WEB TENSION MEASUREMENTS IN THE PAPER MILL

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ABSTRACT

Web tension measuring methods and corresponding instruments have been evaluated at the Graphic Arts Laboratory of the VTT. Together with Valmet Paper Machinery, cross-web tension profiles have been studied in different paper machines and they have been compared to other profiles measured by the process control system in the paper machine. The role of the paper machine tension profile in winding and in paper customer rolls is outlined.

The measuring techniques developed seemed to be practical and are from now on available to analyze the paper machine performance. The realized field measurements have shown quite even profiles in basis weight, dry weight and moisture, which are normally measured at the dry end of the paper machine. Web tension can show drastic variation across the web and especially web edges used to be problematic.

INTRODUCTION

Web handling and runnability properties are strongly affected by the web tension in machine direction of paper machines, winders and printing presses. Even distribution of tension across the web is highly desirable starting from the press section of the paper machine and continuing throughout the whole process.

An uneven tension profile has an adverse effect on paper runnability and roll quality. Web breaks, web flutter, wrinkles and calendar cuts are some of the problems a poor tension profile can cause in the paper manufacturing process. Web breaks, wrinkles and color register errors are the corresponding problems in printing.

The knowledge of web tension has been rather limited. Other profiles, like basis weight and moisture, have been measured for years and they can be adjusted within a couple of percent. Web tension has been out of control in paper machines, even though bad profiles with very slack web edges have been common and clearly visible. The first results have confirmed that tension variation across the web is extremely poor in some cases.
Earlier it has been possible to measure only the average tension level in production. Now new measuring devices have been developed, and they can be used to measure the tension profile across the web. Some research institutes have measured tension in printing presses and now the research work is beginning in the paper industry. In addition to researchers, paper machine and measuring instrument manufacturers have been operating in the field.

MEASURING METHODS

Web Tension Measuring Devices

The conventional method for measuring web tension is to measure the load the web causes on a roller. The web travels over a measuring roll. Load cells are mounted on roll bearings to measure force produced by the moving web. In this way web tension can be measured only as the mean value of the whole web width, and local tension peaks cannot be observed. This type of tension meters can be used to control the web tension level. Several manufacturers produce these load cells and they are a standard option at different positions in paper machines and winders.

The mean value of the whole web width does not give enough information of tensions for controlling process variables on the paper machine. Necessary features of an advanced web tension meter are the possibilities to obtain the web tension profile across the web and to perform high frequency measurements.

There are transportable meters on the market, which can measure only one point of the web at a time. If the sensor of this kind of device scans across the web, a cross tension profile can be observed. A comparison of four web tension measurement devices - Altim Tensometer, ABB Stromberg Tenscan, Scandev Invent Beetle and C-AN Tensor - has been reported earlier /1/.

The Altim Tensometer developed by Altim Control Co. measures the passing time of a sound wave using microphones. The device was constructed almost ten years ago and is no longer in production. The principle used in the Altim Tensometer has been developed and applied in a new meter - ABB Stromberg Tenscan. This web tension meter uses laser beam to measure the passing time of a sound wave in the web. Some results measured with this instrument can be found in articles /2/ and /3/.

One measuring principle is to blow compressed air against the paper, and then measure the reaction force. The web tension is a function of the reaction force. Scandev Invent Beetle converts the pressure to web tension values. According to the comparison test /1/ the measuring principle does not work correctly near the web edge.

A simple way to construct a device is applying a mechanical force against the web and then measuring the reaction force. A hand-held meter - Tensor - has been constructed at the Norwegian Pulp and Paper Research Institute (PFI). The measuring head is pressed against the web and the position of a spring blade is measured by a contactless inductive transducer. The cross machine profile can be quickly recorded by moving the measuring head across the web. A small printer prints the profile on paper. The device is aimed at trouble-shooting purposes /4/.

A device developed by the Swedish Newsprint Research Centre (TFL) uses the principle of acoustic chamber. The sensor of the device is held against the web. The web tension is a function of acoustic impedance of the chamber. Cross-profiles can be recorded when the sensor traverses across the web. A similar device with the same principle has been constructed in the Swedish Pulp and Paper Research Institute (STFI).

