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LOCAL ORIENTATION OF FLOCS IN PAPER

Hermarin Praast and Lothar Göttsching
Technische Hochschule Darmstadt
Institut für Papierfabrikation
Alexanderstraße 8
D-64283 DARMSTADT, Germany

ABSTRACT

So far little attention has been paid to the orientation of flocs in paper sheets. It can be measured by means of an image analyser and the two-dimensional Fourier transform. The principal direction in the power spectrum of a paper in transmitted light is a measure of the floc orientation.

It can be shown that the coefficient of correlation between fibre orientation (Lippke - Tester) and floc orientation amounts on average to 0.7, when profiles across the web are taken into account. Papers, particularly those which are made on hybrid formers, show a two-sidedness concerning floc orientation and anisotropy. The orientation has no significant effect on the uniformity of formation but determines the orientation of cockles. The power spectrum of the local orientation of a paper seems to be very useful in the detection of deterministic variations in orientation, which are invisible in light transmission images.

1 INTRODUCTION

A uniform structure for paper is one of the most challenging targets in papermaking. Therefore, a lot of research work focused on the characterization of formation, curl, cockling and fibre orientation. So far, the mechanism of floc formation is not well understood. It is mainly affected by the characteristics of the fibres themselves, the hydrodynamic variables, pulp consistency and chemical additives. The fibre flocs in suspension exist in a state of dynamic equilibrium between the floc forming process and the disruptive forces created by turbulence or oriented shear flows /1/. At the end of the wire section of a paper machine flocs are more or less fixed and responsible for the nonuniformity of the mass distribution of paper in terms of its formation. The distribution of local grammage in commercial paper had been modelled by the random deposition of low grammage disks representing loose flocs /2/. Little attention has been paid to the shape and orientation of flocs in paper sheets and their relation to fibre orientation. Therefore, this paper deals with the orientation of flocs and fibres in paper sheets.

2 IMAGE ANALYSIS SYSTEM

Floc orientation can be measured by means of an image analyser. The system consists of a chamber with a b/w CCD camera and an illumination system (**Fig. 1**). The video camera picks up the image of paper in transmitted light with a field of view of 100 mm by 100 mm at 100 mm intervals across the web. Image digitisation is achieved by feeding the video signal into a frame grabber, which is plugged into a PC. All images to be analysed are stored on a hard disk. Afterwards the evaluation can start. Individual steps or final results of the image processing as well as the numerical results can be viewed on the PC monitor.

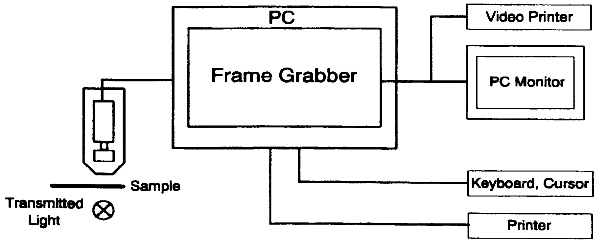


Figure 1: Basic Functional Elements on an Image Processing System

3 MATHEMATICAL BACKGROUND

3.1 Gradient orientation

The measurement of flocs is not an easy task, because it is difficult to define the boundaries of flocs in paper. Jordan and Nguyen have proposed the specific perimeter as a criterion of the floc size /3/. Usually, indirect methods like autocorrelation function, power spectrum and co-occurrence matrix have been used to characterise this structure /4-7/. Here, local orientation is used to quantify the floc structure.

The local orientation can be calculated by applying a gradient operator to an image f(x,y) resulting in a vector O given by /8/

$$O = \begin{bmatrix} O_x \\ O_y \end{bmatrix} = \begin{bmatrix} \frac{\partial f}{\partial x} \\ \frac{\partial f}{\partial y} \end{bmatrix} \tag{1}$$

It is well known from vector analysis that the gradient vector points in the direction of maximum rate of change of the image f at (x,y). This direction of a grey value structure, and therefore its orientation, is represented by the angle φ calculated by

$$\tan \varphi = O_y/O_x \tag{2}$$

The magnitude of this vector (local gradient magnitude) is given by

$$\mathrm{mag}(O) = [O_x^2 + O_y^2]^{0.5} \tag{3}$$

and characterises the maximum rate of increase of f(x,y) per unit of distance in the direction of φ. A small value means that the neighbourhood contains no oriented grey values. Both parameters - tan q) and mag(O) - are required to describe local orientation.

This method can also be applied to images of paper in transmitted light. Fig. 2 shows the local orientation of a paper calculated according to equation 1. It becomes obvious in the pseudo-colour image that the local direction of the structure changes very rapidly. Also areas of high grammage - the clouds- do not have one single orientation angle.

Nevertheless, the local orientation reflects periodic structures in images. The power spectrum of a paper in transmitted light and the power spectrum of its local orientation are presented in the **Fig. 3** and **4**. The main peaks are isolated, numbered and identified in the table according to their distance, that means the spacing of the pattern and their orientations. Low frequencies, that is high wavelengths are located close to the origin of the transforms which is shifted to the centre. Peaks in Fig. 3 describe in this case mainly the marks of a dryer fabric which becomes obvious by looking at the inverse transform of the peaks (**Fig. 5**). Most of these peaks can also be identified in the power spectrum of the local orientation image (Fig.4). But now two peaks close to the centre appear. These deterministic variations in orientation cannot be identified in the transmitted light image. An inverse transform of the pattern gives a clear visible image of the dryer fabric marks superimposed on a more coarse diagonal structure in the spatial domain (**Fig. 6**).

