Wrinkle Formation During the Web Motion in Offset Presses — An Integral View

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Paper characteristics

Abstract: A phenomenon that is dreaded and mostly difficult to control by printers is the wrinkle formation of a paper web. Many projects have tried to find models to make the mechanism of the wrinkle formation tangible and conceivable. Also the complicated mechanical and dynamic models failed in practice because of the necessary material parameters like transversal web force and shearing modules were impossible to determine. Simple approaches basing on mostly zonal tension fluctuation do make the problem comprehensible but are still not quantitatively elusive. An integrated view of external forces, internal stress conditions, the image dependent moisture pick-up and web material typical characteristics like the penetration behavior and the fluctuant main orientation of the printing material grain in concur with external temperature influences, as well as construction-related path length within printing machines is necessary. This presentation will show the different importance factors, their reciprocative conditionality and the opportunities of a prediction of wrinkle formation by means of modern paper evaluation methods. Still unusual but technically feasible possibilities in the field of mechanical spreader appliances and dryers will be pointed out.

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1. Introduction

Primarily, warping and wrinkle formation is a zonal web tension problem. The web travel conditions inside a press that are measurable are mainly characterized by the effect module, thus the correlation between tension and stretch. Web tensions particularly depend on web material characteristics and their constancy across web width, across the entire web length and from roll to roll.

In order to clarify the cause of warping and wrinkle formation a definition of the terminology is needed. In literature this is very often called wrinkle formation, although only warping is meant. A warped paper web, therefore a partial material excess, may be critical as a pre-stage of an emerging wrinkle but is relatively harmless in comparison to a wrinkle fixed within the printing paper web.

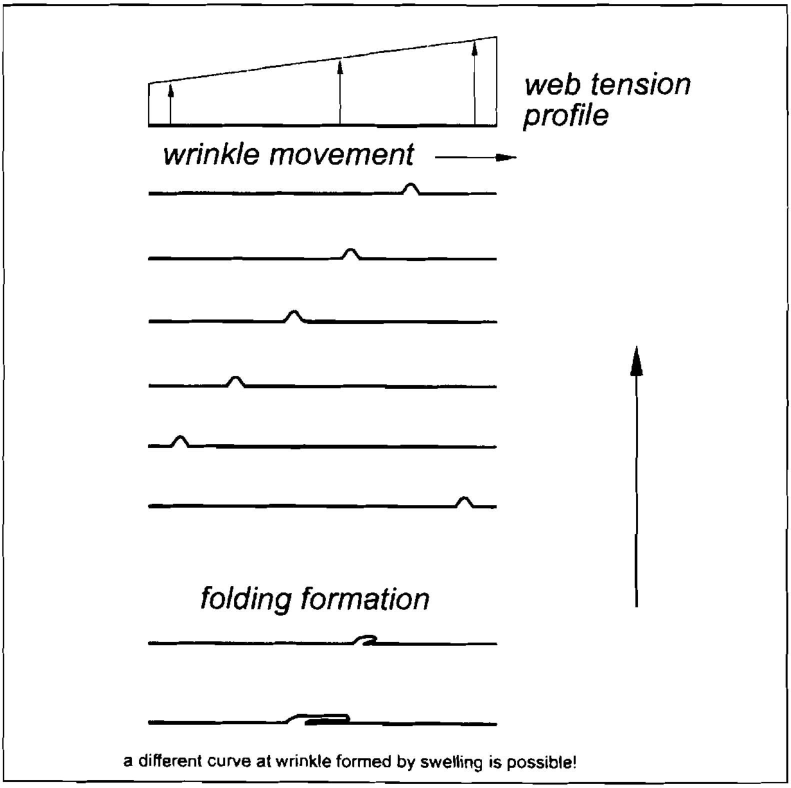


Figure 1: wrinkle formation

Corresponding to fig 1 warped paper is the pre-stage of a wrinkle and can be oriented parallel to the direction of web travel or angled to the travel direction. The wrinkle is the folding coming from a sufficiently warped part of a web folded across another. Additionally, this folding is brought forward by transversal waves and is permanently fixed at a large wrap or in the nip pass and this results in unprinted areas below the folding after the printing. This is also shown in figure 1.

If the available web conditions are analyzed, the different web tensions across the entire web width are still existent. Very often the warping and wrinkle formation are strengthened by an inexpedient size of the web tension, extreme demands on web travel and strong moisture entry.

Therefore, it is differentiated between tension dependent and tension independent warping and wrinkle formation.

The tension dependent variant can be clarified by a simple model. Provided that the tension distribution is unequal and that a micro area is considered, the areas with a large and a small specific web force are in parallel.

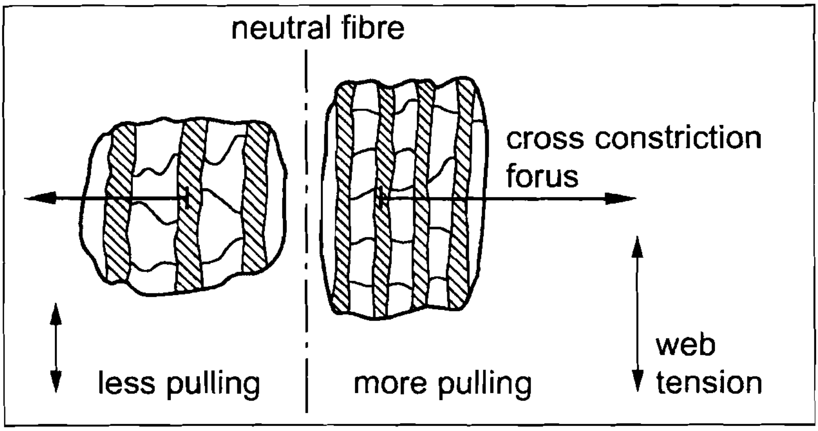


Figure 2: Micro area

Considering the corresponding transversal and friction forces, the resulting force component is directed transversely to the travel direction. This component leads to transversal waves, to zigzagging transversal waves and, in an extreme example, to wrinkles in the following nip pass.

