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DIMENSIONAL STABILITY PROFILE OF COPY PAPER FORMED IN HIGH MD-CD TENSILE STRENGTH RATIO CONDITION

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ABSTRACT

Copy paper used in photocopiers, laser printers and similar devices normally requires lower fiber-orientation indexes, to provide certain "squareness" to the sheet, for enhanced dimensional stability. Due to the anisotropic nature of fibers, a highly-oriented paper formation will leverage the cross-machine hygroexpansivity due to increased web shrinkage in the drying phase of production. This paper presents the transverse profile of CD dimensional stability of reprographic paper manufactured in commercial gap former machine, from 100% eucalyptus chemical pulp at high speed and set for operation at high level of paper anisotropy (>3). The results of CD hygroexpansivity, and shrinkage measurements obtained by image analysis technique, showed the adverse effect of such operating condition on dimensional stability of paper and corresponding anisotropic level of paper web consolidation, both revealed by high levels of hygroexpansion (>0.7%) and CD shrinkage (>8%) at the edge zones, making a significant portion of the web improper for high quality demanding applications of end users. This insight can lead to future actions in order to seek for new setup of paper machine operational parameters and control web anisotropy index toward better paper quality.

Key-words: anisotropy, gap former, hygroexpansivity, image analysis, shrinkage.

1. INTRODUCTION

Copy papers, typically used in photocopiers, laser printers and other office printing devices are characterized by the fact of being cut in small sheet sizes before use (such as USA letter or A4 formats). For this paper grade, hygroexpansivity (in-plane dimensional stability) represents a property of prime technological importance for paper performance at end-use, since this feature is decisive for good paper functionality in printing processes. In copier machines, each paper sheet is printed separately and should be precisely transported through the process [2-5]. Dimensional instabilities such as changes in sheet dimensions or curling (departure from flat form) resulting from moisture variations, are problematic for the process efficiency. Excessive curl can cause repeated paper jams in the processing area and output station, misfeeds and edge tears or binds. The best-performing papers are those that exhibit a low amount of curl after being run through the printer [6].

Several factors in the papermaking process affect the hygroexpansivity (and corresponding dimensional stability) of copy paper, including furnish components, stock preparation and paper machine operations [7]. At the paper machine wet end, in-plane fiber orientation has substantial effect on hygroexpansivity [8]. When the degree of fiber orientation increases, the CD hygroexpansivity increases greatly. The fiber orientation angle is defined as the average direction of fiber alignment, expressed as an angular deviation from MD. The fiber orientation index or degree of fiber orientation represents the extent to which the fibers are aligned at the average fiber orientation angle, instead of perpendicular to that. The fiber orientation index or anisotropy index indicates the degree of difference in magnitude in paper properties between the major and minor directions for fibers. The higher the index, the greater the difference. In industry language, the so-called "square" paper with an anisotropy index of unit would be beneficial for copy paper grades, in order to enhance its dimensional stability. However, it is found in practice that the maximum indexes are about 3-4 and minimum is limited to about 1.3 in commercial paper-machine formers [3].

Nowadays, even though some on-machine fiber orientation measurement devices are available, most procedures still rely mainly on off-machine methods and most instruments, whether on-machine or in the laboratory, measure indirect analogue properties of fiber orientation. Methods using strength properties measurements, define the fiber orientation index (or anisotropy index) as the ratio of maximum to minimum strength, as shown in Eq. 1:

$$I_{fs} = {S_{max}}/{S_{min}} \tag{1}$$

where I_{fs} is the fiber orientation index, S_{max} is the maximum measured strength and S_{min} is the minimum measured strength (orthogonal to maximum).

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Generally, papermakers prefer to use the ratio of MD to CD of strength property, as indicated in Eq. 2, which will approximate the above definition when the fiber orientation angle is small:

$$I_{fp} = {}^{S_{MD}}/_{S_{CD}} \quad (2)$$

where I_{fp} is the fiber orientation index, S_{MD} is the strength measured in MD and S_{CD} is strength measured in CD.

