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INFLUENCE OF LOG TEMPERATURE IN IRREGULARITIES ON STRAND GEOMETRY DETECTED BY DIGITAL IMAGE ANALYSIS

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ABSTRACT

Oriented Strand Board (OSB) wood strands, while often idealized as being rectangular and sler objects, are in fact typically very complex in shape. This complexity is important to the manufac and performance of OSB as it influences forming, screening, blending, formation and ultima performance of the panel. In a mill setting, strand geometry is defined by average length, width thickness values as determined through simple caliper measurements and/or screen analyses (Gils The application of CCD cameras and digital image analysis techniques to rapidly acquire and anal complex strand geometry will allow the processing of large amounts of data, thereby creating potential for statistical process control applications. Aspen (*Populus grandidentata*) strands w produced from logs subjected to -6ºC (20F), 21ºC (70F) and 60ºC (140F). Grey scale digital image individual strands were acquired using a CCD camera (1296 x 1016 pixels) under direct lighting. complexity of strand geometry was characterized by a variety of automated measuring procedures a result of this research the feasibility of applying this methodology to study geometrical distributi in strands was established. Area, length and width presented changes in their distributions due to effect of log temperature. It was found that the irregularity ratio of strands was variable and stron influenced by log temperature at time of stranding as well as other geometries. Statistical correla between strands irregularity and log temperature was found (p-value<0.001).

Keywords: Strand Quality, Digital Image Analysis, Non Parametric Statistics, Strand Geometry, Log Temperature

INTRODUCTION

The anisotropic character of OSB is directly correlated with strand alignment. This relationship been extensively studied (Geimer, 1975; Shaler, 1991; Mayers, 2001; Zombori, 2001; Barnes, 2002). influence of variable strand geometries on alignment and packing are known to be important (Dai Steiner, 1994), but their relationship to optimal process conditions has not been well quantified. Str overlap and out-of-plane strand orientation (waviness) also influence OSB properties creating w boundary layers. However their influence is not well quantified.

Typically OSB wood strands exhibit an irregular geometry. This complexity can be quantified b in terms of the variability among and within strands. Variation in thickness, width, length irregularities along the edges occurs due to handling and machining as well as wood quality variat However strand geometry is often idealized as being rectangular, smooth and regular in shape (Nishin et al. 2004). In a mill setting, even for quality control purposes, strand geometry is evaluated basic in terms of an average length, width and thickness values as determined through simple cal measurements and/or screen analyses (i.e. Gilson test). This approach works fairly well when sta conditions in the logs are present. However, changes in strand geometry can occur due to physical chemical variations of the wood as a consequence of environmental conditions, reaction wood, nat

variations in wood quality, and changes in operational behavior of the stranding equipment and kni
(FPL, 1999; Negro et al., 2003). Such variation in final strand geometry creates a distributio
geometries which in turn influences the efficiency of the screening and forming processes.

The variation in strand geometries can be best captured and used for decision purposes if a rob
statistical description is available. Large sample sizes are beneficial for this purpose; however deta
information on "individual" strand elements in a time effective manner requires an automated or se
automated procedure.

The use of computer based CCD cameras and image analysis techniques are a powerful and relativ
low cost approach to obtain this information. A continuous measurement system may be develo
using image analysis, allowing the development of a time-base sampling rather than a weight or co
sampling scheme. If accurate, real-time measurements of strand geometry can be obtained it co
provide an important input for statistical process control (SPC).

The objectives of this research were:
1) To advance in the development and evaluation of a methodology applicable in an OSB mil
measure and process single strand geometry using digital image analysis;
2) To determine irregularities in strand shape as a consequence of three temperature treatments in
stranding process, and
3) To determine the feasibility of applying this methodology to study the change in single str
geometrical distributions that occurs between the stranding and formation operations in a pilot produc
line.

MATERIALS AND METHODS

Strand Generation and Processing

The study material consisted of three manually debarked Aspen logs of 121.92cm (4 feet) in len
and ranging from 24.13cm (9.5 in) to 25.4cm (10 in) in diameter. The logs were cut from the base
one tree selected to be highly cylindrical in shape. Logs were submitted to freezing (-6ºC/20F), ro
temperature (21ºC/70F) and to 60ºC/140F soaking from butt log to top log respectively. The stra
were produced using a Rotating Carmanah Laboratory Ring Strander (12/48) with target geometry
0.065cm (0.025 in) in thickness, 1.27cm (0.5 in) in width and 15.24cm (6 in) in length.