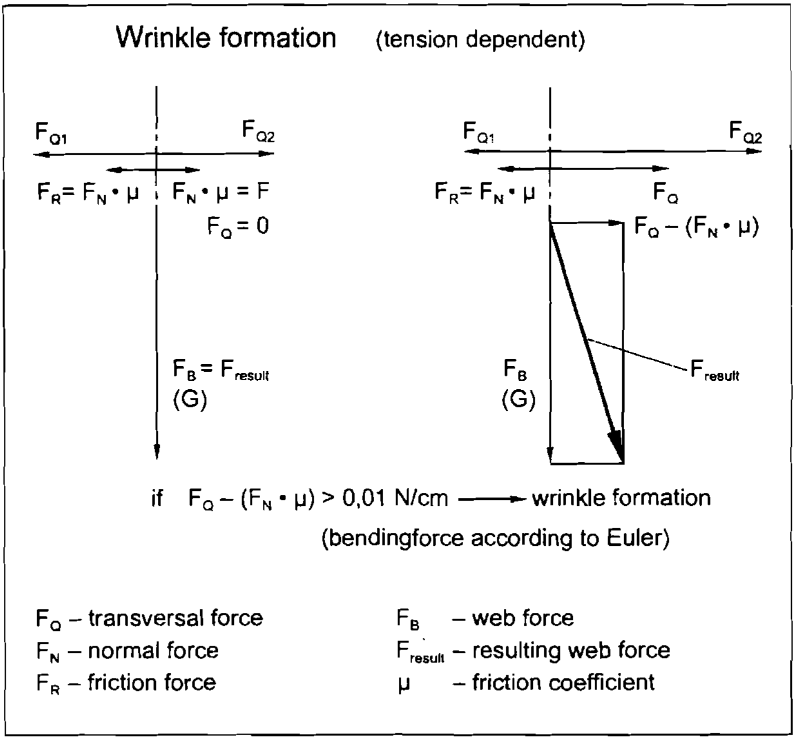


Figure 3: Resulting force component by zonal web tension differences

The second variant is the tension independent wrinkle formation by a zonally different moisture entry or different penetration behavior across the web width.

The causes are:

- Interplay between moisture dependent cross stretch and tension dependent cross contraction
- Moisture dependent cross stretch prevails zonally
- A zonal material excess emerges across the web width
- Short penetration time leads to a web swelling while running through the printing machine
- Long retention period due to low speed and/or long web distances

2. The integral approach

In the analysis of the causes for warping and wrinkle formation several big cause groups are determined. These are partially interlocked but also always separately verifiable. As the above-named comments according to the necessary conditions for these occurrences prove, do waves and wrinkles develop at an unequal web tension distribution across the web width, whereat for each web element the web tension maximum can be longitudinal or transversal to the web direction. Thus all conditions leading to such zonal web tension differences can be the cause of waves and wrinkles.

A further cause lies in different stretch and swell behaviors across the web width, which particularly gains importance in moisture entry into the web (Offset).

Three different cause groups can be deduced:

1 The printing machine with its geometric conditions
2 Paper characteristics, particularly marked by an effective module (tension-stretch-behavior), the longitudinal-transverse ratio of the mechanical characteristics and the constancy of these parameters along web length and web width, as well as the moisture pick-up
3 Process-related causes founded in technological conditions of the printing methods and web travel

These three groups have to be added to a fourth group because the machine operators influence the final result vitally, partly knowingly, partly unknowingly.

4 The abidance of default and limit values of the web tensions, referring to the respective machine types, printing methods and web materials

Following the four cause complexes are to be considered closer. Hereby the opportunities of the evaluation of measurements and exertion of influence will be signified.

2.1 Machine-related causes:

Particularly mentioned here should be single transport elements or whole units, such as printing units, that are oblique. Theses are in most cases assembly faults, in some cases also subsequent changes, for instance lowering of the foundation, wear properties in bearings. Additionally, eccentricities can be noticeable the same way.

Deliberate interferences into the web travel within appliances for the lateral alignment of the web (swing-frame) have a partial impact on the zonal web tension profile across the web width. These mechanical influences on web travel are, and this is a typical sign for such faults, permanently existent. They are, however, different in size and can also have a sinuous run.

The analysis method according to Neuser / 1 / basing on the orthotropic material law developed by Paetow and Göttsching / 2 / and the plate distortion theory by Szabo / 3 /, is very useful in such cases of deciding whether and when a correction is needed (see figure 4).

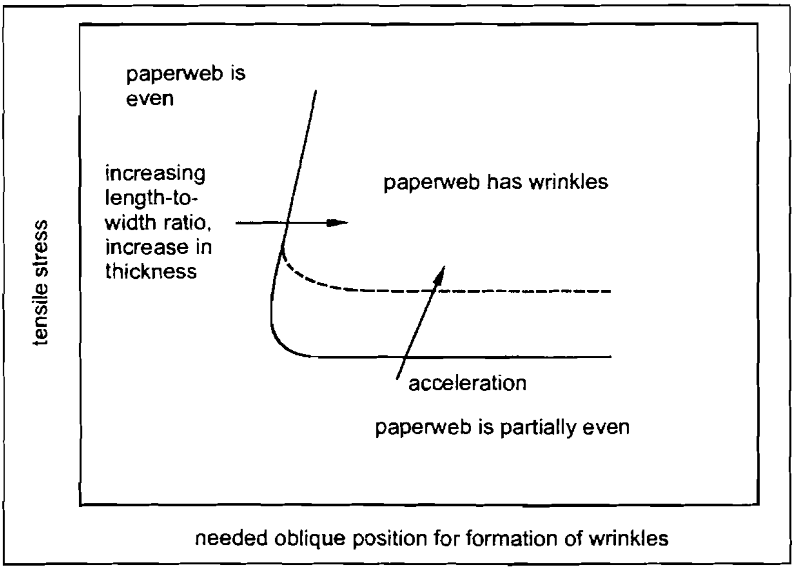


Figure 4: Qualitative run after wrinkle formation across the tilted position of the web lead roller (according to Neuser) / 1 /

Oblique positions leading to wrinkles are:

1. Oblique position at a web deviation in paper grain

2. Oblique position at a straight run vertical to paper grain.

These variants are shown in figure 5. The developing web path extension leads, via the necessary stretch, to a zonal increase of the web tension that can be calculated in dependence on the paper's E-Module, the distance to the fixing points and the existing oblique position.

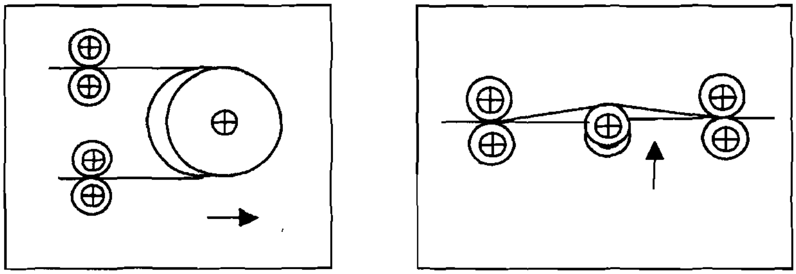


Figure 5 : Oblique position variant with wrinkle formation

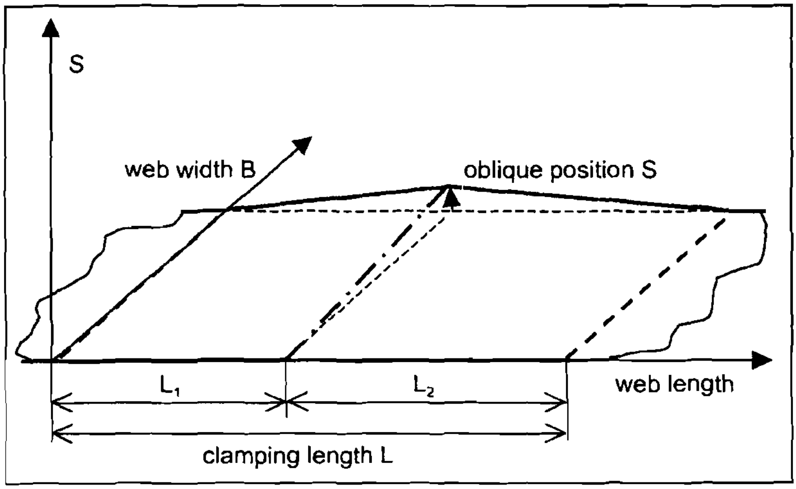


Figure 6: Geometric calculation criteria for a zonal increase of web tension

Resulting from figure 6 is the formula for the rough calculation of the zonal increase of the specific web force for a linear tension-stretch-ratio:

