6 and 7), probably due to the presence of some imperfections that are smoothed with the successive refinings. This aspect could also be explaining the previously discussed characteristic of a lesser beating effect for some properties. The figure 8 shows the density, which proves that the laboratory sheets made after refining in both mills have comparable characteristics (grammage and thickness) and therefore the mills are the only responsible for the differences in the properties.

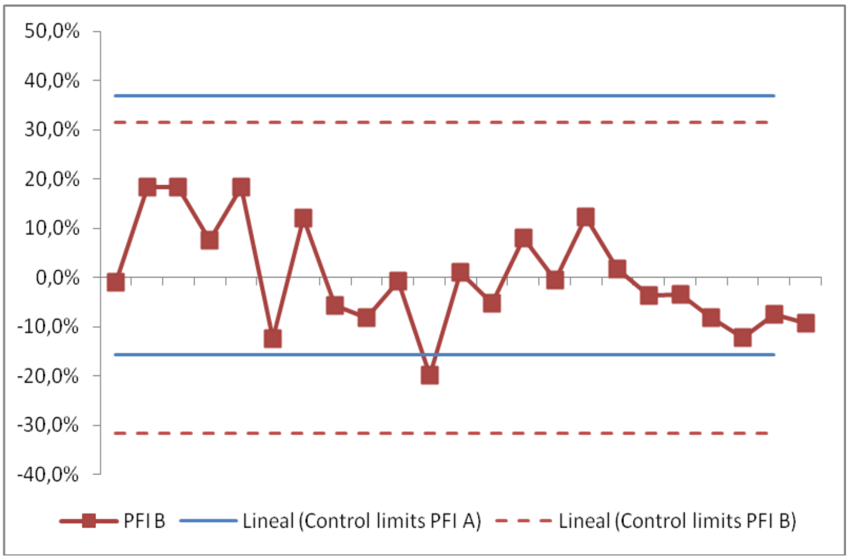

Figure 7. Gurley Porosity evaluation. The 0.0 % represents the average of the measurements made with the PFI B.

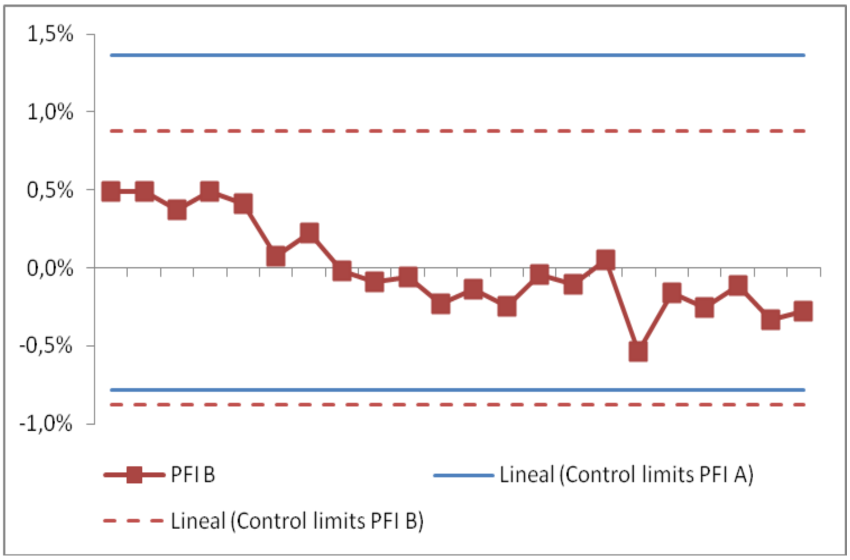

Figure 8. Brightness evaluation. The 0.0 % represents the average of the measurements made with the PFI B.

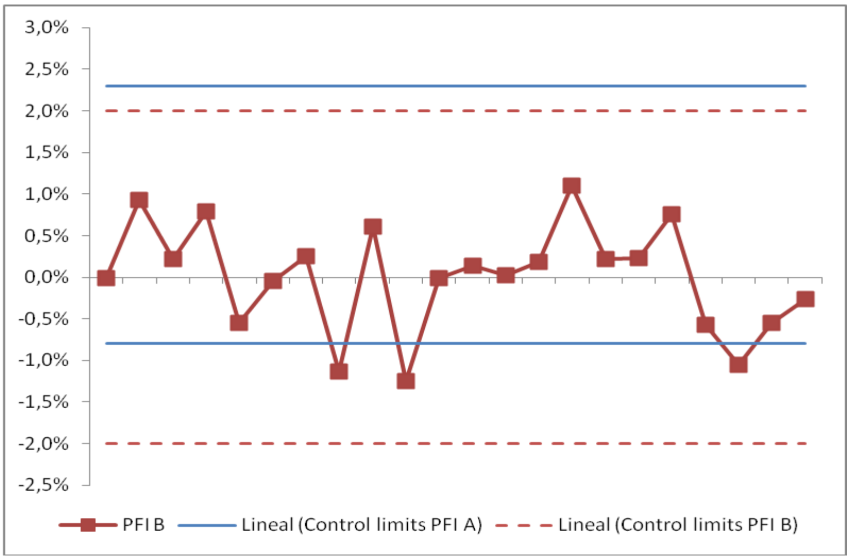

Figure 9. Density evaluation. The 0.0 % represents the average of the measurements made with the PFI B.

Finally, the qualitative visual inspection of the fibers made after refining did not showed anything unusual. However, this should be confirmed with a quantitative analysis, *e.g.* the analysis of length and width of the fibers, dispersion, deformation, curl, *etc.* (Hirn & Bauer, 2006)

CONCLUSIONS

1. The grinding procedure was successful, with both PFIs statistically comparables, and in consequence allowing an indistinct use of them.
2. In the procedure, as the PFI was thoroughly and consciously utilized in different conditions, this grinding process led to an important *know-how*.
3. This knowledge can be replicated for any PFI mill, own or over industry request.

REFERENCES CITED

Hiltunen, E (2000), in *Pulp and Paper testing*, Levlin and Söderhjelm (ed.), Helsinki, Chapter 3.

Hirn, U., Bauer, W., (2006), *Lenzinger Berichte*, 86, 96-105

ISO 5264-2:2011(E) Pulps-"Laboratory beating" Part 2: PFI mill method.

ISO 5267-1:1999(E) Pulps-"Determination of drainability"-Part 1: Schopper-Riegler method.

ISO 5267-2:2001 (E) Pulps-"Determination of drainability"- Part 2: Canadian Standard freeness method.

ISO 23714:2007(E) Pulps- "Determination of water retention value (WRV)"
ISO 5270:2012 (E) Pulps- "Laboratory sheets-Determination of physical properties"
ISO 2470-1:2009(E) Paper, board and pulps "Measurement of diffuse blue reflectance factor" Part 1:Indoor daylight conditions (ISO brightness)
Smook, G.A. (1990). "Manual para técnicos de Pulpa y Papel", Tappi, Atlanta