The knife cutting angle was 85^{o} with setback, which was used for the three temperature treatme
to attain this target geometry. The strand moisture content (MC) ranged from 89% for frozen log
117% for soaked log. A set of two disposable knives were used to manufacture the strands.

A sensitivity test was conducted using aspen strands in order to determine a minimum sample s
to represents the population for image analysis, 4000g of dry strands produced from one log w
individually measured and from these data 10 sub-samples of different sizes were extracted. To perfo
the sub-sampling a constant thickness was assumed. The sub-sample was randomly selected by wei
considering weight as area multiplied by thickness and wood density. Each sample size was extrac
4 times. From the sub-sample median values for width, length and area were computed and the statis
were compared using a Wilcoxon Sum Rank test. The minimum sample size was determined when
p-value presented a significant level. Weight sampling procedure rather than a count sampling proced
was adopted because picking individual strands would cause a bias on the sample due to hand

From the stranded material, an as a consequence of the previous procedure, a 500g randomly selec sample was taken from each temperature treatment. After that, the strands were dried to a 6% using a Koch Low Temperature Conveyor Drier and screened using an Acrowood Trillium screene new 500g sample from each temperature treatment was taken after the screening.

Imaging Process, Measurements and Computations

The strands were placed in random groups on a rectangular black surface in such a way that a g scale (8-bit) digital image (1296x1016 pixels) of all specimens was acquired. A uniform illumina of 1.2×10^5 Candelas/m^2 was used and all images were kept at a constant scale of 0.0254 cm/pixel Figure 1 shows a diagram of the setup used to capture the images. The CCD camera was connecte a capture interface developed in a LabView environment to a standard PC, and the images stored conventional magnetic hard disk drive. Figure 2 shows an example of a group of strands as they w set and recorded. Prior to the computations a Matlab developed subroutine conditioned and filtered image to adjust contrast. The code also identified and separated the individual strands rotating the necessary to 0 degrees with respect to the major axis and creating, at the same time, a binary image a convex hull image of every strand. A binary image is a 2-level image that represents the shape of image; while a convex-hull image is the smallest convex set of points that contains the points of binary image or the minimum polygon that contains the region (Barber, 1993). The convex hull im is created and stored to perform area comparison. Through this procedure it is possible to obtain m geometrical information as crack occurrence and determine shape smoothness. Dimensions of individual strands were measured using a developed MatLab code for digital image analysis (D Width and length measurements of a sub-sample of 200 strands were taken on three different point each specimen using a Mitutoyo Digital Caliper and compared to the automated DIA measurement the same sub-sample.

Figure 3 shows a diagram with the processing and measurements that was applied to each stra

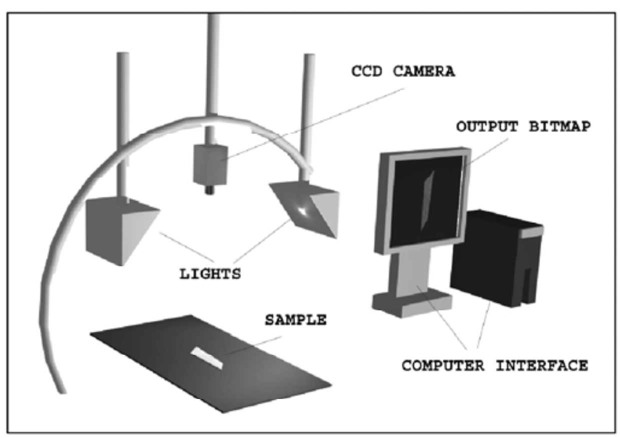

Figure 1: Basic capture setup diagram

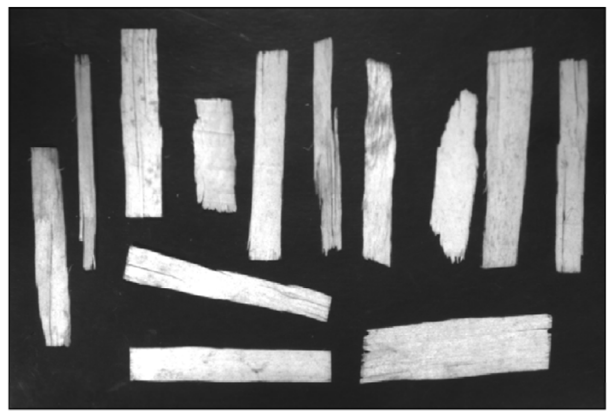

Figure 2: Example image of a group of strands

Since the actual strands exhibit an irregular shape, mean values of width (*W*) and length (*L*) were u instead of measuring the strands at a specific point. Transverse and longitudinal pixels averaging rend average *W* and *L* values. Other measures taken were area (*A*), defined as the sum of pixels in bi image; perimeter (*P*) defined as the number of pixels in the borderline; and convex hull area (*cHA* previously defined.