Many different techniques have been developed for fiber orientation measurement [9-11], but ultrasonic devices are commonly found in paper mill laboratories, for measurement of degree and direction of the orientation of fibers through the measurement of paper tensile stiffness orientation and elastic properties [10,12]. According to this method, the propagation speed of ultrasonic signals, which is related to the specific elastic modulus of the sample, is measured in eight directions equally distributed, in a circle, for each 22.5°. A numerical approximation, based on Fourier analysis with 15 coefficients, is used to transform the signals into a polar diagram. This way, the directions of the maximum and minimum elastic stiffness in the sheet can be identified. This property is called Tensile Stiffness Index (TSI) and the angle difference between the direction of the maximum value of TSI and the MD is called Tensile Stiffness Orientation angle (TSO), which is usually assumed by the paper industry to be equal to the angle of fiber orientation [10]. The anisotropy index of the paper is commonly expressed by the ratio between TSI_{MD} and TSI_{CD} [12].

In the paper-manufacturing process, the fiber network structure has a tendency to align in MD, rather than in CD. The accelerating forces acting on the fiber slurry flow in the headbox slice area and the hydraulic shearing forces present in the forming section of the paper machine represents the major factors associated to this alignment phenomenon, which is increased by the influence of other process parameters like the jet to wire speed ratio, which controls the intensity of fiber orientation in machine direction. The awareness of paper anisotropy is relevant due to its impact in paper quality and in paper properties on the end-use. In most cases, a low orientation index is ideal for paper performance, since it makes the paper properties more similar in all in-plane directions. In this sense, for copy paper and similar grades, the anisotropy index can be low, even approaching unit, by the reason of low orientation index reduces adverse consequences of orientation angle deviations and provides better paper "squareness" for enhanced dimensional stability.

Among several hydrodynamic forces that affect the fiber orientation distribution in paper web, the jet-to-wire speed ratio, i.e., the speed difference between slurry jet and machine wire is the most important. The speed difference creates velocity gradients in z-direction or a shear field in the slurry, which rotate fibers in MD. A large speed difference (in rush or drag mode) will, therefore, lead to a strong MD fiber orientation, i.e., large anisotropy index [1]. On a fourdrinier machine, the minimum fiber orientation anisotropy is achieved at a unitary jet-to-wire speed ratio, which corresponds to equal jet and wire velocities. On a gap-former machine, of forming roll style, when the slurry jet enters gap area between top and bottom wires, it is subjected to drainage pressure, which gradually rises to $p = T/R$, where T is the wire tension and R is the local radius of the curvature of the wire, causing corresponding jet deceleration. If the lowest fiber orientation index is aspired, the slurry velocity after deceleration should assume the same value as that of the wires. Eq. 3 expresses the jet-to-wire speed ratio [1][1]:

$$\left[\frac{v_j}{v_w}\right]_m = \sqrt{1 + \frac{2T}{\rho\, v_w^2 R}} \quad (3)$$

where v_j is the free slurry jet speed, v_w is the wire speed, and ρ is the slurry density. The subscript m denotes minimum fiber orientation effect, i.e., the isotropic condition.

Eq. 3 draws attention to a distinctive aspect for paper anisotropy index control in gap-former machines, meaning that the jet-to-wire speed ratio should be set greater than 1 (one), even for minimum possible fiber orientation and depends on the forming wire speed in inverse proportion.

The objective of this work is to present a CD hygroexpansivity transverse profile of photocopy paper, manufactured from 100% eucalyptus chemical pulp of virgin fibers in a high-speed gap-former machine, set to operate at large fiber orientation index, by measuring and interpreting the impact of this high anisotropy production condition on the dimensional stability across the paper web. This paper also intends to give more insight on possibilities to seek for future actions related to new ways of operational parameters setup, for future improvements in paper quality and functional properties.

2. METHODS

For purposes of this work, the fiber orientation alignment magnitude and paper anisotropy index were characterized by the MD to CD ratio of tensile stiffness index ($TSI_{MD/CD}$). TSO measurements were also carried out in order to verify the corresponding fiber orientation angle profile. Other physical properties selected to be presented in this study are fundamentally connected to the dimensional stability of paper and are shown by transverse profiles of paper hygroexpansivity and shrinkage, both measured in CD.

2.1 Paper machine parameters

The paper machine, from which the paper samples were collect for this study, was designed for copy paper production capacity of 900 tons.day^{-1} at maximum speed of 1500 m.min^{-1}, 5300 mm paper width at reel and features modern principles for high speed

1. Eq. 3 derives from the application of the Bernoulli's energy equation in order to obtain a relationship between the slurry velocity in free jet and the decelerated slurry velocity in the forming wires [1].