$$F_{add} = E_{dyn} \left[\left(\sqrt{S^2 + L_1^2} + \sqrt{S^2 + L_2^2}\right) - L\right] / L$$

With

E_{dyn}	dyn. effect module in N/cm (to be determined in the printing machine)
S	Oblique position in cm
L_1	Distance between the oblique web lead element and the preceding fixing point in cm
L_2	Distance between the oblique web lead element and the succeeding fixing point in cm
L	Fixing length between preceding and succeeding fixing point in cm
F_{add}	Additional zonal specific web force in N/cm

Also changes in diameter of rollers and bars because of ink and paper dust depositions and the swelling resp. dipping of blankets or roller slips are machine-related causes of waves and wrinkles. In addition, this results in different transport lengths per rotation resp. distances that lead to a forced longitudinal stretch and zonal web tension changes, which can involve waves and wrinkles if the output tensions are disadvantageous and the paper characteristics insufficient.

After the localization of the defective area and the determination of causes the new adjustment of the web transport and web lead elements resp. the blanket change and possibly the cleaning of coatings in order to remove the defects. A further possibility to minimize wrinkles in cases that do not provide the first opportunity is the zonal tension-stretch-compensation by a provisional overlay using pasted paper wedges or, better and more to date, the compensation by a banana roller. The function of the banana roller to compensate tension is shown in figure 7.

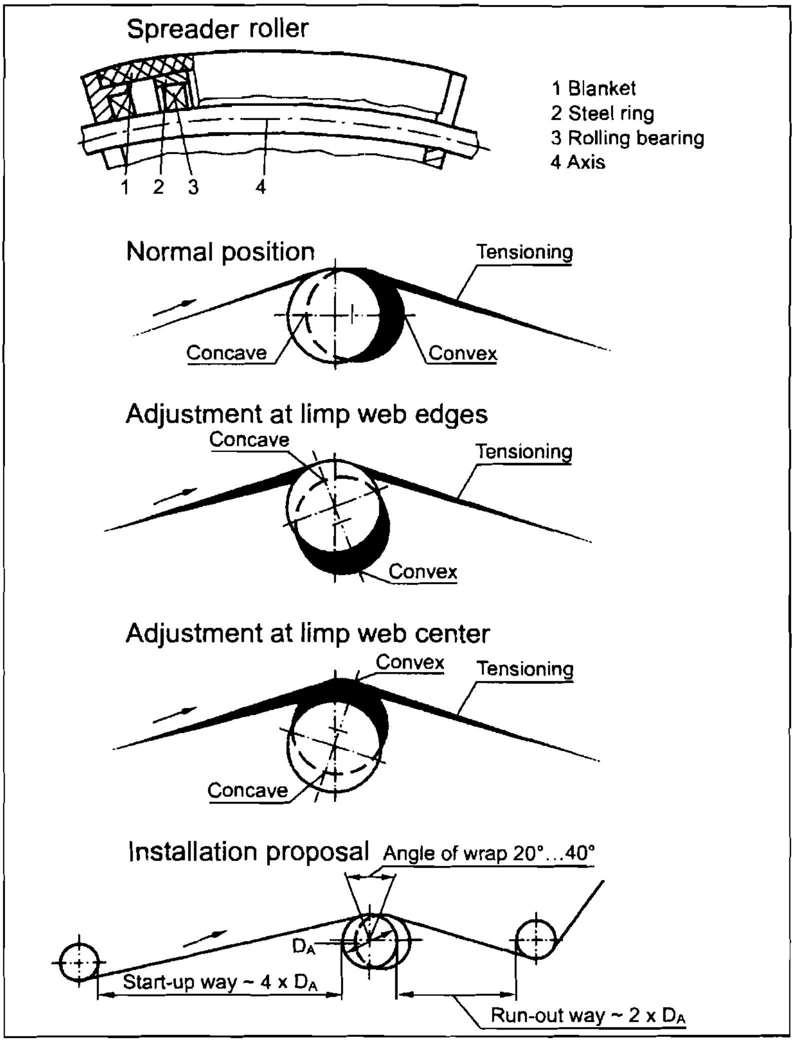


Figure 7: Typical function of the spreader roller (banana roller) to homogenize zonal web tensions

It is more complicated to describe and grasp the second cause complex.

2.2 Paper technical conditions:

The big efforts made in modern paper machines lead to reduction of differences in thickness and density in process control. Modern screens of verti-formers or GUP formers nearly eliminated even the two-sidedness of paper. Nevertheless, problems concerning anisotropy in the headbox do occur, as shown in attachment 1.

Different flow velocities result in unhomogeneous fiber orientation that cannot even be compensated in modern paper machines with shorter screens and limited screen sieving. Only a good supervision of the existing fiber orientation allow therefore a prognosis concerning run behavior and permit to discard insufficient qualities. As we know, for the time being, the paper purchasers are swamped with this. A concrete statement about minimum demands also regarding fiber orientation does not exist. The in literature specified limit values of 8 degrees deviation of the main fiber orientation from web direction can only be a rough clue. And of course are the paper costs for purchasing in the fore, much to the printers' disappointment.

For the determination of the fiber orientation there are easily manageable sonar measuring meters that measure the sonar attenuation rosette-like within the printing material and calculate the main fiber orientation fully automatically. At the same time, the tensile strength index (parameter corresponding E-module) is determined in the preferred direction. It also permits good statements about longitudinal/transversal behavior and therefore the tendency to form waves and wrinkles. The measuring pattern of an L&W TSO tester is shown in figure 8.