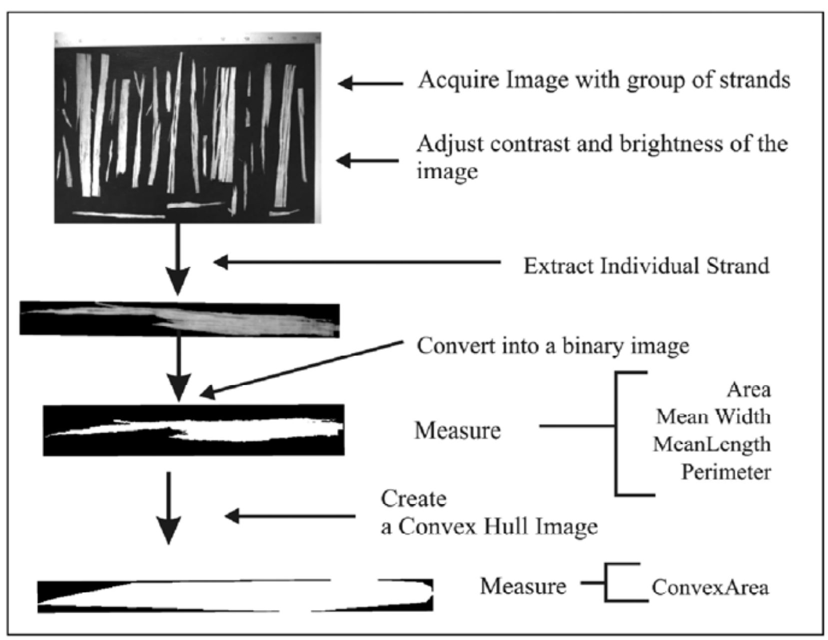

Figure 3: Diagram of Image processing

From the direct measurements on the image the following variables were computed:
1. Shape regularity (*S*), defined as the proportion of the pixels in the convex hull that are also in

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2. Eccentricity (*Ecc*) defined as the ratio of distance between the foci of the ellipse (*df*) and major a
length (*lm*) as shown in Figure 4:

$$Ecc = df/lm \tag{2}$$

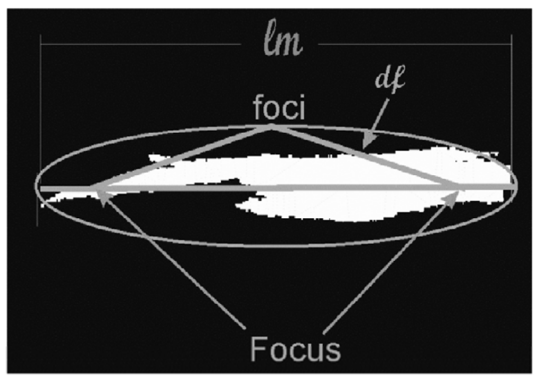

Figure 4: Definition of Strand Eccentricity

3. Slenderness (*SL*) defined as:

$$SL = L/W \tag{3}$$

4. Rectangularity (*R*) defined as the proportion of pixels out of the binary region

$$R = Ab/A \tag{4}$$

where *Ab* is the area of the bounding box. The bounding box is the smallest rectangle that contains
region.

5. Irregularity (*I*) defined as the absolute value of the ratio between the differences of actual str
perimeter and equivalent ideal rectangle perimeter (in pixels) as in equation (4):

$$I = \frac{abs(P-(2W+2L))}{(2W+2L)} \tag{5}$$

Statistical Analysis and Experimental Model

Goodness of fit was performed on all measured and calculated variables at room tempera
condition. This procedure was necessary to determine the statistical tools to be used in future resea
It was applied to room temperature treatment because it is assumed as the typical processing condit

The experimental model is designed to study the irregularities on the strand geometry due to
temperature treatments. The simple model can be expressed as

where m_i is the percentage of irregularity as defined in eq. (5), a is the temperature treatment and e
the experimental error.

