Ultrasound measurement - a new way of controlling paper machinesError! Bookmark not defined.

by
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Summary

Hitherto, paper machines have mainly been controlled using information from on-line thickness, grammage and moisture measurements. Now ultra-sound measurement is making its presence felt, despite its only being available as off-line measurement equipment at present.

Ultrasound measurement or TSO measurement as Lorentzen & Wettre refers to it, has been available for a number of years. TSO stands for Tensile Stiffness Orientation and is a measure of the paper's elastic properties, which can be directly related to the runnability in the paper machine and in the subsequent converting process.

The measurement procedure is simple. A cross profile is cut out directly from the paper machine's machine roll. A cross profile is run through the TSO meter and the four main properties are reported.
TSO angle - provides information about how well the head box is adjusted.
TSI-Machine direction - provides information about how well the press section is adjusted.
TSO-Cross direction - provides information about how well the drying section is adjusted and how the beating is set, and
TSI Machine/Cross direction ratio - provides information about how the sheet strength conditions are adjusted.

The various properties are shown as profiles and can be compared directly with the On-Line system's three principal properties. From experience, we have found the boundary values for the various properties that provide the best running conditions in the paper machine and also provide the least possible variation in the quality of the paper.

The article describes in detail the way in which the various properties are related and should be used to achieve the best possible result.

TSO tester

The L&W TSO tester is really a laboratory instrument that can be used for process optimisation and to simplify quality control.

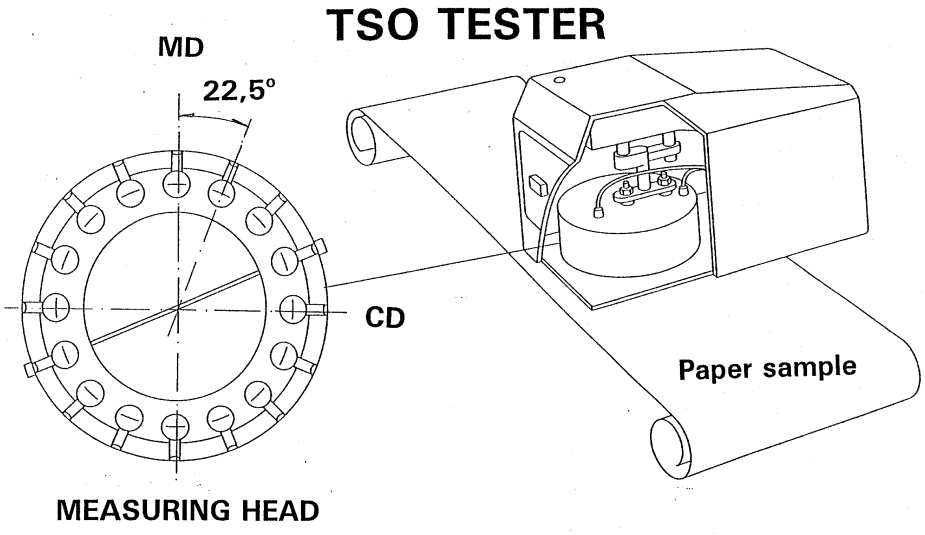

Figure Error! Unknown switch argument.**. The multi-sensor head makes it possible to measure in all directions in the plane of the paper sheet**

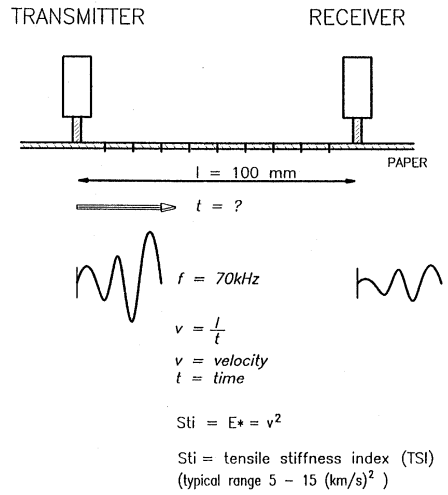

Figure Error! Unknown switch argument.**. The transmitter sends an ultrasonic pulse to the receiver, that propagates through the paper and the velocity is calculated and expressed as TSI.**

It is based on the principle of ultra sound, and involves sending out a longitudinal ultrasonic pulse through the paper, in the plane of the paper, from a transmitter to a receiver. The measuring instrument is equipped with a measuring head that contains 8 pairs of transmitters and receivers, uniformly spaced in a circle on the plane. The signals are converted to describe the elasticity in all directions in the paper. The actual measurement takes 5 seconds per measurement position, so that a complete measurement on a 9-m wide paper machine takes 9 minutes (90 measurement positions). The results are presented as a machine roll report, with mean value, standard deviation, maximum value and minimum value and a graphical presentation of the four main properties' profiles, which are:

- TSO angle - which describes the angle between the machine direction and TSI max., which is the direction of greatest elasticity.
- TSI Machine direction - which describes the elasticity in the machine direction.