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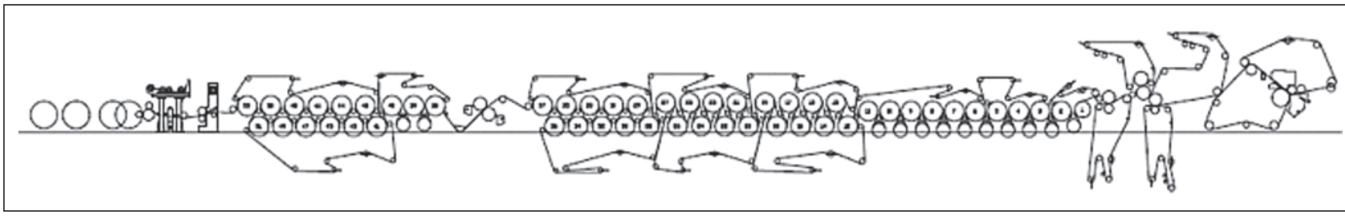

Figure 1. Commercial copy paper manufacturing machine

and paper quality production. The machine configuration, shown schematically in Fig.1, consisted of: a headbox with dilution system for basis weight profile control; a twin-wire former (Duoformer TQ, roll-blade gap-former[2]), a shoe press module in the third nip position of press section, single-tier dryer arrangements only in first cylinder groups of pre-drying and after-drying sections, a film size-press and a single-nip hard calender, followed by a conventional reeler.

For the investigation, a 75 g.m^{-2} copy paper was being produced at wire[3] and reel speeds of 1202 m.min^{-1} and 1256 m.min^{-1} respectively, whose width was 5278 mm at reel and 5600 mm ongoing the dryer section. The jet-to-wire speed ratio was set to 1.02. The paper furnishes consisted of 100% ECF-bleached kraft pulp from eucalyptus virgin fibers. The sheet was filled to the 19% content and was internally sized. The headbox freeness was recorded at 410 ml CSF. Reel moisture was in the level of 3.5%.

2.2 Paper sampling

Samples of approximately 340 mm high (MD) x 250 mm wide (CD) were collected from ten uniformly spaced positions across the web width on the jumbo reel, immediately after turn-up. Five test pieces were cut from each sample, according to the sizes required for specific testing method, with the longer side parallel to the relevant direction, MD or CD. Five uniformly spaced areas with dimensions of 32.5 mm (MD) x 32.5 mm (CD), also from each paper sample, were scanned for CD shrinkage measurement purposes, as described in section below. The samples of paper were carefully cut, in such a way that the edges were, as nearly as possible, parallel and aligned with MD and CD. Except where noted, the results are presented as average values from five measurements of paper properties.

2.3 Hygroexpansivity measurement

Hygroexpansivity tests of paper samples were performed according to ISO 8226-1:94 standard method in a laboratory hygroexpansimeter at the Chemical Department of the University of Coimbra, Portugal, consisting of a thermally isolated test chamber; a supply air conditioning system and a computer based data acquisition and control unit. The test pieces were held vertically inside the hygroexpansimeter chamber by means of fixing and loading clamps with pre-determined mass. The length variations were measured by a laser based motion sensor. More information on the equipment used and testing procedure details can be found in [13].

The hygroexpansivity, for a controlled relative humidity (RH) variation over the range of 33% and 66%, was first calculated as a percentage of hygroexpansion strain, as established by ISO 8226-1:94. To express the hygroexpansivity in a more conventional way to some researchers, it was calculated using Eq. 4 below as hygroexpansion strains normalized with respect to the variation in RH:

$$\beta_{RH} = \frac{\Delta l}{l_0} \times \frac{1}{\Delta RH} \times 10^2 \tag{4}$$

where β_{RH} denotes the hygroexpansivity of paper (% strain / %RH), l_0 the initial length of test piece (mm), Δl the change in test piece length (mm) for a variation of relative humidity from (33±2)% to (66±2)% and ΔRH the range of relative humidity variation (%).