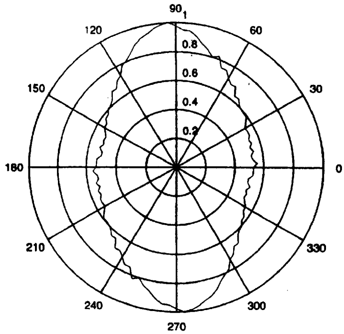
Editors note: *Figs. 2, 3, 4, 5 and 6 are placed after the text (pp 1320-1324) in order to appear in the colour section*

The power spectrum of the local orientation image seems to be very useful in the detection of deterministic variations in orientation.

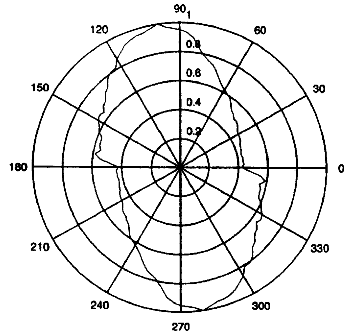
A polar plot of the gradient orientation of two different papers is presented in **Fig. 7**. They are very similar to the plots of Schacanski and Dodson who analysed the anisotropy and variability of paper textures by means of the Prewitt operator /9/. The dominant orientation has to be calculated and is in most cases not in agreement with the machine direction. We considered only local orientations where the local gradient magnitude was higher than 1 percent of the maximum of the gradient. Other definitions are possible of the minimum gradient magnitude that should be taken into account. The orientation of the texture weighted by their gradient magnitude according to

$$\overline{\Theta} = \frac{\sum \mathrm{mag}(O)_i * \Theta_i}{\sum \mathrm{mag}(O)_i} \tag{4}$$

leads to other results in terms of local orientations. This demonstrates a little bit the problem of estimating the gradient orientation.



a)



b)

Figure 7: Polar Plots of Local Gradient Orientation (MD: 90°)
a) Paper Sample 1 b) Paper Sample 2

3.2 Spectral Moments

Our approach for the measurement of floc orientation is based on the power spectrum. It is schematically represented in **Fig. 8**. The frequencies f_x and f_y are in units of spatial frequencies. A coarse structure results in high values concentrated closely to the origin of the power spectrum, while in a fine structure the values will be more spread out. Thus, if one intends to analyse texture coarseness, a set of features that should be useful are the averages of the power taken over ring-shaped regions centred at the origin for various ring radius values. That corresponds to the power of a band-pass filtered image.

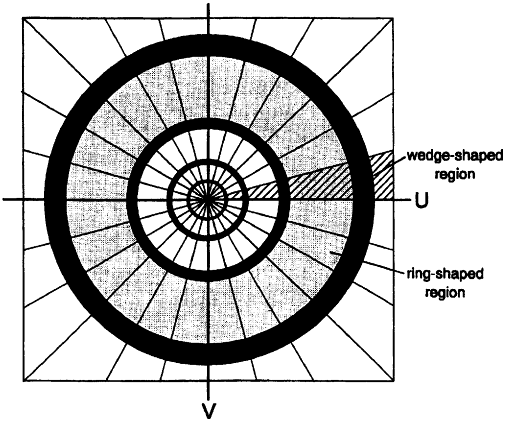


Figure 8: Power Spectrum Feature Masks

Similarly, it is well known that the angular distribution in the frequency domain is sensitive to the directionality of the texture. The averages of the power spectrum taken over wedge-shaped regions entered at the origin for various wedge slopes are able to characterise the orientation. This method is reported in the technical literature /10/. One of the drawbacks is the limited resolution of the wedge sample geometry and the large volume of information one has to deal with. Therefore, we deceided to find one single value that can characterise the main orientation of flocs and the mathematical background used has to be introduced.

Consider a paper in transmitted light whose optical formation is a random function of two variables. Its magnitude spectrum is defined by /10/:

$$F(u,v)=\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} f(x,y)e^{-i2\pi(ux+vy)}\,dxdy \tag{5}$$

The power spectrum can be obtained by:

$$S(u,v)=|F(u,v)|^2 \tag{6}$$

Now the spectral moments are introduced in terms of the power spectrum S(u,v) /11/. They can be defined as

$$
\begin{aligned}
m_{00} &= \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} S(u,v)\, du\,dv \\
m_{11} &= \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} S(u,v)\, u^{1}v^{1} du\,dv \\
m_{02} &= \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} S(u,v)\, u^{0}v^{2} du\,dv \\
m_{20} &= \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} S(u,v)\, u^{2}v^{0} du\,dv
\end{aligned}
\tag{7}
$$

It is assumed that the moments exist up to all orders. In this case, only the first and second moments are needed. For example, m_{00} defines the total energy (variance) of the paper. We are interested in the principal directions in the power spectrum of the paper which is defined as a measure of the floc orientation.

The moments depend on the location of the origin and the orientation of the reference axes. For a given origin, the moments vary as the axes are rotated about that origin. We have to find the values of the angle θ that make the second moment a maximum and a minimum. This occurs always in two directions at right angles, given by

$$
\tan 2\Theta = \frac{2m_{11}}{m_{20} - m_{02}} \tag{8}
$$

The direction Θ corresponding to the maximum is called the principal direction of the structure. That is what we call floc orientation. This equation reminds us of the calculation of the principal axes of moment of inertia. It has the same mathematical background.

The maxima and minima of the second spectral moments $m_2(\theta)$ are given by

$$m_{2\max}, m_{2\min} = \frac{1}{2}\left[(m_{20} - m_{02}) \pm \sqrt{(m_{20} - m_{02})^2 + 4m_{11}^2} \right] \tag{9}$$

Now

$$\left(\frac{m_2(\Theta)}{m_{00}} \right)^{1/2} \tag{10}$$

is the RMS of the waves in the direction Θ. The relationship between the maximum and minimum of the second moment is a measure of the long-crestedness which is denoted by γ^2.

$$\gamma^2 = \frac{m_{2\min}}{m_{2\max}} \tag{11}$$

γ^2 is the ratio of the moments of the power spectrum in both principal directions and characterises more or less the randomness of the orientation.