- TSI Cross direction - which describes the elasticity in the cross direction.
- TSI Machine/Cross ratio - which describes the relationship between the machine and cross direction. The ratio is a measure of anisotropy, to be compared with the ratio between the classical strength properties, like Tensile strength, Stiffness in bending, compressive strength, etc.

POLAR ANGLE DIAGRAM

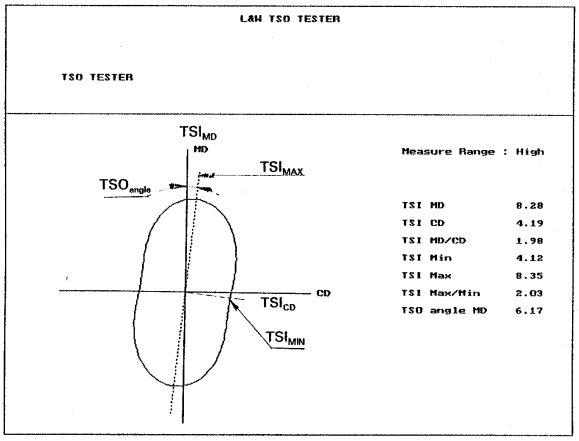

Figure Error! Unknown switch argument.**. The measurements are expressed in a polar plot diagram, where the main properties are reported**

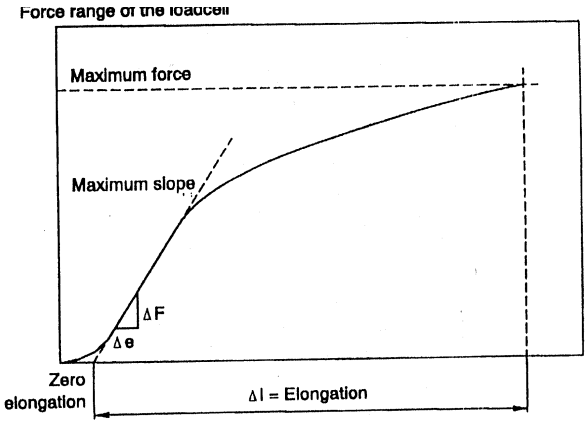

Figure Error! Unknown switch argument.**. The TSI - Tensile Stiffness Index can be measured with a Tensile Tester and be expressed as the maximum slope of the Stress-Strain curve, or the Young's Modules.**

Experience from the mills that today regularly use the TSO meter to control their process has given us certain recommended values to fall back on.

TSO angle

The TSO angle tells us whether the paper in question has a tendency to curl/twist. The actual curl comes mostly from the two-sidedness in the paper, while the twist component is due to the Orientation of the elasticity.

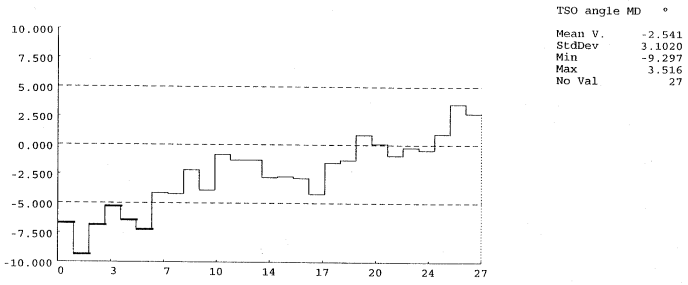

Figure Error! Unknown switch argument.**. The TSO angle taken from a sample from a Foudrinier type paper machine running in Rush mode. The Orientation is expressed as "toe-out".**

For all grades of paper, except perhaps for sack paper, the recommended value should be between ± 5 degrees, while the mean value should be about 0 degrees. A mean value other than 0 degrees (tolerance ± 0.5 degrees) indicates that the head box is not correctly balanced.

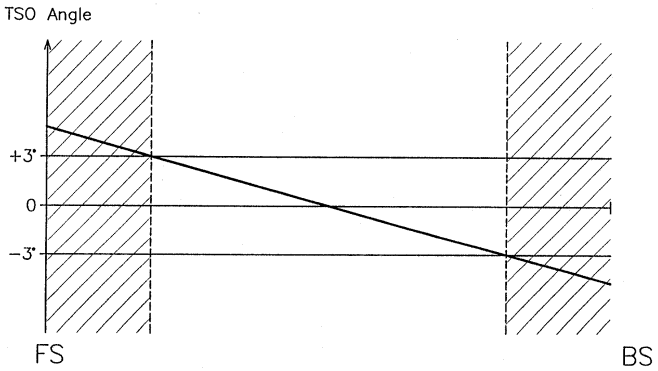

Figure Error! Unknown switch argument.**. The mean value of the TSO angle should be at 0 degrees, which means that the head box of the paper machine is well balanced. Variation should be within +/- 5 degrees**