2.4 Shrinkage measurement

Image analysis techniques were employed to find out the transverse CD shrinkage profile of the paper web, by detecting wire marks from MD yarns (left in the paper during the forming phase of papermaking) and measuring the distance variations between them for differential shrinkage calculations. Digital images of paper samples were acquired by a flatbed scanner (Hewlett-Packard, China) connected to a Satellite PC (Toshiba, USA) where paper images were processed by two-dimensional Fast Fourier Transform (2D-FFT).

The Fast Fourier Transform is useful to convert digital images from space domain to frequency domain, to allow the identification and measurement of periodic patterns present in the paper sample. Considering a digital image containing M rows and N columns, denoted by $f(x,y)$, with $x = 0, 1, 2, ..., M\text{-}1$ and $y = 0, 1, 2, ..., N\text{-}1$, the Fourier Transform of $f(x, y)$, designated by $F(u,v)$, is given by Eq. 5 below:

$$F(u,v) = \sum_{x=0}^{M-1} \sum_{y=0}^{N-1} f(x,y) e^{-j2\pi\left(\frac{ux}{M}+\frac{vy}{N}\right)} \tag{5}$$

for u = 0, 1, 2, ..., $M-1$ and v = 0, 1, 2, ..., $N-1$. The 2D-FFT spectrum consists of displaying the amplitude of each frequency

2. Manufactured by Voith Paper.
3. Triple-layer, SSB style, in top and bottom positions of the gap-former.

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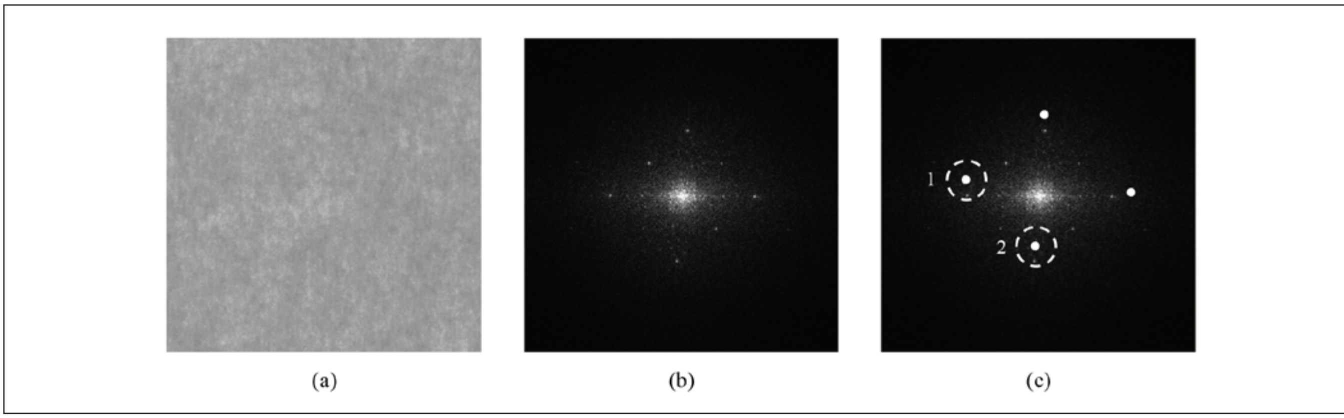

Figure 2. (a) Digital image of 75 g/m² copy paper sample, sized to 512 x 512 pixels (256 grey levels); (b) 2D-FFT spectrum in frequency domain obtained from the image of (a); (c) 2D-FFT spectrum of a paper sample image showing highlighted peaks used for CD shrinkage measurement.

for proper visualization. Fig. 2(a) depicts the digital image of a copy paper sample, in grey scale, and Fig. 2(b) the corresponding Fourier spectrum.

The bright white dots correspond to amplitude peaks, caused by a periodic yarn mark pattern found in the sample examined. The low areas in the Fourier spectrum are dark and the high areas, which include the highest amplitudes or peaks such as the white dots produced by periodic marks imprinted in paper by forming fabrics, are light. The position of the peaks relative to the center of the spectrum corresponds to their particular frequencies and allows the separation between the periodic marks to be measured, as there is a well-defined relationship between space and frequency domain intervals [14,15].