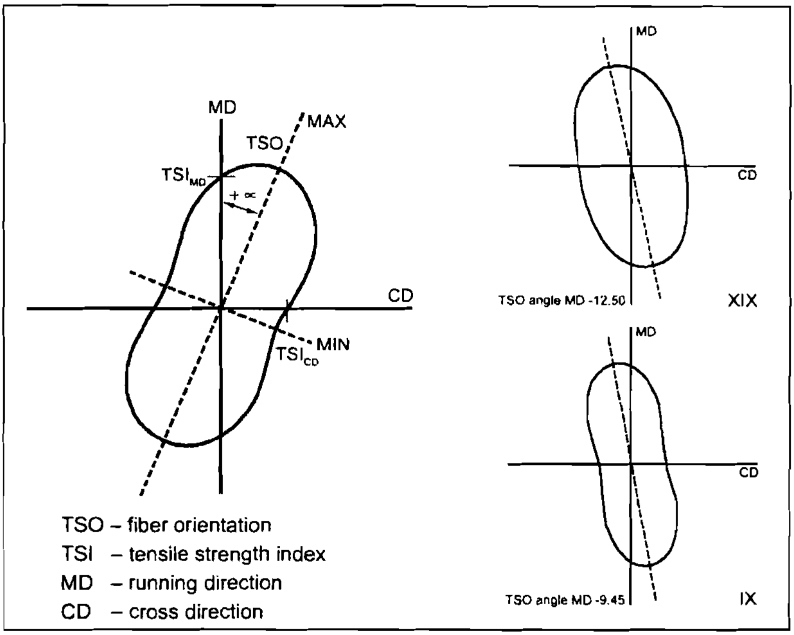


Figure 8: Anisotropy, cause of wave- and wrinkle formation with 2 samples from table 1

If the fiber orientation along the web and across the web width is analyzed, the tendencies shown in figure 9 and 10 can be determined. These will, according to the position of the roll in the tambour, lead to different run conditions because changes of the main stress direction within the web have the same effect as transversal positions of transport elements or a strongly differentiated web tension across the web width.

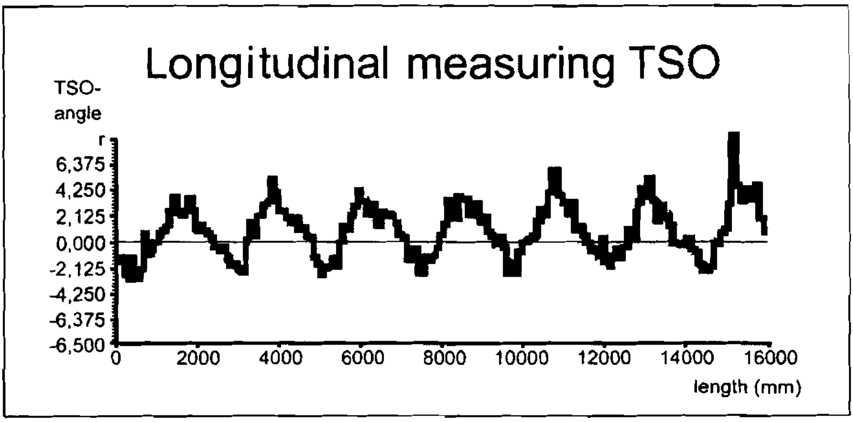


Figure 9: Fiber orientation along the web / 4 /

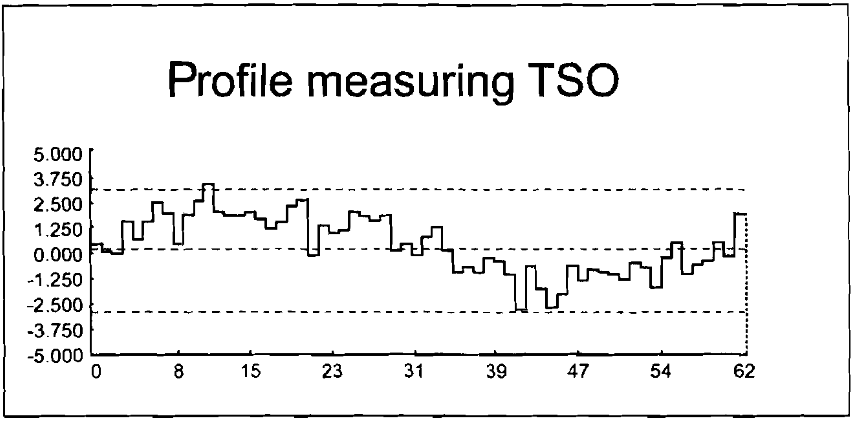


Figure 10: Fiber orientation across the web width of the tambour / 4 /

According to the researches of the Voit and Sulzer company / 5 / these two overlapping influences occur in old headbox systems. They are, however, reducible by aimed machinery technically interferences or are to be removed completely. Offered on the market is, for instance, the system MuduleJet.

Testings of well running papers and those that tend to wave- and wrinkle formation clarified the correlation between fiber orientation and wrinkle formation.

Table 1 shows the fiber orientation of 28 paper grades of different producers, with different grammage and equipment.

grade	TSIMD	TSIC D	TSIM/C	TSIMax	TSIMin	TSIMax /Min	TSO max	span TSO	printed unprinted	notes
I	10,12	2,73	3,71	10,14	2,73	3,72	- 2,0	3,7	unprinted	U
II	9,61	2,64	3,64	9,66	2,64	3,66	3,1	6,1	printed	wrinkles
III	8,57	3,67	2,33	8,58	3,67	2,34	- 2,3	2,9	unprinted	
IV	8,53	4,14	2,06	8,53	4,14	2,06	- 0,2	1,2	printed	
V	8,01	2,25	3,56	8,01	2,24	3,58	- 0,5	2,0	unprinted	
VI	10,32	3,66	2,82	10,36	3,66	2,83	- 2,8	4,8	unprinted	
VII	8,45	3,78	2,24	8,48	3,77	2,25	3,5	5,0	unprinted	
VIII	8,62	3,44	2,51	8,62	3,44	2,51	- 0,6	0,8	unprinted	
IX	8,47	2,89	2,93	8,82	2,86	3,09	- 9,5*	19,6*	printed	wrinkles
X	10,49	3,8	2,76	10,5	3,79	2,77	1,8	2,7	printed	
XI	8,64	3,49	2,48	8,67	3,49	2.49	- 2,8	2,6	printed	
XII	11,45	5,72	2,0	11,46	5,72	2,0	- 1,6	1,3	unprinted	
XIII	9,4	4,79	1,96	9,47	4,78	1,98	- 5,2	2,3	unprinted	
XIV	10,85	5,56	1,95	10,86	5,56	1,95	1,0	3,7	unprinted	
XV	10,01	2,73	3,66	10,04	2,71	3,7	2,0	2,0	unprinted	
XVI	7,97	2,81	2,84	8,06	2,81	2,87	- 5,1	5,7	printed	wrinkles
XVII	7,98	3,21	2,49	8,01	3,21	2,5	- 3,0	4,3	unprinted	wrinkles
XVIII	9,68	2,24	4,31	9,72	2,24	4,35	2,9	4,3	unprinted	wrinkles
XIX	7,65	4,22	1,81	7,97	4,21	1,89	- 12,5*	23,3*	printed	wrinkles
XXI	10,80	5,34	2,02	10,81	5,33	2,03	1,5	0,9	printed	wrinkles
XXII	9,48	5,38	1,76	9,53	5,38	1,77	- 4,8	3,0	printed	wrinkles
XXIII	9,99	4,75	2,1	10,02	4,75	2,11	3,1	0,8	printed	wrinkles
XXIV	9,11	1,62	5,63	9,13	1,61	5,68	2,3	4,2	printed	wrinkles
XXV	7,42	2,34	3,06	7,59	2,43	3,13	- 8,4	13,9	printed	wrinkles
XXVI	6,32	1,83	3,45	6,34	1,83	3,46	4,0	7,1	printed	wrinkles
XXVII	8,43	2,53	3,59	8,49	2,35	3,62	- 3,4	4,4	printed	wrinkles
XXVIII	8,29	0,97	8,53	8,32	0,97	8,57	6,2	4,7	printed	wrinkles
XXIX	8,12	3,2	2,54	8,31	3,17	2,62	- 7,6	14,3	printed	wrinkles
XX										
Legend: Gray underlaid papers with differences in TSO resp. A TSO span bigger than 4 degrees, extremes with *										