This unbalance may be due to many reasons, but it is mostly due to incorrect regulation of the recirculation valve. Other causes that are important for a perfectly adjusted head box are:

- the Approach system
- the Header pressure distribution
- the Head Box tube pattern (especially edges)
- the Cross flow conditions (such as use of stock bleeders and injection
- the Slice lip profile
- the Stock spread on the wire
- the Forming activity

For copying and laser papers, for instance, our customers have found that the requirements must be stricter. Values of ± 2.5 to 3 degrees are common criteria for almost all mills manufacturing this type of paper grade. This permits printers who do reprinting for forms etc., for example, to feel calm and avoid expensive disturbances to the process. Nor does it raise complaints from copying-machine and laser-printer manufacturers or users.

These criteria cannot be applied across the board to Sack paper. Sack paper is normally run with an anisotropy value of around 1, that is the strength properties and elasticity are equal in both the machine and cross directions. On the other hand, we have found that it is valuable that sack-paper manufacturers also adjust their head boxes on the basis of a somewhat oriented paper before the paper's anisotropy value is adjusted to close to 1 or that a Clupack unit is connected in.

It is also important to mention that fibre Orientation and TSO angle are not the same thing. The TSO angle or Tensile strength Orientation is a composite property in which the fibre Orientation is one component and the others are built-in stresses and strains in the paper. These stresses and strains come in part from the press section and in part from the drying section. A paper that is coated or is in any other way subjected to wetting after the actual drying subjects the paper to additional built-in stresses and strains. A paper that is moistened after the manufacturing process and has been allowed to dry freely gives basically the same value for the fibre Orientation as for the TSO angle.

Tests have also shown that the dimensional stability or, more exactly, the hygro-expansion and then also the shrinkage, is perpendicular to the TSO angle and not to the fibre Orientation. This is yet another reason for following the TSO angle on the paper grades dependent on giving good four-colour printing without register problems or where stack lean can be a problem.

TSI Machine direction

TSI Machine direction or the Tensile strength index in the machine direction is a property that can be directly related to many of the runnability problems that today occur in a paper machine and in subsequent converting.

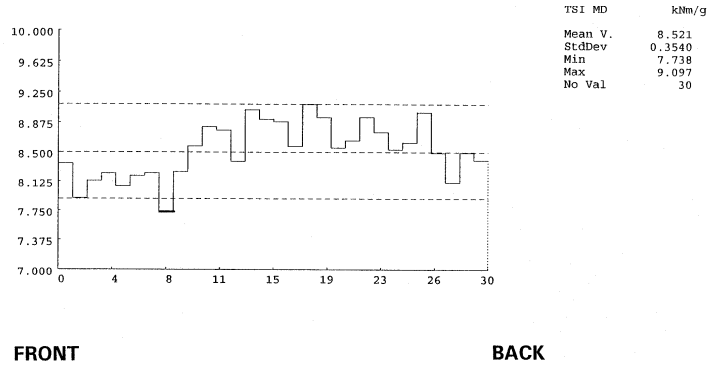

Figure Error! Unknown switch argument.**. A typical TSI-MD profile, showing a tendency to give both ”baggy edges” and ”wrinkles”.**

The actual profile must be as plane as possible. This provides us with a uniform elasticity across the machine. Variations that can be allowed are between 5 and 10%, depending on the grade of paper

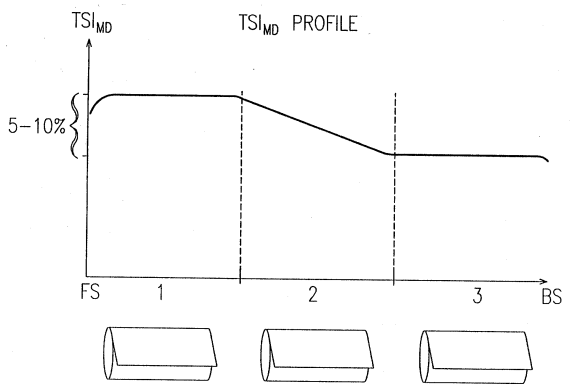

Figure Error! Unknown switch argument.**. Variation of the TSI-MD values should be kept within 5 - 10%.**

A strongly oriented paper such as newsprint, should lie with a variation in the lower area, so as to be able to avoid long edges, web failure in the paper machine and in the printing press, wrinkles, crease formation, etc.