The same spectrum of Fig. 2(b) is shown in Fig. 2(c), but intentionally detaching two highlighted peaks for visualization. Both peaks were selected from the geometrical pattern of the white dots caused by the marks of the SSB triple-layer forming fabric. The distance from peak close to horizontal axis (1) to the center of the spectrum is related to the separation of marks produced by MD yarns of forming fabrics and its length is directly proportional to the number of pixels in the width of the digital images and pixel size. The peak close to vertical axis (2) refers to the marks coming from the CD yarns of the wire. Additional information on the method used can be found in [16].

2.5 TSO and TSI measurements

Tensile stiffness orientation (TSO) measurements were conducted at the mill laboratory using an L&W TSO Tester 150 (Lorentzen & Wettre, Sweden), which consists of an ultrasonic measuring device. An L&W Tensile Tester 060 (Lorentzen & Wettre, Sweden) was employed to perform tensile stiffness tests in MD and CD (according to TAPPI T494:96 standard) for after tensile stiffness index (TSI) calculations. The paper basis weight were determined by weighting an A4 size sheet in an PB 303 semi-analytical scale (Mettler-Toledo, USA) and dividing the result by the sheet in-plane area (as per TAPPI T410:98 test procedure).

3. RESULTS AND DISCUSSION

Table 1 shows the results of measurements performed on samples collected in transverse positions of a jumbo paper roll, from front side (FS) to back side (BS) of the paper machine. Resulting transverse profiles of CD shrinkage, CD hygroexpansivity and MD to CD ratio of tensile stiffness index ($TSI_{MD/CD}$) showed a continued increase in magnitude from the center towards the edges of the paper web. The behavior of these profiles is affected by lesser drying restraints at the web edges and by higher degree of fiber orientation in MD (paper anisotropy). The combination of both factors maximizes the effect on paper CD properties. Fig. 3 shows corresponding transverse profiles of tensile stiffness index ratio ($TSI_{MD/CD}$) and paper hygroexpansivity measured in CD.

$TSI_{MD/CD}$ levels from 3.7 to 4.8 reveals the high degree of anisotropy of the paper investigated in this work. This structural parameter, determined as expressed by Eq. 2, results from low fiber orientation alignment angles (as also shown in Table 1) and on the extent to which the fibers are aligned to MD, confirmed by high tensile stiffness values found in MD. The results of the measurements presented herein are somewhat exceeding values found in literature for copy paper. Previous work show typical values from one grade to another from, e.g., 1.1 (sack-kraft) to 5.0 (newsprint), being 1.4 to 2.2 the recommended range for cut-size copy and laser printing paper [12]. Other author have found that the maximum $TSI_{MD/CD}$ seen in practice is about 3.0 to 4.0, at large jet-to-wire speed differences (rush or drag modes), and the minimum attainable is around 1.3 [3]. Copy paper is said to require lower anisotropy indexes or some "squareness" degree in order to provide for better paper functionality in printing process, due to improved dimensional stability resulting from that lower anisotropy. The limitation for obtaining low values comes from the paper structure tendency to align in the machine direction (MD) rather than in cross direction (CD), as a result of accelerating and shear forces that the slurry is subject to in the headbox and in the forming section of the paper machine [17]. The excessive CD differential shrinkage resulted from high paper anisotropy and the low drying restraint provided by the two-tier arrangement of

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Table 1. Paper properties measured in the jumbo reel paper samples from FS to BS (continues)

Paper properties		Transverse positions (m)				
		0.26	0.79	1.32	1.85	2.38
Basis weight, $g.m^{-2}$ (a)		77.70	77.50	77.40	77.10	77.20
TSO_{angle}, degree		-5.20±0.56	-6.56±2.91	-3.40±0.52	-1.06±1.13	-1.88±0.28
Tensile stiffness, $kN.m^{-1}$	MD	619.3±15.6	596.9±9.7	638.8±12.6	628.0±13.6	651.9±12.0
	CD	136.5±8.5	148.8±6.2	159.2±6.1	162.3±5.4	188.0±8.5
TSI ratio (b)	MD/CD	4.5±0.4	4.0±0.2	4.0±0.2	3.9±0.2	3.5±0.2
Hygroexpansivity x 10^{-2}, %/% (c)	CD	2.23±0.07	2.13±0.11	1.72±0.08	1.70±0.09	1.69±0.05
Shrinkage, %	CD	8.42±0.62	7.20±0.40	5.20±0.49	4.05±0.52	4.08±0.52

(a) Only one measurement available.
(b) MD to CD ratio of measured tensile stiffness normalized by the basis weight in each position.
(c) Hygroexpansion (% strain) normalized with respect to the change in relative humidity (%RH).