Table 1: Tensile strength indices and fiber orientation deviation

The first part of this table contains papers whose samples were compiled arbitrarily from several printing companies. The second part contains only paper samples of problematic papers that stood out because of wrinkle formation.

Hereby, the limit values of maximum tolerances of 5 resp. 8 degrees (according to grade) given by the paper industry do not seem to be sufficient because to all measurements the fluctuation in run direction is added as uncertainty factor but which cannot be evaluated or only with big efforts.

Two particularly big deviations are shown by the grades IX and XIX. Looked at the unprinted but also the printed webs, especially these grades show a strong tendency to wrinkle formation. See figure 11.

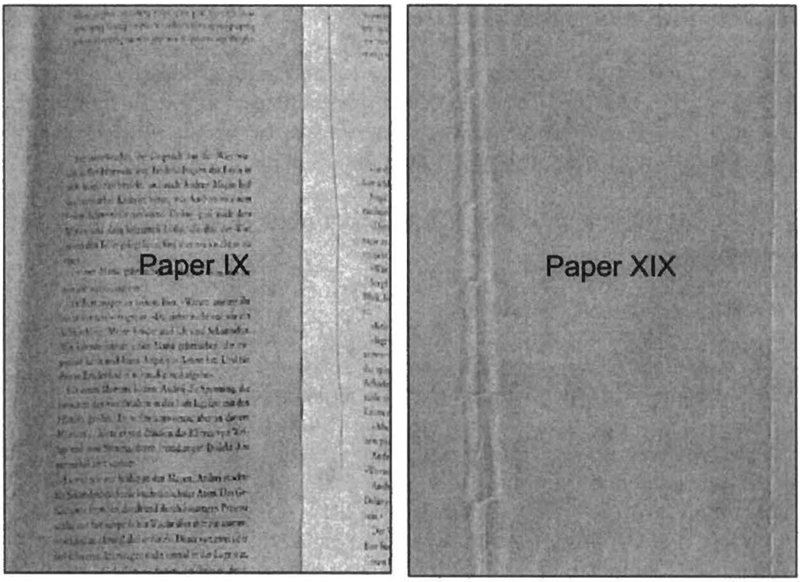


Figure 11: Examples of wrinkles in the papers IX and XIX

The values corresponding to the elasticity module of the tensile index longitudinal and transversal that are recorded during the measuring and the change of the longitudinal-transversal ratio due to the strong fluctuation of the fiber orientation allow to predict the web travel conditions.

Only in two cases of printed samples wrinkles occurred during the printing process although the fiber orientation of these papers is not objectionable. The causes for this wrinkle formation are different.

As the tests have shown, wrinkle formation can already be expected at a deviation of the fiber orientation between 4 and 5 degrees when no other paper quality is responsible for the occurrence of wrinkles. Fluctuations in web travel that are not retrieved in a single measurement come into question as an additional source of error.

For the enforcement of the existent technical progress to equal the fiber orientation by changed headbox conditions, it is necessary to control the fiber orientation also in the printing companies and to discard papers with insufficient conditions.

2.3 Printing technologically related causes

The third complex of causes is technology related and particularly common in offset printing. Technological main causes for the wave- and wrinkle formation is the zonally different moisture entry into the paper, which leads to a partial material excess resp. not differentiated detraction in the dryer.

Material excess results in waves if it does not occur equally across the entire web width.

Two effect mechanisms operate here.

1. The moisture entry decreases the longitudinal tension via stretching why the transversal contraction decreases.
2. A transversal stretch emerges at the moisture entry.

As in the register behavior, the crucial factor is the penetration of water into the paper and the retention period of the paper inside the machine. In addition, in this case the cognitions can be deduced from the sonar measurements. The water penetrating the printing material and the resulting change in structure and swelling of the grain can be evaluated by penetration measurements, for instance by means of the dynamic penetration measuring device DPM by the company EMCO Leipzig / 6 /.

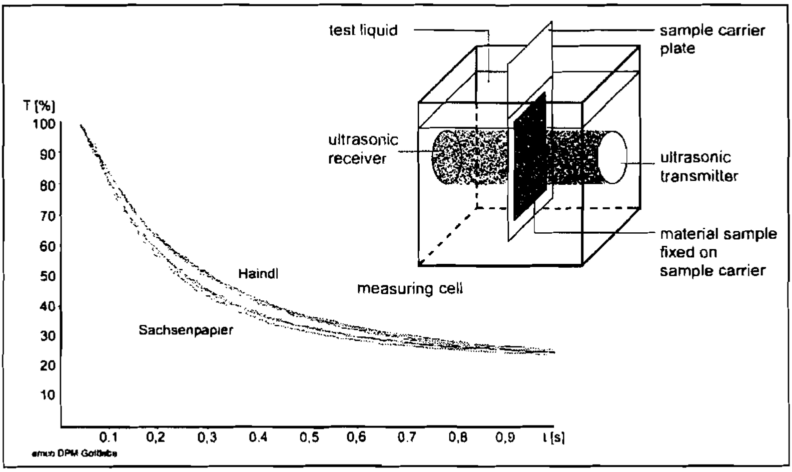


Figure 12: Principle of the penetration measuring instrument with a sample record chart

Attachment 2 shows the moisture-entry-related transversal stretch of several newsprints recorded by the same device and additional apparatus (dynamic stretch module). According to machine configuration, meaning web length inside the machine, and web speed the tendency to wrinkles can be predicted or excluded for the reasons of the moisture entry.

Comparable results are also achieved by the TSI test, with which it was verified that TSI-CD and the transversal stretch behave reciprocally proportional (see figure 13) / 4 /.