Papermakers are more familiar with the MD/CD ratio. Therefore, the ratio of the energy of the power spectrum in MD and CD was calculated, too.

3.2.1 Window Function /12/

The foregoing results apply to two-dimensional functions which are of unlimited duration. It is of interest to examine the practical case where an image is sampled only over a finite region. Under these conditions the original Fourier transform can be only isolated when the image we are looking at is band limited and periodic, with a period equal to the image size. In this case the corruptions caused by the finite sampling interval cancel out, allowing complete recovery of the image in spatial domain if the sampling theorem is satisfied. The recovered image still extends from $-\infty$ to ∞. The image segments to be analysed are in real world not a period. Therefore, the boundaries of the images have got different values which are responsible for high amplitudes along the frequency axis in the power spectrum. To suppress this problem, it is common to multiply the image in the spatial domain by a window. There are several alternatives for such windows. None of these can be termed best in a theoretical sense. We decided for the von Hann window, which is given by

$$w(x,y) = \sin\left(\frac{\pi x}{511}\right) \sin\left(\frac{\pi y}{511}\right) \tag{12}$$

with

$0 \le x \le 511$ and $0 \le y \le 511$

It is equivalent to one period of a squared sinus function with zeros at the edges and the maximum in the centre of the image. By multiplying the original image with this weighting function we get exactly one period.

3.2.2 Frequency Range

Furthermore, the orientation analysis can be performed at different frequency or wavelength resolutions. We would like to look at flocs. Therefore, the fibre structure of high frequencies are not of any interest. High frequencies and low wavelengths respectively are located in the outer part of the centred power spectrum and have to be attenuated. **Fig. 9** is a plot of the measured floc orientation angles in a paper sample as a function of different wavelength. If the calculation takes into account all wavelength above 1.0 mm or 1.7 mm similar curves are obtained. A cut-off wavelength of 2,5 mm or higher leads to unrealistic high orientation angles of about 25 degrees at the edges for this example. Based on these trials, it was concluded that all further measurements should include wavelength above 1 mm. This makes sense because the floc sizes in paper and board are anywhere between 0.5 mm and 4 mm /7/. Furthermore, Farnood, Dodson and Loewen demonstrated that the formation of commercial papers can be modelled by random deposition of mean disk diameters or floc diameters respectively in the range of 1 mm to 3 mm /2/. If only the wavelengths between 1 mm and 5 mm are used for the determination of floc orientation it is interesting to see that these values are more or less identical with the results we get by including all wavelengths above 1 mm in the calculation.

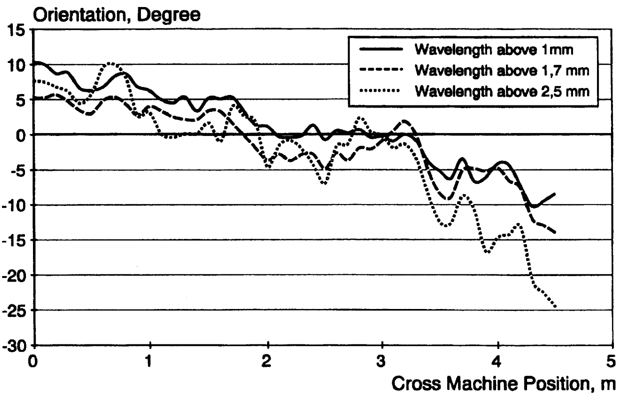


Figure 9: Orientation of Flocs at different Wavelength Bands

For the discussion of the following results it should be kept in mind that all floc orientation profiles are smoothed by an moving average operation to suppress the variations. We assume that the variations are affected to some extent by slice lip bending at the headbox.

4 RESULTS

4.1 Measurements on Test Pattern

So far, it is unknown whether the applied method leads to reliable results. Line patterns printed under different angles on paper samples were used to test our procedure. The agreement between the results of image analysis and the measurement by a goniometer was good.

In the next step a cross profile of a tracing paper containing dyed stiff plastic fibres was analysed. In that case the single fibres could be isolated by image analysis. Their length and orientation was measured by an image analysis system of Kontron. The orientation of the fibres were weighted by their lengths according to

$$\overline{\Theta} = \frac{\sum L_i * \Theta_i}{\sum L_i} \tag{13}$$

with

L_i : fibre length
Θ_i : angle of fibres

Fig. 10 demonstrates a good correlation between the direct measurement with the Kontron device and by means of the spectral moments. These trials confirmed the validity of the applied mathematics.

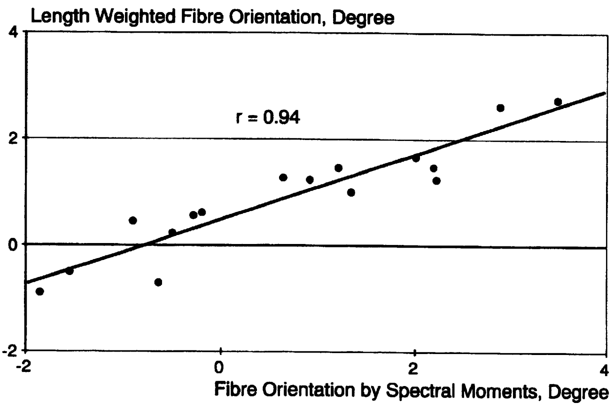


Figure 10: Relationship between Fibre Orientation (Length Weigthed) and calculated Angle by Spectral Moments

4.2 Correlation between Floc Orientation and Fibre Orientation

It is well known that headbox design and operation highly influence the profile of fibre orientation. Several problems in papermaking arise from the nonuniformity of fibre orientation. These range from twist and warp problems in the board grades to diagonal curl in printing papers. Therefore, research work had been concentrated on the development of laboratory measures of fibre orientation anisotropy. It is inferred from microwave attenuation, ultra sonic speed attenuation, X-ray diffraction, ratio of zero-span tensile strength between MD and CD, the scattering of visible light in paper and other methods. So far, the effect of fibre orientation on the orientation of flocs has not been discussed. A relationship between both could be expected.