Table 1. Paper properties measured in the jumbo reel paper samples from FS to BS (continued)

Paper properties		Transverse positions (m)				
		2.90	3.43	3.96	4.49	5.01
Basis weight, $g.m^{-2}$ (a)		76.96	76.85	77.06	77.02	77.23
TSO_{angle}, degree		-1.48±0.82	-3.23±0.54	-2.62±0.61	1.60±0.52	-2.68±0.39
Tensile stiffness, $kN.m^{-1}$	MD	629.8±13.1	649.4±8.5	625.1±17.4	618.5±17.1	628.7±15.3
	CD	175.7±5.6	167.9±4.0	182.7±9.9	151.0±4.5	131.3±5.0
TSI ratio (b)	MD/CD	3.7±0.2	3.9±0.1	3.4±0.3	4.1±0.2	4.8±0.4
Hygroexpansivity x 10^{-2}, %/% (c)	CD	1.35±0.03	1.55±0.06	1.65±0.11	2.00±0.10	2.12±0.07
Shrinkage, %	CD	4.51±0.42	4.42±0.49	5.07±0.53	6.02±0.54	8.52±0.73

(a) Only one measurement available.
(b) MD to CD ratio of measured tensile stiffness, normalized by the basis weight in each position.
(c) Hygroexpansion (% strain) normalized with respect to the change in relative humidity (%RH).

cylinders in last dryer sections of existing paper machine led to an overall web shrinkage of 5.75%, as observed by comparing sheet widths in and out of the drying operation. High overall transverse shrinkage of paper is connected to problems of narrower sheet widths in the reel. High CD differential shrinkage is linked to poorer paper quality problems found at the edges of the web.

The jet-to-wire speed ratio affects the TSO angle profiles and the fiber orientation index, as well. Higher jet-to-wire speed differences result in higher $TSI_{MD/CD}$ ratios, i.e., in more anisotropic paper structures. Looking at the operational jet-to-wire speed ratio of the investigated paper machine, where v_j/v_w = 1.02, it follows that for the wire speed v_w = 1202 $m.min^{-1}$, the corresponding jet velocity is v_j = 1226 $m.min^{-1}$. From the evaluation of these parameters through Eq. 3, one can observe that for a minimum orientation effect, in a gap-former roll-bade former, the value of v_j/v_w = 1.04 would be the recommended, meaning that the required slurry jet speed would be about 1247 $m.min^{-1}$, i.e., 21 $m.min^{-1}$ above actual or 45 $m.min^{-1}$ above wire speed. Settings of $v_j/v_w > 1.04$ would characterize the rush mode of operation. In opposite way, settings of $v_j/v_w < 1.04$ would establish the drag mode. According to this principle, the actual operation condition at the time of paper sampling for the present work, the paper machine was, in fact, set for operation in drag mode (for an equivalent v_j/v_w = 0.98 after slurry jet deceleration between top and bottom wires), what promoted the high fiber orientation degree in MD and led to a higher anisotropy forming operation mode, as found in this work. This effect is also reported in literature, e.g., showing increased MD to CD ratio of tensile strength [1] and elastic modulus [12] obtained by adjusting the jet-to-wire speed ratio to rush ($v_j>v_w$) or drag ($v_j<v_w$) modes. The reasons for paper anisotropy control through jet-to-wire speed ratio settings underlie the fundamental connections between fiber orientation and paper physical properties: a) the tensile strength of an individual fiber is greater along the fiber longitudinal direction than across it; b) the hygroexpansivity is greater across the fiber than along it. In