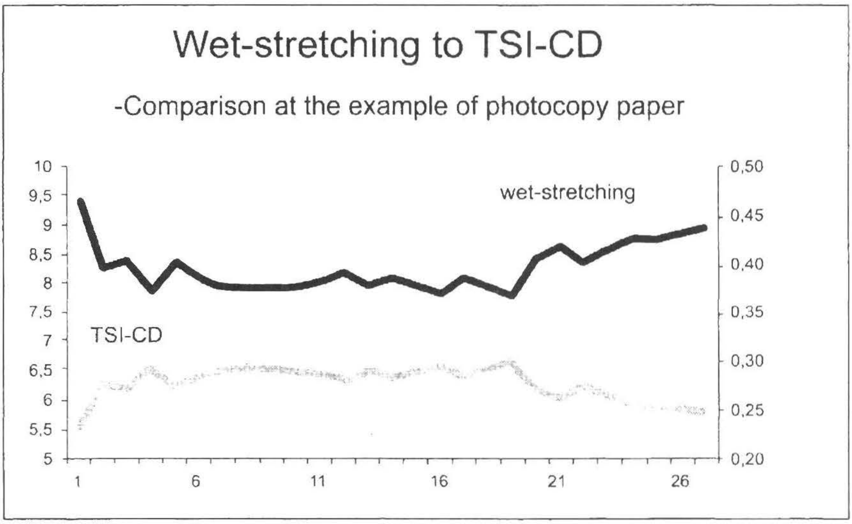


Figure 13: Correlation between TSI-CD and wet-stretching / 4 /

The water detraction in the dryer as a further technological-related cause of wave- and wrinkle formation is based on the change of the effect module due to thermal stress and fixation of these characteristics in combination with the subsequent cooling unit.

The changes in structure elapsing here are still insufficiently explored. It is certain, however, not only proven by practical tests, that the E-module of printed and dried paper differs from the E-module of the same but unprinted paper. This deviations can be considerable, as attachment 3 exemplifies.

If different there are drying levels because of an unequal moisture across the web width in the dryer, differences in the effect module across the entire web width will develop and the result will be conditions as in web tension differences or fiber orientation differences. Subsequent remoistening installations that are to revoke these defects can only be effective if they operate zonally. The low efficiency factor of remoistening, however, strengthens the need for new cooling systems that take on the remoistening (evaporative cooling).

2. 4 Human cause complex (machine operation)

Still the machine operation crucially influences the printing result, the web travel quality and therefore also the formation of wrinkles. Despite modern preset systems and adjustment installations many decisions demanding a high professional competence and the overview of numerous technological correlations are left. At the same time paper characteristics cannot be recognized by simply looking at them and feeling them. Often there is also a contradiction between the demands on the optimal print-out and the demands on the web travel, then only a compromise is remaining.
Unfortunately, the limit values have not been sufficient and differentiated for several types of printing machines. The Institute for Print- and Media-Technology at the TU Chemnitz will together with partners from the industry work on this problem.
Table 2 gives general limit values for web tensions and web stretches, which ensure a wrinkle free web travel if there are no extreme deviations in paper quality existent.

Tension and stretch limits for printing papers (collection of experiences at the TU Chemnitz and according to Glöckner / 7 /)				
Paper	Tension upper limit	Tension lower limit	Stretch upper limit	Notice
40-65 g/m²	1,5-3,5 N/cm	0,8 N/cm	20 % Breaking stretch	Valid for newsprint and light commercial printing papers
65-100 g/m²	3,5-5,0 N/cm	1,2 N/cm		
100-120 g/m²	5,0-6,0 N/cm	1,5 N/cm		
general	20 % Breaking tension max. 6 N/cm	Corresponding to formula (3)		
wet, inhomogeneous	10 % Breaking tension to 2,5 N/cm	Corresponding to formula (3)	10 % Breaking stretch	
Inhomogeneous papers are papers with more than 4 degrees deviation in fiber direction to direction of web travel and edge rollers of the paper machine				

Table 2. paper limit values

In addition, according to Glöckner the limit speed ratio is to be taken into consideration against the developing of a sack before the pullout / 7 /. It applies:

$$\frac{V_{PU}}{V_{PO}} = \frac{E_{dry}}{E_{dry} - \sigma_1} \quad (3)$$

With: V_{PU} = speed of the printing units
V_{PO} = speed of the pullout
E_{dry} = E-module of the dry paper
σ_1 = web tension before the printing units

3. Conception for avoiding waves and wrinkles

Regarding the multitude of causes there are also various possibilities to reduce waves and wrinkles:

- Definition of necessary paper characteristics in dependence on the type of printing machine (penetration characteristics, E-module, TSO)
- Paper entry control (characteristics of paper and evenness of rolls) Definition of technological limit parameters (upper and lower limit of tension)
- Control of the machine presets
- At least two zonal web tension measuring points (before and after the DE)
- Compliance with given tension levels by web tension compensation by means of controlled single drives, considering existent changes of the E-module (advance adjustment)
- Web tension compensation across the web width according to the profile (by means of the banana roller)
- Compensation of waves that occur because of diffusing moisture pick-up by a zonally variable spreader application
- Maintenance of the optimized web characteristics by preventing zonal over drying through zonal drying differentiation

4. Technical Solution Proposals

The evaluation of all causes of waves and wrinkles is enabled by a zonal web tension measuring via the paper web width. Such a measuring is therefore absolutely needed, for retrieving the causes as well as for the control resp. evenness of the web tension profile. Figure 14 shows a combined measuring system with a reflex pressure sensor and common measuring roller with flexural beam bearing. The use of such a system is possible at nearly all points of a printing machine because of the developing air cushion between planning plate and paper web that prevents the set-off of fresh ink.

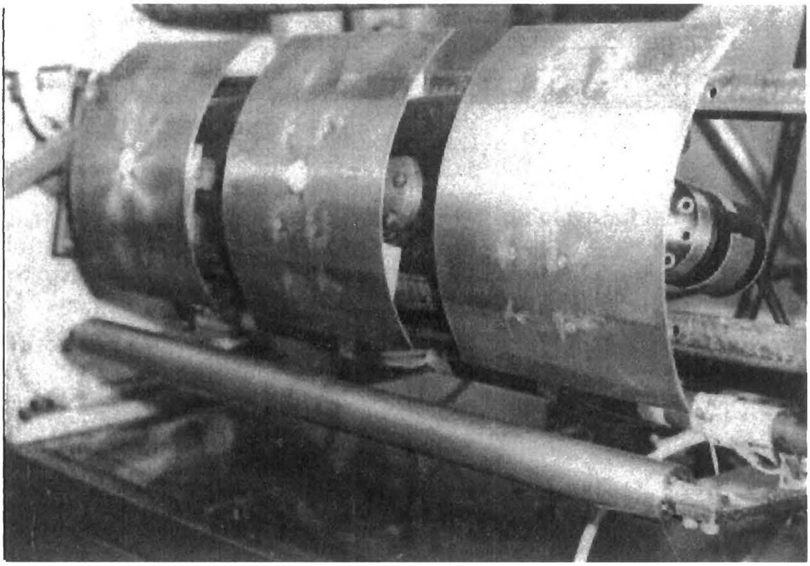


Figure 14: Zonal web tension measuring system with reflex pressure sensor system (TUC)

In case there are still waves and wrinkles in the web despite a reasonable material selection and an influence on the web tension in the printing area, they can be decreased or removed by spreader applications. As known, today's spreaderrollers have a notch.