Some results are now presented. When the orientation of the flocs in a commercial paper are measured at 100 mm intervals across the web, the following profile can be obtained (**Fig. 11**). The angle is positive if it points to the front side and negative if it points to the back (drive) side. Results of fibre orientation measurements by the Lippke-Tester and TSO-Tester are plotted in the same figure by dashed lines. Although both

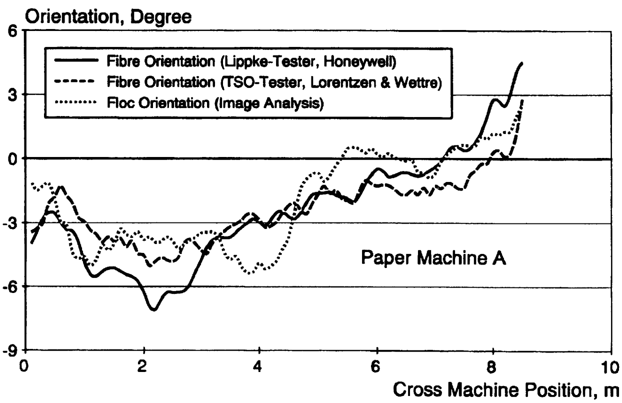


Figure 11: Orientation of Fibres and Flocs across the Paper Web

fibre orientation methods based on different physical principles, that is light diffraction and ultrasonic velocity measurements, they are in good agreement in this example.

The TSO ultrasonic instrument of Lorentzen and Wettre determines the orientation of the strength properties as tensile stiffness which is sensible to drying stresses and strains being present in the paper sheet /13,14/. This is not the case with the laser techniques. Therefore, the Lippke-Tester characterises better the apparent fibre orientation and will be our reference in the further discussion.

According to Fig.11 the floc orientation profile has a similar shape as the fibre orientation profiles. The coefficient of correlation between floc orientation and fibre orientation (Lippke-Tester) of some analysed papers are presented in **Table 1**. It is obvious that the coefficient of correlation between both properties amounts on average to 0.70, when profiles across the webs are taken into account. In the case of lower correlations the global trend of both measurements are sometimes very similar. Nevertheless, the absolute orientation angle can differ by several degrees. It should be remembered that the measurements were performed on profiles taken across the paper machine width. If the slopes of the profiles are not exactly under 0° this will be reflected by the measured orientation angles.

Sample	**Coefficient of Correlation between Fibre and Floc Orientation**		
	Top Side	**Bottom Side**	**Average**
A	0,98	0,97	0,98
B	0,64	0,81	0,73
C	0,86	0,94	0,90
D	0,74	0,82	0,78
E	0,60	0,78	0,69
F	0,48	0,71	0,60
G	0,72	0,64	0,68

Table 1: Relationship between Floc and Fibre Orientation

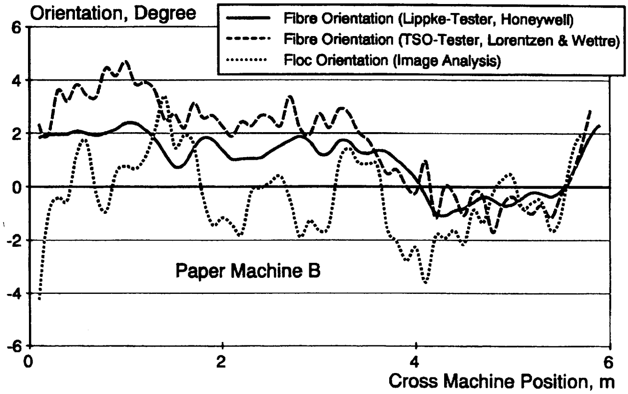


Figure 12: Orientation of Fibres and Flocs across the Paper Web

Fig. 12 illustrates a second orientation profile of a newsprint paper. Three different curves are obtained on the front side. The TSO-Tester as well as the floc orientation indicate increasing angles but in the opposite direction. The Lippke values are located between them.

A further plot is shown in **Fig. 13**. Very high floc orientations are measured at the front side compared to the fibre orientation. A good explanation for this phenomenon is still missing. Flocculation seems to enhance the fibre orientation. It is tempting to believe that floc orientation characterises a third property which corresponds in many cases to fibre orientation.

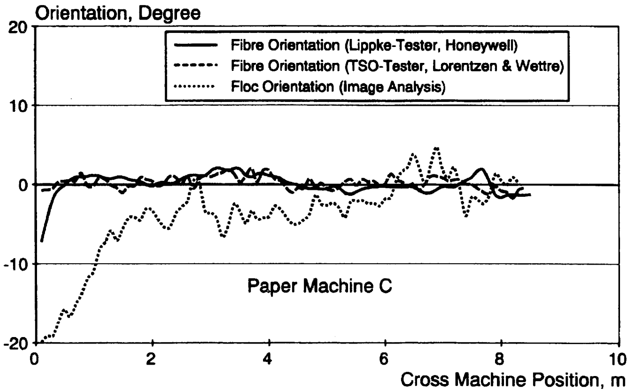


Figure 13: Orientation of Fibres and Flocs across the Paper Web

4.3 Two-sidedness

The analysis of diffraction patterns of visible laser light incident on paper by the Lippke- Tester as well as the light transmission used for the evaluation of the flocs depends mostly on the surface condition of the paper. Both methods do not reveal the average anisotropy of the whole thickness of a sample. This drawback allows, on the other hand, the evaluation of the two-sidedness of fibre and floc orientation respectively. Let me come back to the paper machine previously discussed.