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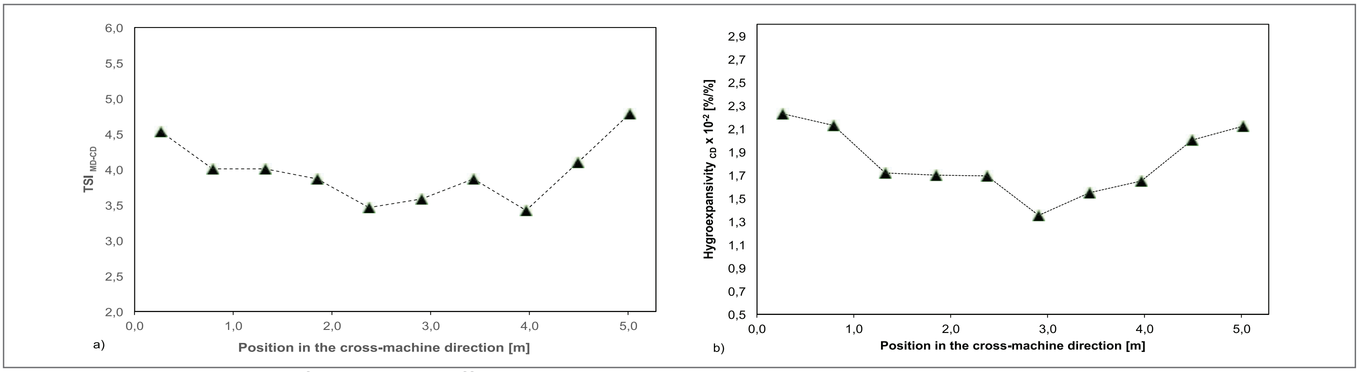

Figure 3. Transverse property profiles: a) Tensile stiffness index ratio; b) Hygroexpansivity measured in CD.

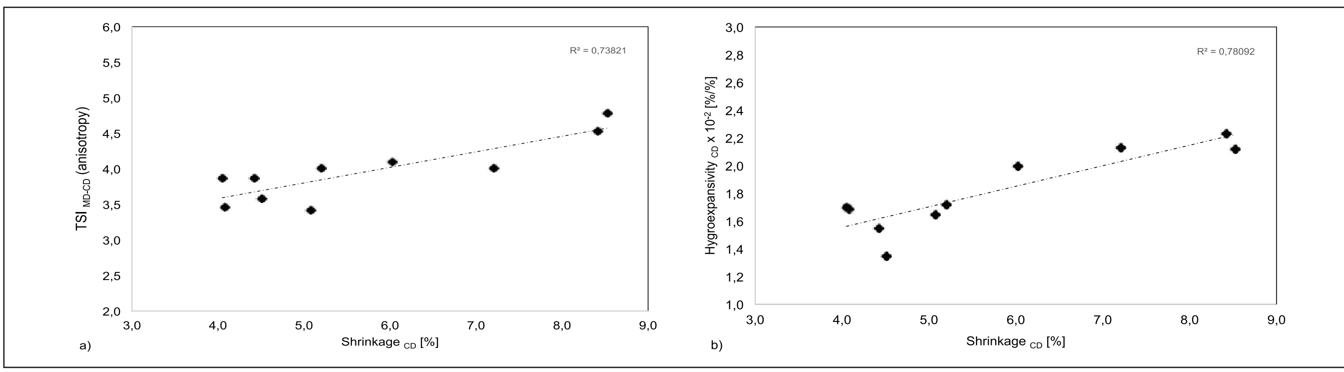

Figure 4. Effects of fiber orientation degree: a) on CD shrinkage as function of MD to CD anisotropy; b) on CD hygroexpansivity as function of CD shrinkage.