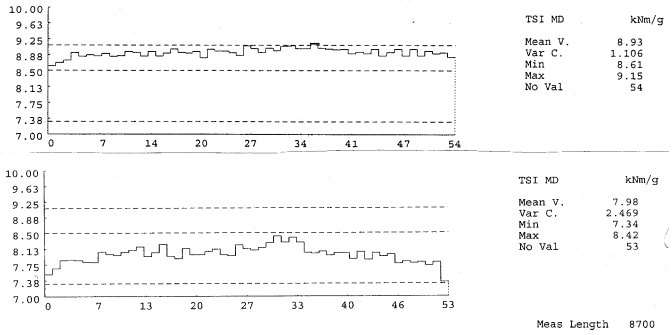

Figure Error! Unknown switch argument.**. The top profile shows a newsprint machine running in Drag mode, and the below shows a newsprint machine running Rush. The Drag machine shows much lower variation, and has no problems with ”press room brakes”, nor ”wrinkles”.**

In comparison with, for example, liner or fluting, in which the compression properties are important, we can relate the TSI machine direction to the SCT Machine direction (strip compression strength) and the CMT (Concora Medium test). Due to the large scatter in results from the classical methods of measurement and also disturbances in the actual method of measurement that are more difficult to describe, the comparison between the TSI Machine direction and the SCT Machine direction and the CMT are often questioned. We wish to assert that the TSI value gives better and more accurate information about the way in which the paper will behave in the finished corrugated fibreboard box than what the more established properties tell us. The future will show the path we will follow to obtain faster, more credible information and better paper quality.

To be able to improve the TSI Machine-direction profile it is important that the press section is well adjusted and that the press felts are in good condition. All felt suppliers' service engineers are today equipped with an L&W Scanpro PressTuner or JetMem for checking the dewatering in the press section.

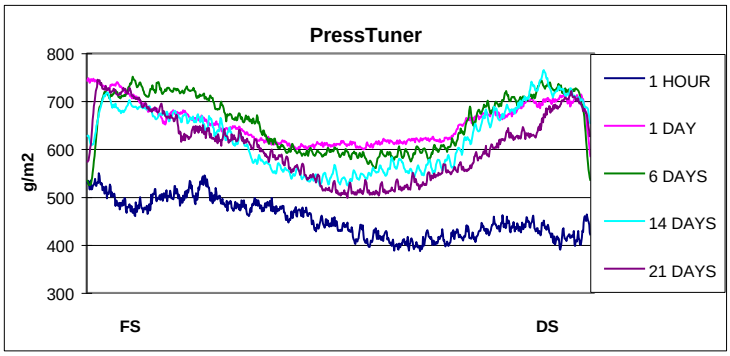

Figure Error! Unknown switch argument.**. PressTuner measurements on a machine felt, made at several occasions.**

The information from these Scanpro meters is important for optimising the press section and the TSI Machine-direction profile. The meter measures the water content of the felt and can with this information show how well the press section is dewatering, how the suction boxes are working and whether the press roll is correctly crowned. Another aid that is starting to become more and more common is the L&W Scanpro FeltPerm.

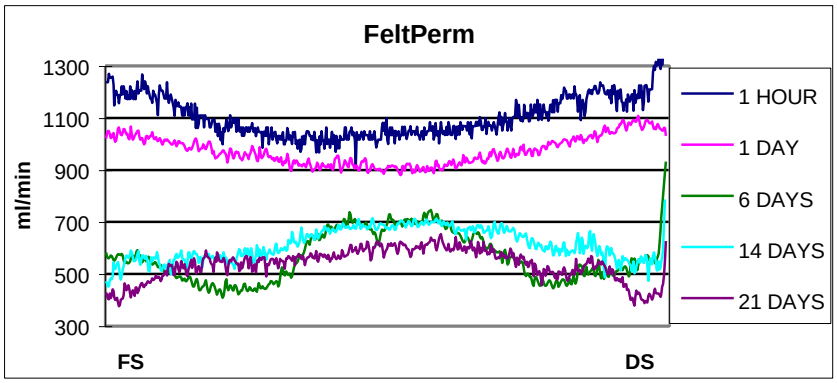

Figure Error! Unknown switch argument.**. Typical profiles taken with the L&W SCANPRO FeltPerm, showing the differences from when the felt was new until it starts to clog and needs to be cleaned.**

This meter is based on the principle of water permeance, where water under a known pressure is sprayed through a nozzle of a determined diameter, through the press felt. By this means we can calculate the permeability of the felt and also see if it is clogged or in good condition.

Factors that affect the TSI Machine-direction profile are:

- the Refining
- the Draw in between the different Press sections
- the Condition of the suction boxes
- the Dewatering in the Press sections
- the Felt condition
- the Press nip pressure

- the TSO-angle

TSI Cross direction

The TSI Cross direction or the Tensile strength index in the cross direction can be directly related to demands on the paper as regards the strength in the cross direction and also shrinkage/expansion across the machine.