In evaluating the potential applications for this multiple geometry analysis, 30 bin histograms
all the variables measured and computed were analyzed. Statistical analysis was performed us
Statgraphics Centurion XV and R.

RESULTS AND DISCUSSION

Data acquisition

The comparison between caliper measurements and digital image measurements is shown in Fig
5. In this graph it is possible to see the accuracy of the measurement provided by the Matlab c
(R^2=0.9908). Small differences are due to the manual selection of the caliper measurement points

In addition to the accuracy of the measurement, the caliper measurement for this sub-sample requ
1.5 minutes/strand of labor for two persons. The cumulative time spent in sampling, image acqui
and processing for DIA was 0.075 minutes/strand for one operator. This time is 40 times fa
considering measurements of *W* and *L* only.

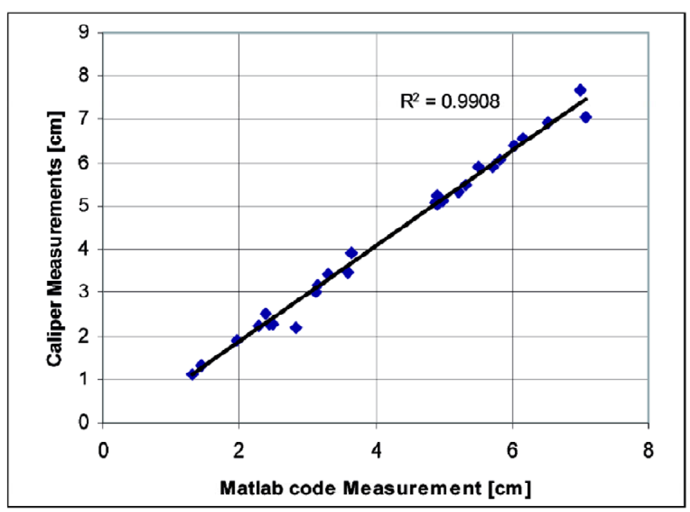

Figure 5: Caliper and Code measurement comparison for mean width

Goodness of fit

Table 1 summarizes the goodness of fit for different distributions for the variables of this resea
A Kolmogorov-Smirnov statistic D was used to determine how well the data fit to the distribu
(NIST, 2006). Nine different distributions were tested. For the measured variables (*A*, *L*, *P*, *eHA*)

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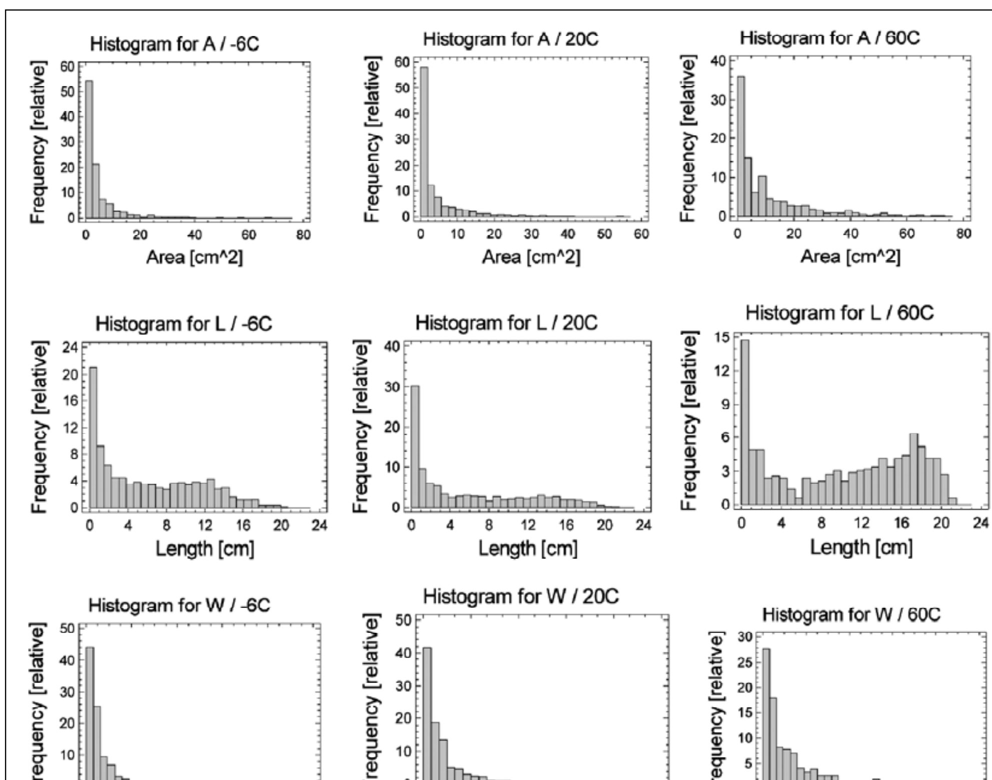
Table 1: Summary of Distribution Analysis