The cross machine profile can be obtained by dividing the wide web into several narrow areas which are measured separately. This is the principle of Shapemeter produced by Davy McKee /5/. A machine-wide roller is divided to several Rotors. Each Rotor has an independent air bearing. The CD tension profile is then calculated from the load indicated by each Rotor. A 1,65 m wide unit has been tested in a rewinder.

Performance of the Tension Measurements

All the cross-profiles of web tension in this article were recorded with a Tenscan device. The sensor of the device was mounted to a specially constructed balk designed by Valmet. This balk consists of different parts of aluminium and can be assembled for variable lengths. This gives the possibility to use the same equipment for different web widths - from 0,5 to 9,5 meters. The balk is transportable and can be mounted to the dry end of a paper machine or winder. The electrical scanning system of the sensor is remote controlled. The measuring equipment is shown in Figure 1.

Normally ten cross-web scannings can be made during a machine reel. The tension data is recorded by a computer disk and by a printer. After ten scannings an average profile can be calculated. A special software program is used at this stage. This average profile can be compared with other process profiles. All required profiles are normally put into a Microsoft Excel worksheet in order to obtain figures.

Several trial runs have been made with paper machines. At first the reference situation in the mill is defined. After this a scheduled test program is run. The test points include for example: changing of the jet/wire-ratio, changing of the line pressure in the pressure nip, changing of re-moisturing, changing of paper draw and so on.

Because of the transportable balk it is also possible to measure tension profiles in the paper machine and then transfer the measuring equipment to a winder and measure the same machine reels again. This has been done in two-drum winders and in single-drum twin-winders.

In some cases customer rolls can be measured in a printing house during printing. The sensor is usually mounted after a reel stand before the first printing unit but the flexibility of the measuring system makes it possible to mount the sensor between two printing units. Typical runnability problems in the press can be solved with the help of the measurements. The disturbances can be traced to the rolls or to the press itself.

Other Measurements

Data on basis weight, dry weight, moisture and caliper is collected from the control system of the paper machine. Hardness profiles are measured from the machine reel and from the customer rolls with a Schmidt hammer.

Paper samples can be taken across the tambour and at the winder across a set of customer rolls per tambour. From these samples all the desired paper properties are measured in the laboratory.

WEB TENSION PROFILES

Tension Profiles in the Paper Machine

The tension profile across the web in machine direction has been measured in several paper machines. Often the highest tension is in the middle part of the web. The edges are more or less slack. Dry weight and web tension profiles in a MF paper machine can be seen in Figure 2. Tension profile is poor regardless of quite acceptable dry weight as well as moisture profiles.

The tension distribution of the whole web in a SC paper machine and in a newsprint machine is shown in Figure 3. The SC machine has a round profile and the tension level is high in the middle of the web. The newsprint machine has quite even tension in the middle but both edges are utmost slack. Runnability problems can be expected when the edge rolls with skew tension are run in the printing press.

Figure 4 shows tension profiles in three MF paper machines. A rather even profile is typical for these machines. One of the machines has a slightly skew profile.

Effect of Process Variables and Winding

The tension profile must be possible to adjust in the paper manufacturing process so that its optimization is sensible. Several variables has been found in the tests carried out earlier /2,3,5,6/. The effect of paper draw and basis weight profile adjustment on web tension have been studied in a MF machine. Tension changes from the paper machine to the winder have been estimated in some other tests.

Web tension level increased when paper draw in the measuring position was increased (Figure 5). The tension level increase was not the same across the whole web. The high tension areas in the middle became tighter still but the tension increase was minor in the edges. This means that it is impossible to obtain an even profile by changing the tension level.

The basis weight profile was adjusted by opening the lip screws in the edges and by closing them in the middle (Figure 6). The tension profile became more rounded than before the adjustment (Figure 7). Tension was higher in the middle and lower near the edges.

Web tension curves are normally rather similar to the profiles measured from the same rolls in the paper machine and in the winder. The typical features in the profile are inherited from the paper machine and they can be seen in the winder but also new peaks or valleys can be found (Figure 8).

The slack areas can be measured again in the printing press. The effect of the printing press becomes evident after the first printing unit. Especially old printing presses together with the dampening water used in offset printing may change the profile so that the initial tension cannot be seen any more. Warehousing and transportation influence roll properties and tension distribution if some handling faults occur.