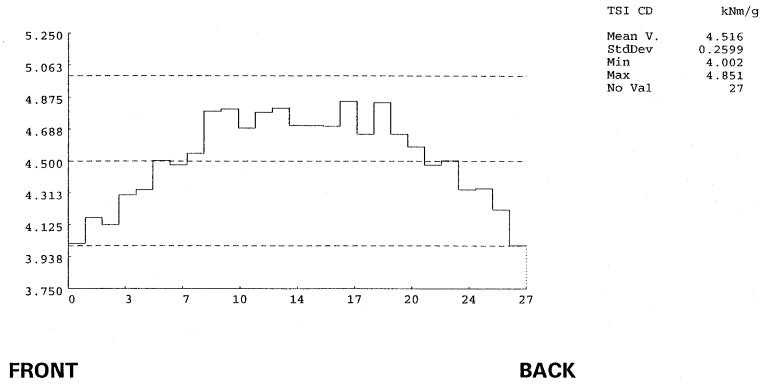

Figure Error! Unknown switch argument.**. A typical TSI-CD profile, where the effects from the dryer section is clearly shown.**

A typical TSI Cross-direction profile can be described as an upside down banana with the highest point in the middle and the edges low. A typical variation is in the region of 20% when the other three running parameters - thickness, grammage and moisture - are kept within a range of ± 1 - 2%.

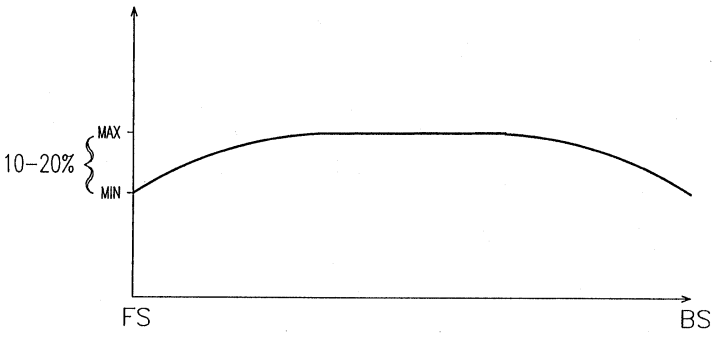

Figure Error! Unknown switch argument.**. The variations of the TSI-CD profile should be within 10 - 20% depending on grade.**

But we have observed certain deviations from this, specially for newsprint, whose normal variation is above 20%. Another example is base paper for labels, which requires a good support for punching, and is therefore strongly beaten, with low air permeability and, as a result, a plane TSI Cross-direction profile.

The TSI Cross-direction profile can be simply related to the SCT Cross-direction (Strip compression test) and the RCT Cross direction (Ring Crush Test), two very important properties for determining compression strength of Kraftliner and Testliner.

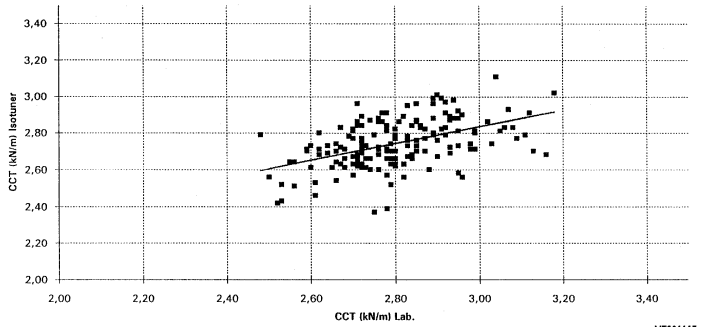

Figure Error! Unknown switch argument.**. The correlation between calculated CCT and measured CCT (CCT = Concora Crush test, can also be measured as RCT or SCT). The calculated CCT is related to TSI-CD and Basis weight.**

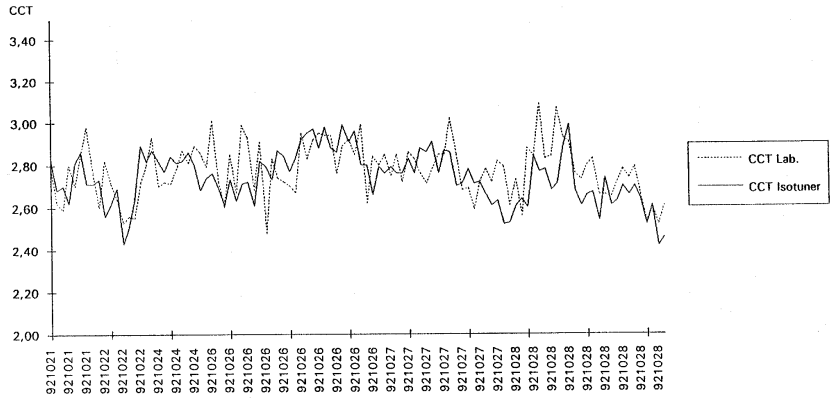

Figure Error! Unknown switch argument.**. Long-term variations of CCT values measured and calculated.**

The factors that steer the level and appearance of the TSI Cross-direction profile include the velocity difference between the jet and the wire. In addition, the refining affects the shape of the profile. This, together with the possibility of affecting the cross draw in the dryer section, makes it possible to control the shrinkage in the cross direction. This is important as the shrinkage affects the form of the TSI Cross-direction profile.