Fig. 14 is a plot of the measured floc and fibre orientation on top and bottom side. The floc orientation profiles are very similar on both sides, whereas a remarkable two-sidedness in fibre orientation is seen on the front side. According to Fig. 14 there are differences of 5.7 ° or 1.6 ° between both sides in the orientation of macro- and micro-scale. This, compared to other results listed in **Table 2**, indicates, that the two-sidedness of the fibre orientation ranges from 0.5° to 2.7° in the case of newsprint and SC papers manufactured on gap formers. A difference in floc orientation of 3,5 ° or higher is quite uncommon but can sometimes be observed in cockled papers. Papers from hybrid formers show sometimes a significant two-sidedness (**Table 3**). It is attributed to the fact that the fibres deposite later on the top than on the bottom side and have more time to orientate. A typical example for a hybrid former is shown in **Fig. 15**. In this case the difference in floc orientation amounts on average to 3,7 ° and only 2,1 ° in fibre orientation.

Sample	**Absolute Difference in Degree**	
	Fibre Orientation	**Floc Orientation**
A	1,4	1,1
B	0,6	2,5
C	2,2	0,7
D	2,7	3,5
E	0,5	1,4
F	1,0	2,4
Average	1,4	1,9

Table 2: Two-sidedness of Fibre and Floc Orientation of Newsprint Papers from Gap Formers

Sample	**Absolute Difference in Degree of**	
	Fibre Orientation	**Floc Orientation**
A	2,1	3,7
B	4,3	1,1
C	0,1	3,1
D	0,5	6,0
Average	1,8	3,5

Table 3: Two-sidedness of Fibre and Floc Orientation of Newsprint Papers from Hybrid Formers

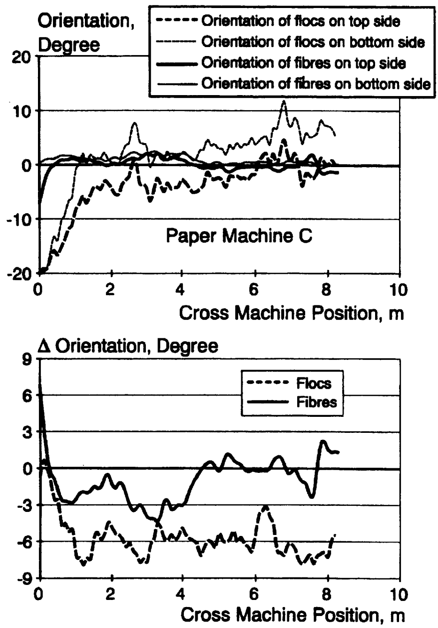


Figure 14: Two-sidedness of Floc and Fibre Orientation of a Gap Former
a) Orientation Profiles across the Web on Top and Bottom Side
b) Difference in the Orientation between Top and Bottom Side

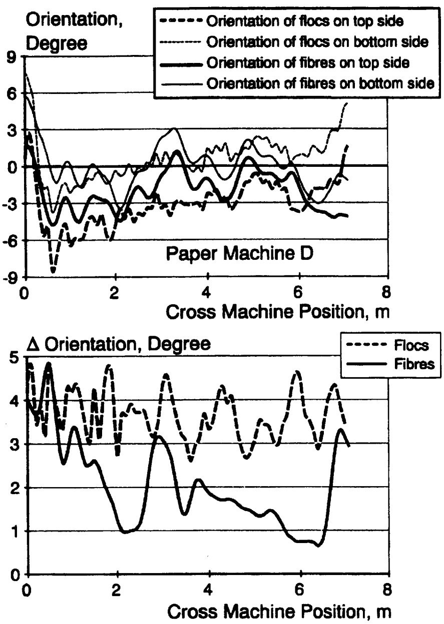


Figure 15: Two-sidedness of Floc and Fibre Orientation of a Hybrid Former
a) Orientation Profiles across the Web on Top and Bottom Side
b) Difference in the Orientation between Top and Bottom Side

4.4 Anisotropy

The MD/CD ratio is a measure of the randomness of the orientation. A high value indicates that the paper has many fibres or flocs aligned in one particular direction. We sum up the energy or the square of the amplitude in both directions out of the 2D power spectrum to characterise the floc anisotropy whereas the Lippke-Tester detects the light diffraction in MD and CD. The anisotropy ratio of the flocs in all analysed papers was nearly constant across the web with average values in the range of 1.1 and is in the extreme about 1.3. Much better results are obtained when taking into account wavelengths between 1 mm and 5 mm. Now, fibre and floc anisotropy were found to correspond sometimes (**Fig. 16**). In this case the numerical values of both curves are very similar. The second example documents the anisotropy for a newsprint that has been discussed before, too. The alignment of flocs is much higher than that of fibres. It can clearly be seen that there are no relationships between both measurements at the front edge. This is a further proof that fibres and flocs behave differently and are independent properties. That's also our explanation for the more pronounced MD/CD fibre orientation ratio on the top side compared to the floc anisotropy in **Fig.17**.