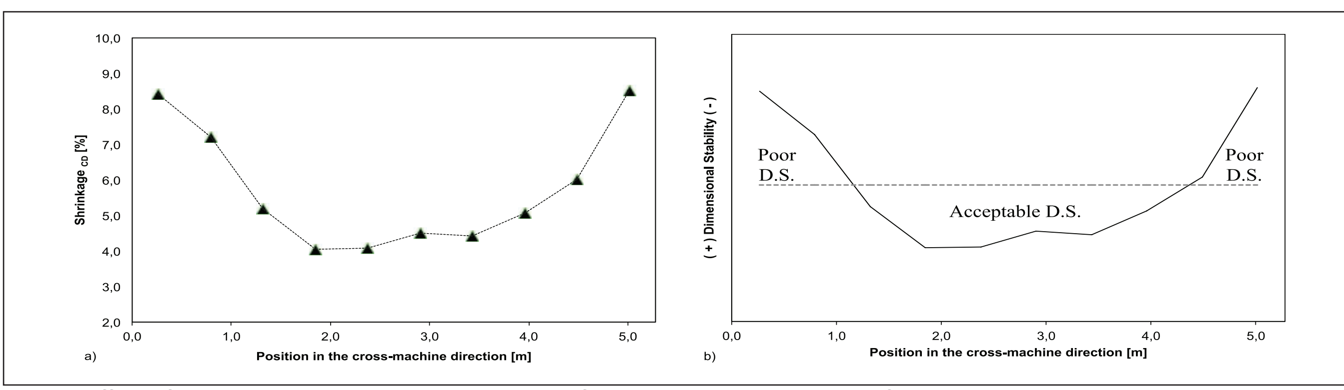

Figure 5. Effects of high paper anisotropy: a) on CD shrinkage profile; b) on dimensional stability profile

this way, agreeing with the literature, the dimensional stability of paper studied in this work is closely dependent on individual fiber anisotropy and degree of orientation in the web.

Although high paper anisotropy indexes can contribute to good machine runnability by minimizing sheet break risks, making in certain occasions this fact to become the primarily process criteria adopted by the papermaker, they produce adverse effects on paper quality, such as inappropriate overall dimensional stability and uneven transverse CD elastic property profiles. The effect of fiber orientation index and corresponding anisotropy on paper CD shrinkage is shown in Fig. 4(a). Similarly, Fig. 4(b) depicts the effect of paper CD shrinkage on its CD hygroexpansivity property. The results of measurements indicate good correlations between paper MD to CD anisotropy and CD shrinkage and between CD shrinkage and CD hygroexpansivity, as expected.

The strong coefficient of correlation between CD hygroexpansivity and CD shrinkage (R^2=0.7809) shows a great interaction factor connected to these parameters and demonstrates the adverse effect of the non-uniform CD shrinkage on the dimensional stability of paper. In Fig. 4(a), an also satisfactory coefficient of correlation (R^2=0.7382) shows the same interaction strength between MD to CD ratio of tensile stiffness index and shrinkage. The paper shrinkage at the edges of the web (>8%), indicated by the points located at the final right side of the graphs, was found to be significantly higher than in middle areas and approximately 3% higher than overall web shrinkage (5.75%).

Fig. 5(a) exhibits the CD shrinkage profile resulted from the specific operational conditions of the paper machine, which can be converted to a similar chart for qualitative interpretation of dimensional stability profile as shown in Fig. 5(b).

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Based on the remarkable correlation between CD shrinkage and CD hygroexpansivity, Fig. 5(b) represents a practical way to prospect and detect regions across the paper web likely to present problems of lack of dimensional stability grade. The hypothetical horizontal cutting line, defined for a certain minimum level of the property, delimits zones of estimated accepted and unaccepted dimensional stability levels (in the present analysis it refers to about one meter from each web edge), saying that 5%-6% CD shrinkage would be maximum limit for giving adequate performance of paper in end use.

4. CONCLUSIONS

This study investigated transverse profiles of CD physical properties of 75 g.m^{-2} reprographic paper manufactured from 100% bleached kraft pulp of eucalyptus virgin fibers, directly on a commercial paper machine by means of a set of measurements carried out on paper samples collected from uniformly spaced positions across the web width on the jumbo reel, immediately after turn-up.

In first part of this work, the anisotropy of paper was investigated and characterized by the tensile stiffness index ratio ($TSI_{MD/CD}$). The results showed a high level of anisotropy developed in forming section by the jet-to-wire speed ratio set-up. Results also show a large transverse variability of this property, caused by uneven CD differential shrinkage profile resulted from the combination of the highly oriented fiber structure and lack of drying restraint at web edges.

In second part, the effects of the CD shrinkage profile developed under the specified operational conditions of the paper machine on hygroexpansivity and, consequently, on dimensional stability aspect of the copy paper analyzed. The results exhibited a significant impact, particularly at lateral areas of the web, which makes an important portion of paper inadequate for end use in high quality demanding processes.

Finally, this work gives evidence on the importance of monitoring and optimizing papermaking process parameters such as the jet-to-wire speed ratio, to tread new operating ways towards the continuously increased demand for paper quality. ■

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