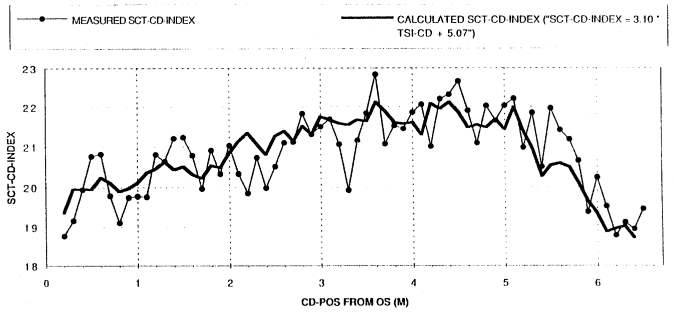

Figure Error! Unknown switch argument.**. Comparison between SCT-CD measured and calculated from TSI-CD and Basis weight. SCT can vary up to 20 - 25% within an entire machine reel.**

The factors that directly affect the TSI Cross-direction profile are:

- the Dryer section
- the Refining
- the Draw in the machine direction
- the Draw in the cross machine direction
- the Speed difference between the Jet speed and the Wire speed

TSI Machine/Cross-direction anisotropy

The TSI Machine/Cross-direction ratio or the Tensile-Stiffness index ratio is controlled by the difference between the jet velocity and the wire velocity.

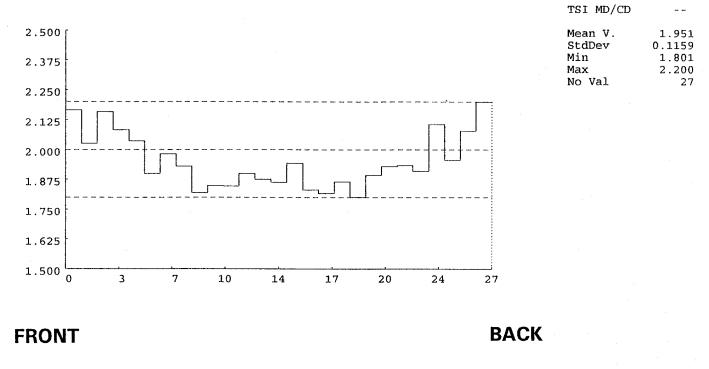

Figure Error! Unknown switch argument.**. A typical TSI-MD/CD ratio profile**

The relationship has been known for a long time. It is also known that the best formation and minimum tendency to curl is obtained in the equilibrium state, that is when the difference between the velocities is 0. But it is very difficult to run a paper machine in this position and efforts are made to run with either a negative or positive velocity difference close to the equilibrium position. It may be mentioned that the jet/wire velocity ratio that the paper machine's control system usually specifies is not the whole truth. The velocity of the jet is usually calculated using variations in pressure as the starting point. A very reliable way of determining the equilibrium position is to measure the web width, which is greatest in the equilibrium position.

We have found the following recommended values for the TSI Machine/Cross-direction ratio for various grades of paper:

Copying and Laser paper	1.8 - 2.3
Roll to roll printing paper	2.3 - 2.7
Newsprint	3.0 - 5.5
Liner (strength related)	2.0 - 2.5
Liner (bursting-strength related)	3.0 - 3.5
Paperboard	2.0 - 2.5
Sack paper	1.0 - 1.3

The variation in these values is related to the magnitude of the variations permitted in the component profiles. If both the TSI Machine direction and TSI Cross direction are in the upper area, this immediately gives great variation in the anisotropy.

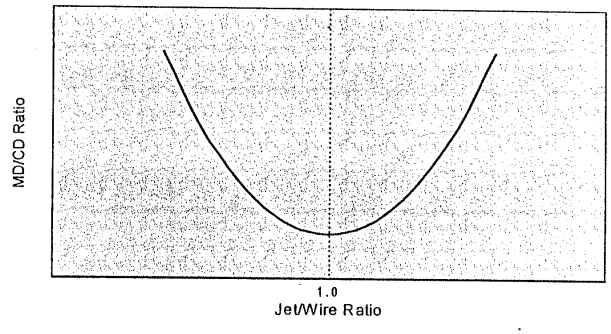

Figure Error! Unknown switch argument**.. The relationship between Jet/Wire ratio (Rush/Drag) and TSI-MD/CD ratio.**

Comparisons have been made in which values have been obtained for the TSI Machine/Cross-direction ratio, the Tensile strength Machine/Cross-direction ratio and curl in relation to the velocity difference. This has been done for copying paper, amongst others, on a Valmet paper machine. The lowest curl was indicated at an equilibrium position, while the lowest TSI and Tensile strength ratios were found at a negative velocity difference.