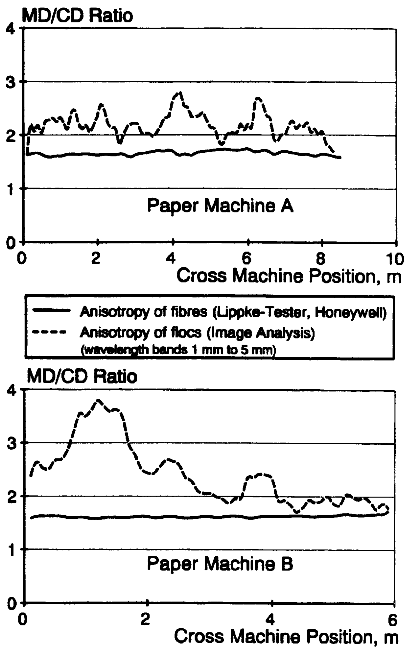


Figure 16: Anisotropy of Fibre and Floc Orientation of two Newsprint Papers

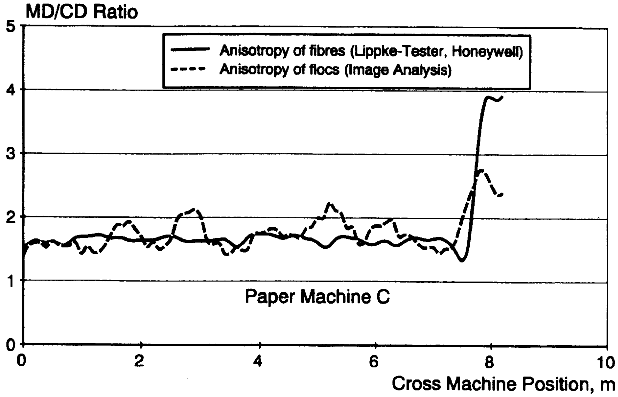


Figure 17: Anisotropy of Fibre and Floc Orientation

Anisotropy exhibits also a two-sidedness, which originates from different scattering contributions of both paper sides. The fibre anisotropy of the bottom side does not show the high gradient at the back side which can always be observed in the MD/CD floc anisotropy (Fig. 17). This phenomenon is not a two-sidedness problem in respect to flocs.

4.5 Relationship between Formation and Fibre as well as Floc Orientation

The question arises, whether the micro-scale variability of flocs and fibres influence paper uniformity. It is related to micro-scale grammage variations in the sheet. The common way to evaluate this unevenness is by viewing a paper in transmitted light. The visual perception, called formation, is mainly characterised by the floc size as stochastic areas of high basis weight and by the intensity between light and heavy spots in the paper, the contrast. Both variables can be measured by parameters based on first and second order statistics by means of an image analyser. The contrast is the overall variation in the grey tone image which can be simply characterised by the coefficient of variation. A texture feature of the co-occurrence matrix, called correlation, describes the linear grey tone dependencies in an image. It expresses the correlation between neighbouring elements. The higher this correlation value the bigger the floc sizes in the paper. We introduced a formation index by multiplying the coefficient of variation with the square root of the correlation. It is a sensitive index of the overall paper formation /7/.

A typical example between formation index and floc and fibre orientation is given in **Fig. 18**. The overall result of this study is that there is no correlation between our formation index and the orientation of the micro-structure. The same conclusion can be drawn for the anisotropy of flocs and fibres. These findings are in agreement with theoretical calculations of Dodson and Schaffnit /15,16/. They stated that the uniformity of grammage is not significantly influenced, if at all, by the degree of anisotropy. Nevertheless, sometimes we got the impression that high floc and fibre orientations or a significant anisotropy has some affects on paper formation.

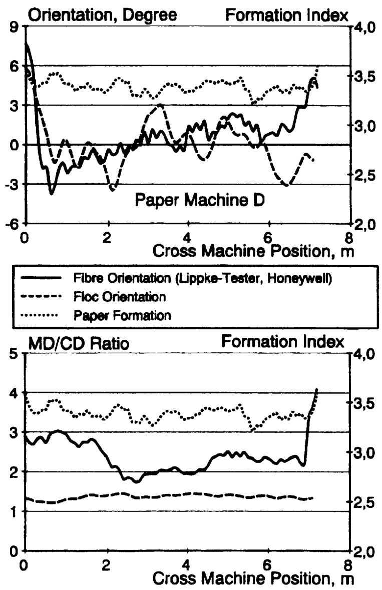


Figure 18: Comparison between Floc and Fibre Orientation or Anisotropy as well as Paper Formation

4.6 Fibre and Floc Alignment and their Effect on Cockling Orientation

The introduced method for measuring floc orientation is a universal tool and its application is not only limited for the analysis of floc orientations. Cockles have historically plagued many papermakers and they are still a serious problem with some papers such as newsprints and with copying papers. A cockled paper has lost its planarity because small randomly spaced areas have bent out of the plane. The variation of surface height is usually only of the order of one millimetre. We can contrast this effect by illuminating these papers under a flat angle. When looking at such images, different brightness at the two opposite edges are visible. They result from the nonuniform illumination due to the incident light from the right side and can be corrected. Furthermore, it is quite obvious that the cockles have an orientation. It can be determined by applying our method and taking into account all wavelengths greater than 2 mm. The results are presented in **Fig. 19**. Flocs, fibres and cockling orientation shows the same trend. It is tempting to believe that a direct correspondence exists between cockling alignment and fibre orientation. This is at least not in contradiction to Kajanto's findings of more oval cockles with stronger fibre alignment. Maybe these findings can improve our understanding of the cockles.

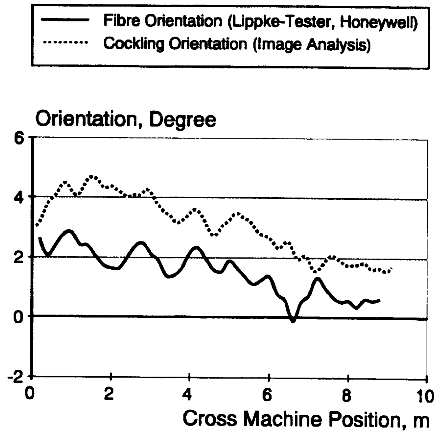


Figure 19: Orientation of Cockles and Fibres

5 CONCLUSIONS

Variations in paper properties remain an important issue because they effect both quality and productivity. Image analysis provides a tool for an objective assessment of paper quality in order to get a better understanding of the sheet forming process and its drawbacks.

It could be shown that the coefficient of correlation between fibre orientation (Lippke-Tester) and floc orientation amounts on average to 0.7, when profiles across the webs are evaluated. In the case of lower correlations the global trends of both measurements are in many cases the same. Differences are explained by the fact that flocs are an independent property.