According to rotation direction, web tension, wrap and possible relative speed the spreader effect (or contrary effect) is bigger or smaller. The effect, however, is nearly constant throughout the entire web width.

As said in the remarks above, the material, web, machine, and technological influences responsible for the formation of waves and wrinkles are always zonally different. The development of waves and wrinkles itself is bound to existence of such zonal differences. Thus the continuously operating applications cannot perform an optimum across the entire web width.

This problem is solved by a simple constructive trick. The zonally differentiated efficiency of the only externally similar looking spreader applications a variation of friction forces is achieved. The size of the friction forces depends on the web tension, the surface structure of the roller and the printing material, the geometry of notch and cylinder, the relative speed and the longitudinal-transversal ratio of the tension-stretch properties of the web material.

The zonally variable spreader application is an enclosed-ventilated roller separated in several sections. Each section itself can be filled by means of ambient air pressure, with excess- or under pressure (suction- or blow air). This leads to an increase or decrease of the friction forces down to zero and with this to a zonal change of the efficiency, which can therefore be adjusted to the zonal conditions within the paper web.

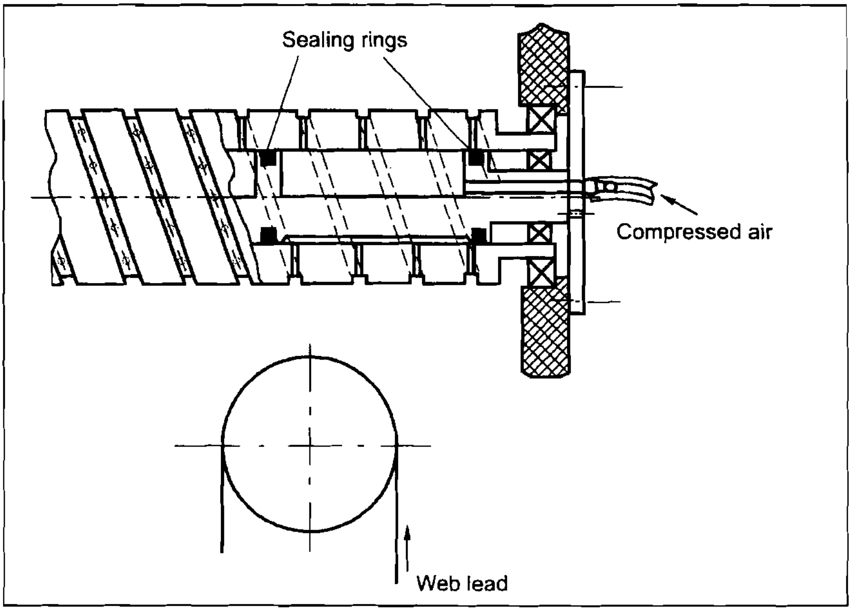


Figure 15: Principle of the zonally variable spreader device

Due to manufacturing and monetary reasons, as well as to limit the control expense, the separation is limited to 2-3 sections and therefore 2-3 influential zones.

The installation shown in figure 15 can not only be used for spreading of even partially wavy webs but also for aimed web setting.

Big problems concerning the formation of wrinkles and finishing arise in heatset printing. During the drying process the technologically required dryer detracts water from the ink. Since the web does not have the same moisture content in all areas and the temperature profile develops differently throughout the web, especially the edges become too dry. The tension states of the paper web, caused by external forces or uneven material and different moisture absorption during the technologically determined multiple moistening, are fixed within the paper web by ironing effects caused by high temperatures and the subsequent cooling device. Researches have shown that the average effect module in this area can double compared to the unaffected web.

These partially also zonally limited material hardenings affect finishing and are responsible for wrinkles in the folding unit of the printing machine. Dryer that do not dry up the paper this heavily have been on the market for a short time and new cooling devices adopt the post-moistening. The problem of the different drying needs in several zones of the paper web and a correlated thermal overstressing of single areas during the drying process is only decreased if the dryer is zonally adjustable and the drying condition is zonally retrieved.
It is more difficult to effectively repatriate excess water that was detracted from the printed paper by remoistening. Figure 16 shows a dryer configuration that adjusts its drying output to the zonal drying requirement. Beside avoiding overdrying a saving of energy is to be expected / 8 /.

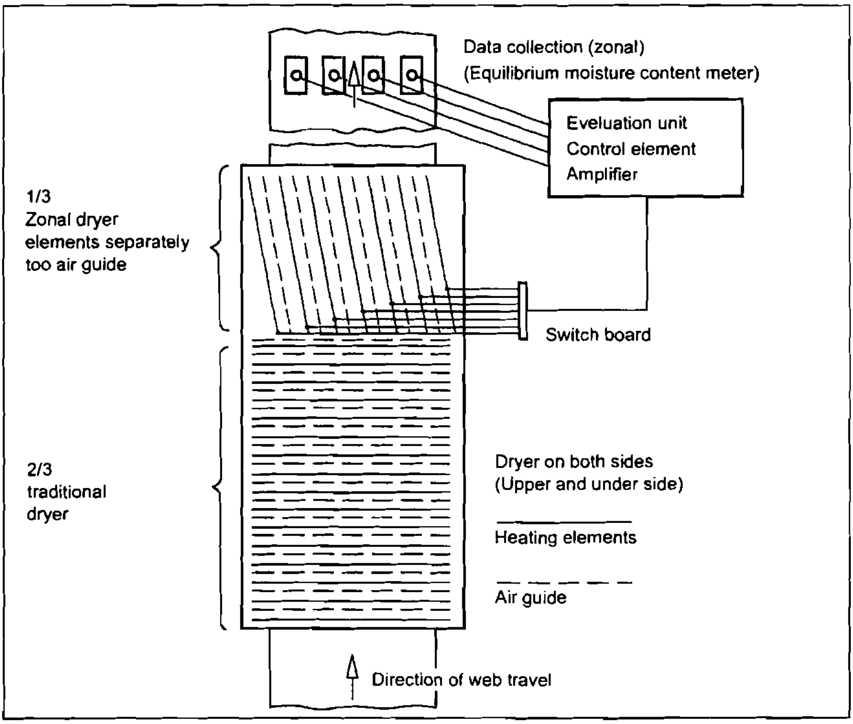


Figure 16: Zonally controlled drying station

In the part between the printing and folding unit, modern printing machines with single drives offer the cleverly selected web tension leveling and to adjust the final tensions to the existing printing material characteristics and impact of the dryer and cooler. The Institute for Print and Media Technology and the Institute for Automation at the TU Chemnitz mutually developed a new control strategy and a new web tension control method for fixed webs that are transported by means of controlled single drives. / 9 /

This regulation allows the abidance of preset tension levels considering minimum and maximum tensions in dependence on the conditions set by the material characteristics and processing technology. The same control strategy is possible to compensate deviations of the web tension across the entire web width.