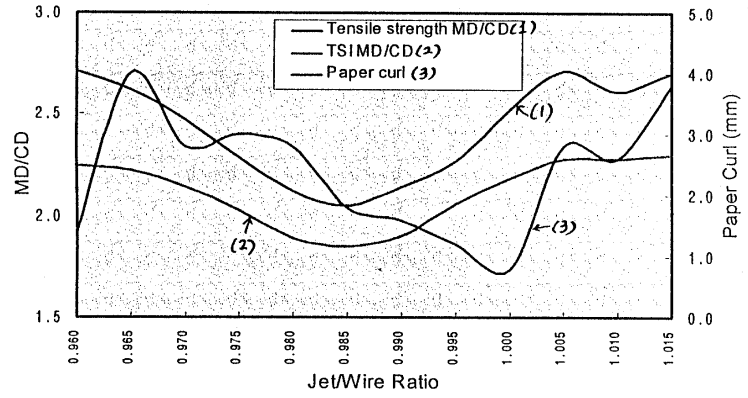

Figure Error! Unknown switch argument**.. The comparison between TSI-MD/CD ratio, Tensile strength MD/CD ratio and Curl tendency to Jet/Wire ratio.**

Procedure for optimising a paper machine using ultrasonic measurement of the TSO

The first thing to be done is to check that the machine is correctly set as regards parallelism, level, vacuum flow, velocity variations, concentration of the stock, felt and wire condition, etc.

As we intend to start with the head box, we should also note the running parameters used. It may also be of interest to measure the jet velocity, as this is normally calculated via the machine control system.

Cross samples are taken from 10 or 20 different positions in the machine roll and tested in the TSO apparatus. The relatively large number of samples is necessary to be able to observe whether there is any machine-direction variation that affects the TSO angle. When the measurements have been made the results are transferred to a calculation sheet (e.g. EXCEL) to permit calculation of the mean slope of all profiles in the series of measurements (translation) and the angle at which they are located.

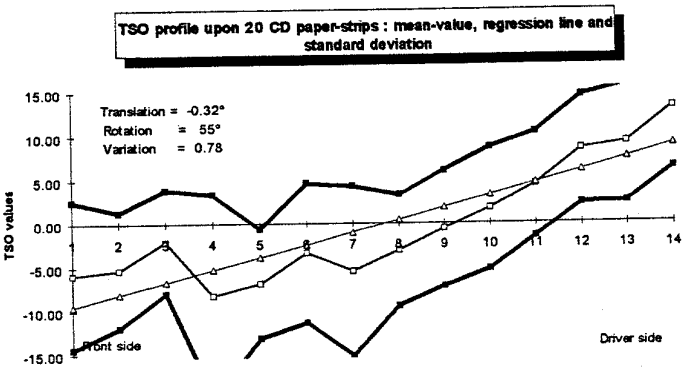

Figure Error! Unknown switch argument.**. When the 20 profiles are put together and the mean value calculated together with the variation within all the profiles, it is possible to establish what kind of actions to be taken to rectify the problems in the head box.**

We can then also observe whether the variation in the machine direction is greater or smaller than that in the cross direction. To obtain the frequency and appearance of any machine-direction variation, a test strip is taken in the machine direction. This strip may be of the same length as or longer than the wire.

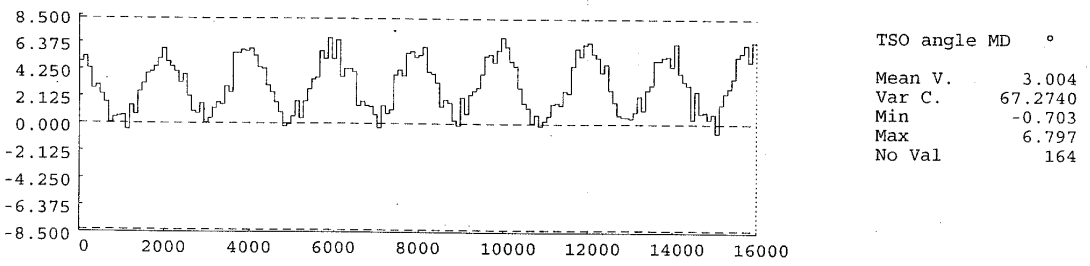

Figure Error! Unknown switch argument.**. A sample taken in the machine direction, showing variation with a specific frequency. These variations are related to a shaker built-in to the forming table to get better formation.**

After running in the TSO meter, we can analyse the results and possibly find the origin of the variation. It is very common that unbalance in the head box gives rise to a machine-direction variation. Other causes are pulsation's that occur before the head box or mechanical vibrations in any of the paper machine's rolls.