Goodness of fit Kolmorogov Smirnov D value for room temperature log strands									
	Weibull	**Gamma**	**Lognormal**	**Loglogistic**	**Exponential**	**Laplace**	**Logistic**	**Normal**	**Unifo**
A	0.056	0.080	0.084	0.074	0.311	0.392	0.287	0.272	0.68
L	0.089	0.087	0.112	0.104	0.180	0.276	0.197	0.180	0.36
W	0.073	0.091	0.058	0.062	0.124	0.262	0.231	0.233	0.66
P	0.098	0.096	0.116	0.099	0.097	0.221	0.165	0.153	0.57
cHA	0.051	0.075	0.092	0.078	0.296	0.379	0.275	0.260	0.66
S						0.162	0.141	0.191	0.82
Ecc	0.227	0.299	0.306	0.302	0.516	0.363	0.290	0.285	0.73
SL	0.110	0.087	0.068	0.072	0.209	0.191	0.168	0.164	0.61
R	**0.031**	0.078	0.102	0.075	0.313	0.058	0.037	**0.031**	0.14
I	0.061	0.059	0.068	**0.029**	0.099	0.159	0.134	0.168	0.64

Relative histograms for *A*, *L* and *W* are shown in frozen, room and soaked conditions in Figure 6 this figure it is possible to see the changes in the geometrical distributions for strands in response to temperature treatments applied to the logs and also, it is possible to visually confirm that the distributi do not fit normal distributions. The same behavior was detected in all the other measured and compu variables.



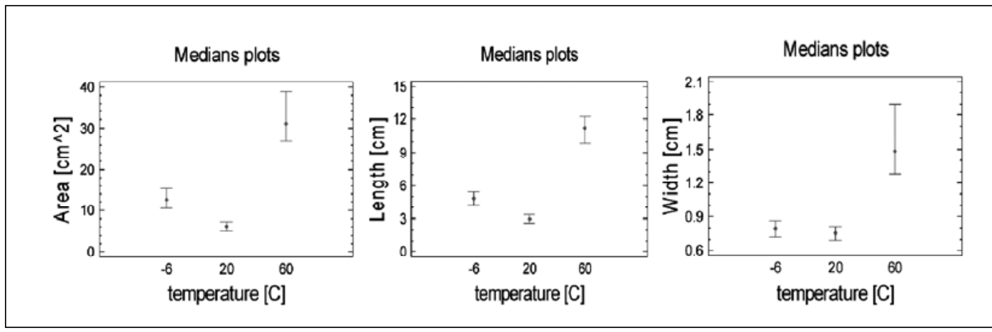


Figure 7: Medians comparison for A, L and W

The influence of soaking on median area (*A*), length (*L*) and width (*W*) of strands is show Figure 7. In this figure it is noticeable that there is no difference in *W* between frozen and ro temperature treatments; and the effect tends to be inverse to the expected in *A* and *L*. This phenome can be due to the unusual low MC of the frozen log, which might affect the freezing. Since m width, length and area are often considered as response variables when using image analysis, a spe caveat has to be taken in account to properly analyze the results.

Figure 8 presents the distribution of *I* for the three log temperatures. A simple regression to determ the correlation between *I* and temperature was conducted as shown in Table 2. According with ANOVA table, there is a statistically significant relationship between *I* and log temperature (Figure