5. Conclusion

The technical potentialities correspond with the conception to completely prevent waves and wrinkles. The general trends for the web travel optimization that are condensed here once more raise hopes for solving the problem within a short period of time, particularly if no cheap but good value papers are used.

Trends for web travel optimization and wrinkle prevention:

- Grammage of the printing materials decreases
- E-Modules decrease
- Papers are more even (across the width)
- Fiber orientation is improved
- Water entry in the printing process is minimized
- Single drives allow a more complex control of the web travel
- More, also zonal, measurements of the web travel parameters
- Possibilities of arbitrary interferences by the machine operators are reduced

Bibliography:

/ 1 / Hars, Neuser, Institutsbericht TH Darmstadt, Institut für Druckma-schinen und Druckverfahren, 1/1993

/ 2 / Göttsching, Paetow, „Papier als berechenbarer Werkstoff", Das Papier, 43. Jahrgang, Heft 7 1989

/ 3 / Szabo, Höhere Technische Mechanik, 4. Aufl., Springer Verlag 1964, pp. 323

/ 4 / L&W- Dokumentation zum TSO-Seminar, München, 1999

/ 5 / Voit und Sulzer, Vortrag zum TSO-Seminar, München, 1999

/ 6 / EMCO-Firmenschrift, Leipzig, 2000

/ 7 / Glöckner Dissertation „Untersuc Figure 2: Micro area hungen zum Papierverhalten in Zeitungsoffsetdruckmaschinen zur Qualitätssteigerung bei Mehrbahnbetrieb und für Bahnspannungsregelung

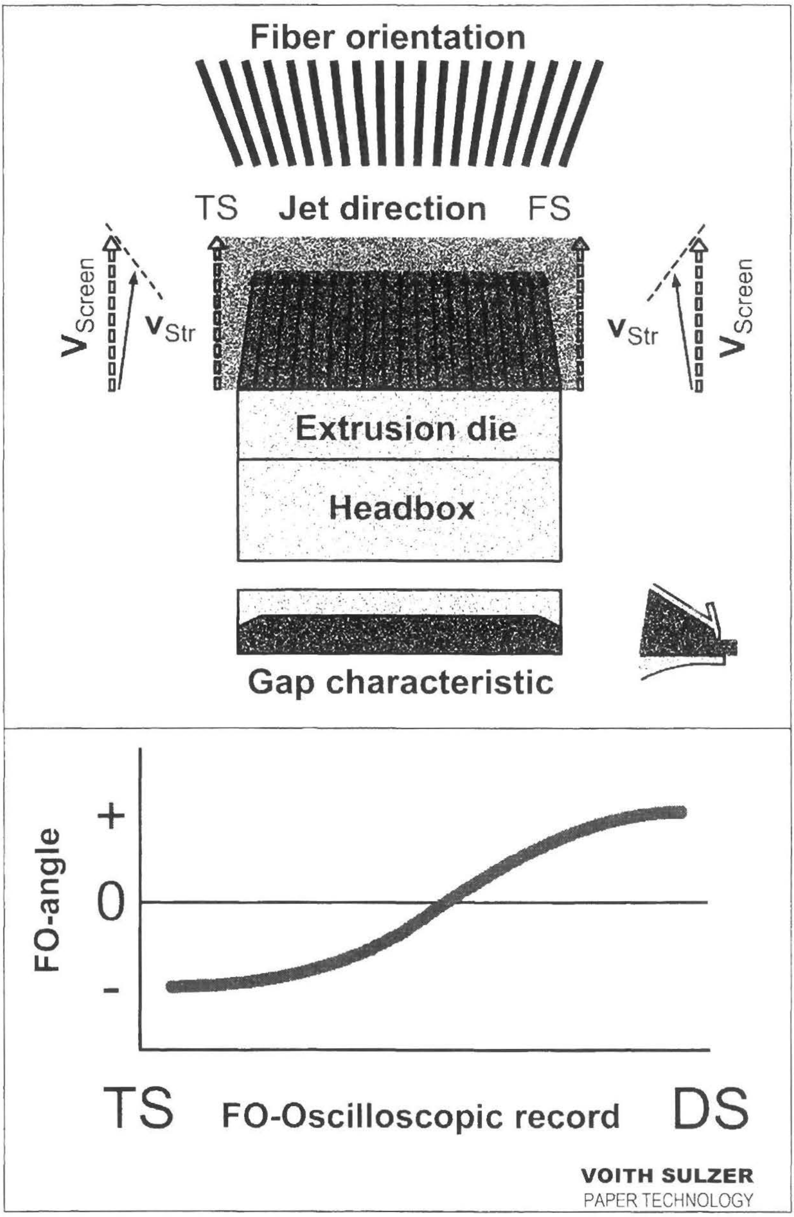
/ 8 / Patent Variabler Trockner, Offenlegungsschrift DE 19533673 A1, 1995

/ 9 / Winkler, Elaboration and Testing of a tensile Tension Control for Commercial Web Offset Presses Thesis TU Chemnitz 2000

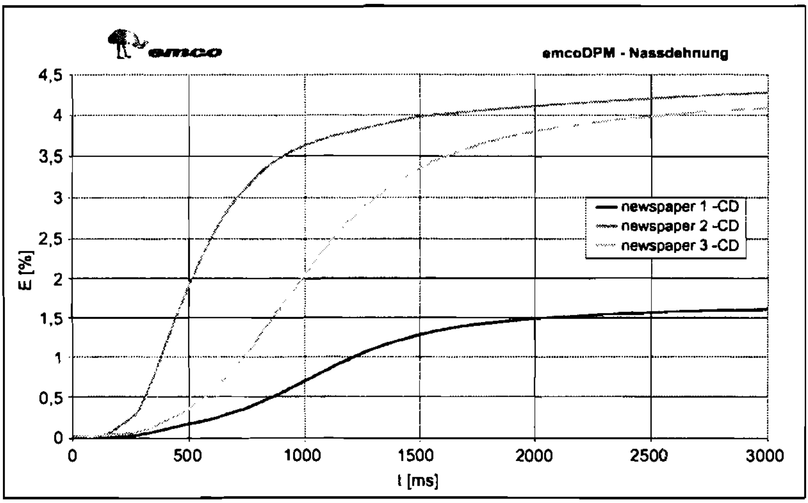
Attachment list:

Attachment 1:	Problems with fiber orientation in the headbox
Attachment 2:	Emco-DPM with a dynamic stretching module
Attachment 3:	Changes in the E-module by printing and drying

Attachment 1: **Die gap geometry and fiber orientation / 5 /**



Attachment 2: **Time-dependent wet stretch of newsprint / 6 /**



Attachment 3: **Influence of the dryer and cooler on the effective module of paper (example)**