When we have determined the actions to be taken to adjust the head box, this is adjusted and the test repeated until we have achieved the best possible result.

When the head box has been adjusted satisfactorily it is time to continue forwards in the paper machine. The forming board and wire part are in fact the next stop, but should have been remedied before the head box was adjusted, as the wet section affects the final result.

The press section comes next. We should make the measurements using the Scanpro moisture meter, L&W SCANPRO PressTuner, to find out if everything is as it should be. An L&W Scanpro FeltPerm should also be used for measuring the permeability by water, as a clogged felt cannot provide the dewatering required. The press roll nip should be checked as regards the pressure distribution, load and linear load. In addition, the draw between the press rolls should be checked as this affects the variation in the TSI machine-direction profile. Check also the beating and stock concentration, so as to change the appearance of the profiles.

It is important the whole time that we do not change the thickness, grammage and moisture profiles more than we can permit. These should be checked for each change made.

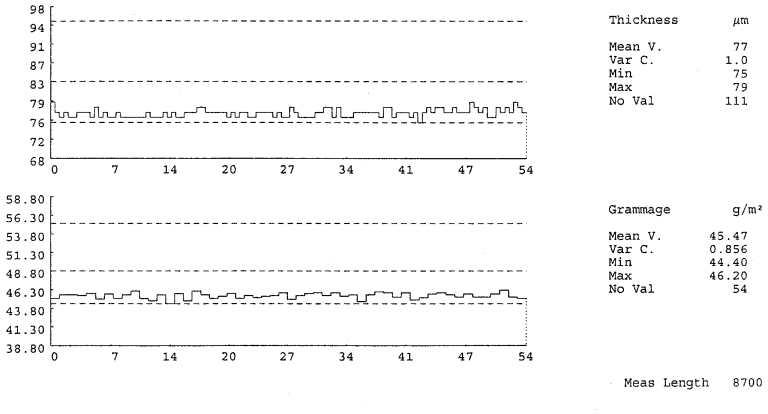

Figure Error! Unknown switch argument.**. Calliper and Basis weight profiles taken on a sample from a newsprint machine running in Drag mode.**

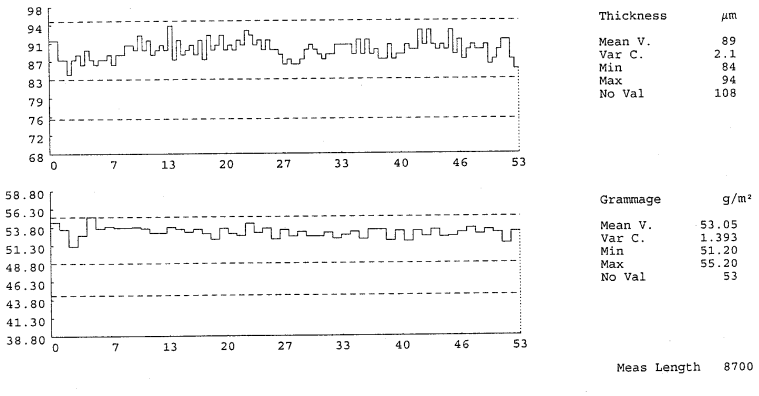

Figure Error! Unknown switch argument.**. Calliper and Basis weight profiles taken on a sample from a newsprint machine running in Rush mode.**

We have seen examples of paper machines that are incorrectly set in the press section as regards the TSI machine-direction values, in order to compensate for a poor moisture profile. This showed itself as a hump in the TSI machine-direction profile and the mill felt obliged to run the machine in this way.

When we have got a grip of the press section, we can try to remedy the drying section. It is perhaps not the easiest to do but there are certain possibilities, such as changing the draw between the drying cylinders, temperature regulation between and in respective drying cylinder. The effect of the beating should not be forgotten and also the velocity difference at which the machine is being run.

Conclusions

We have tried in this article to show the potential of using modern measurement techniques like ultrasound for optimising a paper machine.

Paper manufacture is a complex process and long experience and a great deal of knowledge are required to do it correctly. We are no paper manufacturers but we have great experience of measurement techniques and also evaluation of the results obtained from the instruments we manufacture.

Experience from the mills that more or less follow the schedule described in the article as regards optimisation possibilities has shown itself to be very valuable. The runnability has been greatly improved, resulting in less scrapping. The quality specifications have become stricter, which in turn has resulted in cost savings.

Looking at the elasticity instead of the classical strength properties gives us a better picture of the paper's runnability and gives us unexpected opportunities for further improving the paper.

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