Further results are as follows:

- Papers, particularly those which are made on hybrid formers, show a two-sidedness concerning floc orientation and anisotropy.
- The uniformity of formation is not significantly affected by floc and fibre orientation and the degree of anisotropy. Similar results were reported by Dodson.
- The orientation of cockles is in agreement with the orientation of flocs and fibres.
- The power spectrum of the local orientation of an image seems to be very usefull in the detection of deterministic variations in orientation, which are invisible in light transmission images.

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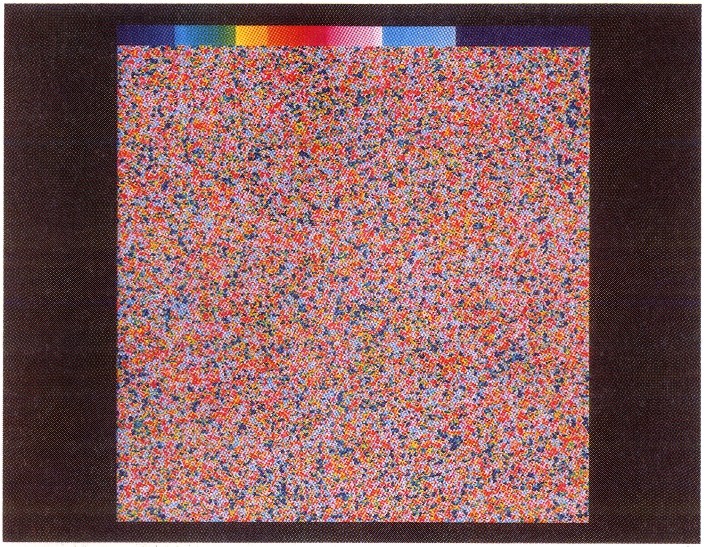

Ranges of Floc Orientation

dark blue	0°	-	30°
blue green	31°	-	60°
yellow	61°	-	80°
red	81°	-	115°
pink	116°	-	145°
blue	151°	-	180°

Figure 2: Local Floc Orientation in a Sheet of Paper captured by Light Transmission
(Size of Paper Sample: 9.5 cm x 9.5 cm)