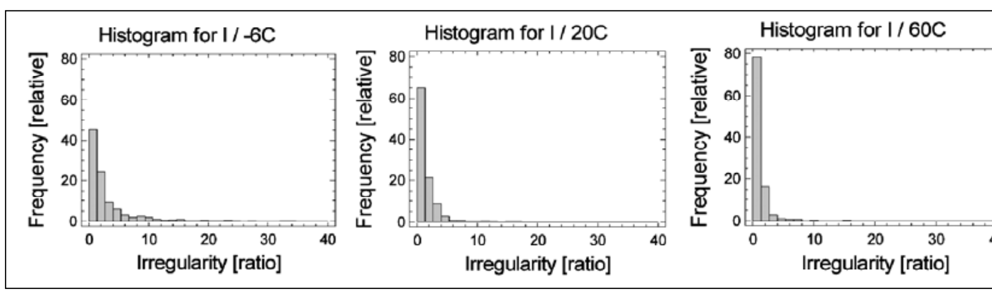


Figure 8: Distributions for I and log temperature

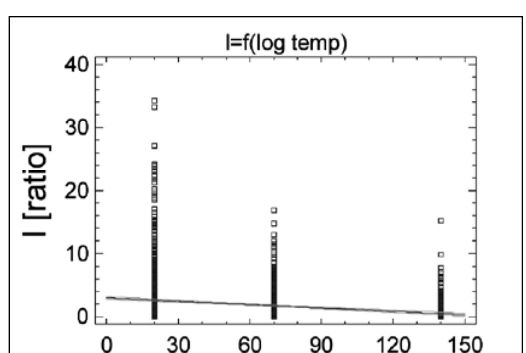


Figure 10 shows the distributions for *R* upon the different conditions. As stated earlier, this is only variable that behaves statistically normal for room conditions. Significant relationship of *R* log temperature was found as well (F=314.19 with a p<0.01 in the ANOVA).

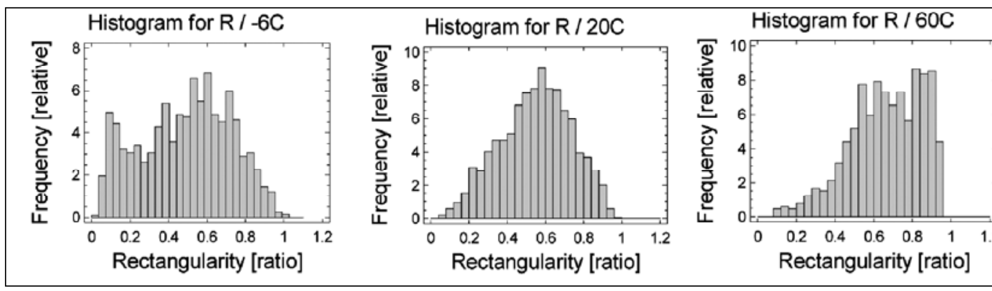


Figure 10: Distributions for R and log temperature

Table 2: Linear regression on I v/s log temperature

Linear model: Y = a + b*X

Parameter	Least Squares Estimate	Standard Error	T Statistic	P-Value
Intercept	2.98119	0.0821298	36.2985	<0.001
Slope	-0.0175736	0.00105427	-16.6689	<0.001

Analysis of Variance

Source	Sum of Squares	Df	Mean Square	F-Ratio	P-Value
Model	1885.36	1	1885.36	277.85	<0.001
Residual	25465.7	3753	6.78543		
Total (Corr.)	27351.1	3754			

The change in geometry and specifically in irregularity and rectangularity due to the tempera treatment can be explained as changes in wood reducing stiffness and increasing plasticization wood matrix (lignin) as log temperature increases. On the other hand, in frozen conditions wood beha more brittle; the stranding knives cut and break fibers following random weak planes existing in frozen composite rather than following the knife edge. This fact promotes the occurrence of la fines fractions and it may affect screening and alignment processes by the creation of strand clust

CONCLUSIONS

Digital image analysis is a useful technique to process high amount of data and quickly and accura determine geometrical distributions. The potential use of this methodology for on line measureme is noticeable. Multiple variable and highly detailed measurements can be done with this setup us available and inexpensive equipment.

Log temperature has an important effect in the geometry of the strands. As temperature increa from 20ºC to 60ºC, larger and less irregular strands are produced. However, further research is necess to determine the cause of reduction in geometries from -6ºC to 20ºC. Irregularity, as defined in paper, is the geometrical property that exhibited the strongest statistically significant effect of temperature on stranding.

Non-parametric statistics must be applied to study the geometrical distribution of strands. Mod Median comparison, Kruskal-Wallis, Kolmorogov-Smirnov or other statistical tools must be app to study this type of data. A further study will be necessary to develop optimum statistical tool analyze this type of data and develop protocols to evaluate the results on a time-base sample sche for continuous process.

Additional research is necessary to study the relationship between the irregularities on stra geometry and the effectiveness of screening and on mat formation process respect to the strand alignm

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