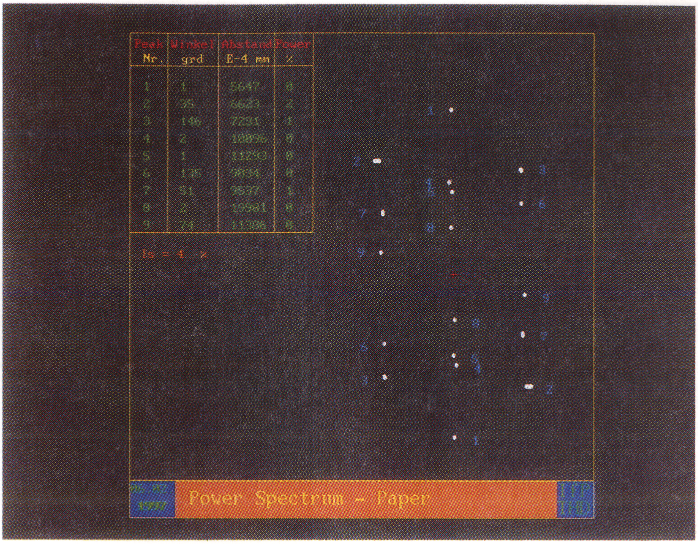

Figure 3: Power Spectrum of a Paper in Transmitted Light

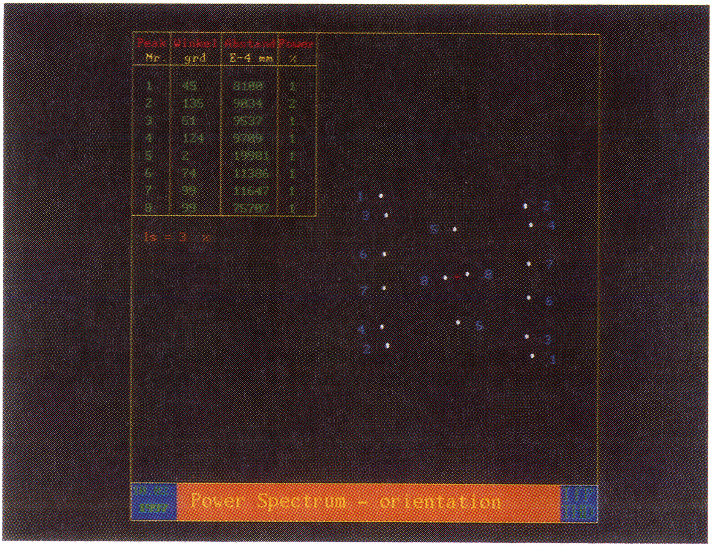

Figure 4: Power Spectrum of the Local Orientation of an Image

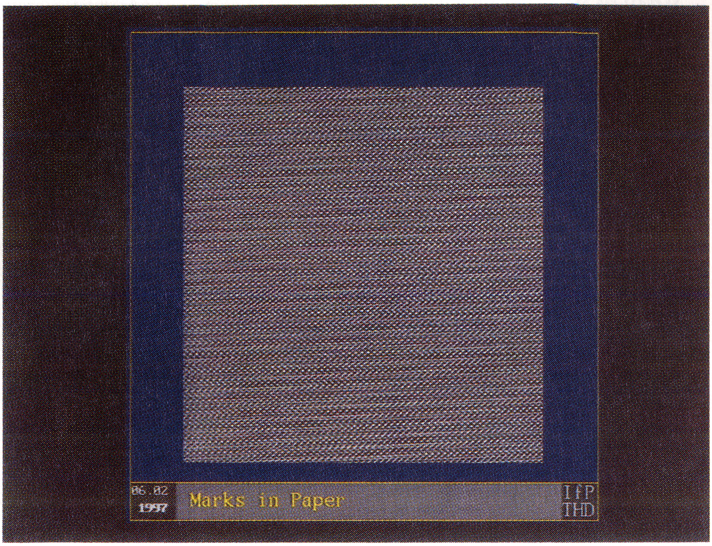

Figure 5: Isolated Marks from a Paper in Transmitted Light

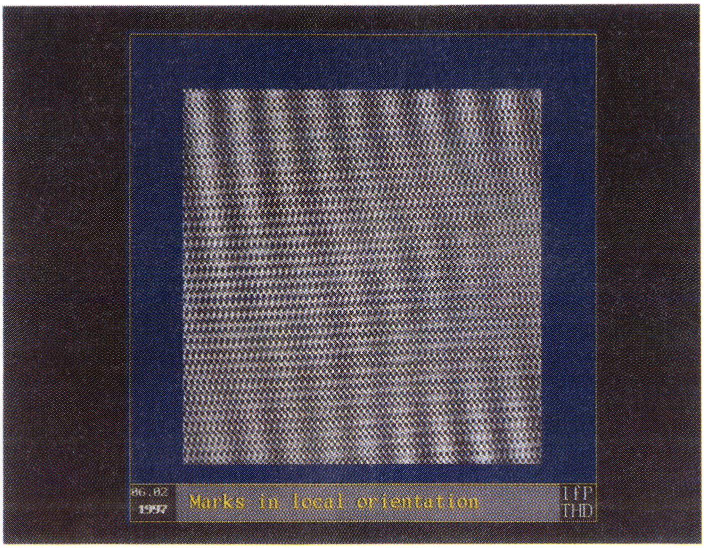

Figure 6: Isolated Marks from the Local Orientation of an Image

Transcription of Discussion

Local Orientation of Flocs in Paper

Hermann Praast, Lecturer, Institute fur Papierfabrikation, Germany

Christer Fellers, Senior Research Scientist, STFI, Sweden

I would like to clarify something. In Figure 19 you talk about orientation of cockles and fibres. There seems to be good correlation but you consider the fibre orientation to be the dominating factor, not the floc orientation. Am I right?

Hermann Praast

Yes, that's right.

Christer Fellers

I wasn't sure whether you came to the conclusion that fibre and floc orientation were the same.

Hermann Praast

Yes, we think the orientation of the cockles result from the fibre orientation, that is what I want to say. So fibre orientation is the reason for the orientation of the cockles.

Professor Bo Norman, KTH, Sweden

There should be more difference in fibre orientation between the two sides than in floc orientation. Your results seem unrealistic.

Hermann Praast

If you look at a sheet of paper in transmitted light, the surface which is close to the camera dominates the effect of the structure and so you don't reveal the average floc orientation. The surface has a very dominating effect on the measurement and that's also the reason why we measure a two sidedness concerning floc orientation by image analyses and a two sidedness concerning fibre orientation when using the Lippke Tester.

Bo Norman

The flocs are not on the surface like a wire mark, flocs are all the way through the sheet. There should be more difference in fibre orientation, not like in your case you get less difference in fibre orientation on the two sides and more difference on the flocs and that seems unrealistic.

Professor C T J (Kit) Dodson, UMIST, UK

To go back to the colour picture you had, and passed off as incidental, I'm very interested in the thresholding there where you used orientation intensity localized in space to produce a map of what could be flocs. It isn't clear that they are flocs but have you obtained any statistics of the size distribution of those objects - the red ones?

Hermann Praast

The red areas in Figure 2 represent a wide range of orientation, maybe 20°. We looked at the paper structure itself and then isolated the flocs and so we could superimpose the floc image on the orientation image. Then we found out that flocs do not have one single orientation. We didn't look at the sizes of the areas in Figure 2, because that depends of course on the threshold you use.

Dr Ing Jean-Francis Bloch, EFPG, France

You have defined the misalignment between the direction of the machine and the main axis of the distribution of the fibre orientation. I was wondering if you have seen an influence of the paper structure on the measurement accuracy. For example, an isotropic paper has the same probability in each direction, and then you get a lot of variation in the misalignment for this angle. When you are changing the anisotropy of the paper, that is to say the difference between the jet and wire speeds, you will obtain a more or less oriented structure. What is the influence, from your point of view, of this level of orientation anisotropy on the misalignment, as both, I think, are measured with the Lippke equipment.

Hermann Praast

There are two things we have to look at. Firstly the orientation of the flocs. If we look again at the polar plot we have to calculate the main orientation but another thing is the intensity. How strong is the alignment of these flocs in one direction. There is a little bit in my paper about what we do to characterise this. We sum up the energy along the main axis of the 2D power spectrum. It's ratio gives us an indication of the anisotropy and alignment of the flocs. So we calculate both parameters like the Lippke Tester does. We calculate the orientation and also the alignment of the flocs by summing up the energy along the main axis. It is very important to multiply the original image with a window function before doing this kind of calculation.

Stuart Loewen, Associate, LSZ Paper Tech Inc, Canada

Having looked at many of these images noted in your work, have you seen but weren't willing to speculate in your talk, on when you get differences between what we call the fibre alignment angle and the floc alignment angle? When you do get wide differences in those two angular descriptions, is there any unique characteristic you may have noticed about the images you are looking at, and would you be willing to speculate on what kind of mechanisms in the paper forming process might lead to a large difference in these two measures?

Hermann Praast

That's a good question. We didn't see any unique things when looking at these images. When we had a big difference between fibre and floc alignment as, eg, shown in Figure 13 we measured the paper several times. We always ended up with the same result. So far we don't have an explanation for the difference between fibre and floc orientation. Maybe you have a good idea to explain that?