Tension Profiles vs. Other Profiles

The interaction between tension profiles and some other profiles of the most important paper characteristics has been studied during these tests.

The moisture profile at the pope reeler changed at the same time when the basis weight profile was adjusted with the help of headbox slice control. The heaviest areas in the edges became wetter and the middle become drier than before the adjustment (Figure 9). At the same time the tension profile became more rounded, as shown in Figure 7.

Many physical paper properties have a given profile across the web, especially strength properties measured in cross direction. Tensile strength and tensile stiffness have higher values in the middle of the web than in the edges, while tensile stretch and tensile energy absorption have higher values in the edges. Paper is also normally thicker in the edges. If the edges differ from the middle, a too simple conclusion can be drawn from the interaction between tension and other profiles. It is seen, however, that e.g. the tensile stretch in cross direction has a significant negative correlation with tension.

FORMATION OF WEB TENSION

A suitable, steady level of the longitudinal web tension along the paper machine without wild variations in cross direction is required for both runnability and paper quality.

Web tension is the product of dry weight, strain and elastic modulus of the sheet. Because the dry weight is normally very even, the other two factors dominate the web tension profile in papermaking.

In a stationary moving web with a variable speed lengthwise, the relative stretch equals the relative change in speed. In the papermaking process where the speed of the web is very much the same in any lateral position, any noticeable differences cannot exist in the stretch profile. However, the stress relaxation profile is not necessarily even. In other words, the decrease in stretch makes the tension zero i.e. the reversible strain varies slightly in cross direction. It can be summarized that the differences in reversible strain and the variation of the elastic modulus together make the tension profile vary locally in cross direction.

The tension level is controlled by drawing the web between the different speed controlled groups during drying. This must be done to resist the radial forces pushing the web. They can be static pressure differences, pressure pulsations, and centrifugal forces when the web follows cylinders etc. A general target is to minimize the speed differences. However, a minimum speed increase is always required between the groups. Below this minimum the web runnability collapses. This critical value depends on both the machine concept and the paper grade and increases with machine speed and unevenness of the tension profile.

It has proved most important to manage the dryness profile along the entire dryer section in order to maintain an even tension across the web. Wet places will be loose and vice versa. It seems to be necessary to produce an even moisture profile already after the press if a smooth tension profile in the reeling position is required.

Normally the moisture profile in the machine reel can be adjusted if any remoisturizing unit is available although the press section produces an inadequate moisture profile. If so, the result is an uneven tension profile. In this case, a low tension area can often be observed in the position where the moisture was low in the beginning of the dryer section (Figure 10).

In many cases the web edges are slack in MF machines. Also here the history of the moisture content is obviously of high importance. However, the high lateral shrinkage in the edge areas is expected to contribute to the longitudinal tension relaxation.

Increasing the fiber orientation increases the elastic modulus as well as the tensile strength of the sheet. This will help in to decrease the draws in the dryer section. According to our experience the intensity and the misalignment of fiber orientation do not have any high contribution to the web tension profile at least not in newsprint making.

The tension profile measured before reeling does not change too much when unwinding the reel in the winder. However, if high variations in tension, in moisture and especially in caliper exist, also changes in tension from the paper machine to the winder are expected.

CONCLUSIONS

Test results have indicated that the importance of a regular cross-machine tension control should be carefully studied in the paper manufacturing process. Profile defects detected in the paper machine transfer to the winder, sometimes slightly filtered but at the same time reinforced by the disturbances originating from the winding process. The defects can further be seen in customer roll properties. In printing also other factors, as damages in transportation and the effect of the printing press, influence tension distribution and web runnability.

Basic research is still needed to understand the mechanisms affecting tension formation in the paper machine and to see how tension can be manipulated by process parameters.

VTT and Valmet Paper Machinery have carried out several tests in different paper machines to collect more information about tension profiles. According to these tests a new measuring procedure has been developed. It includes the following stages:

1. Selection of the control parameters possible in the studied paper machine. As the measurements will be done during a production run, the selected adjustments should not cause waste production but, however, should give essential changes in web tension.

2. Planning of the test program, where response between the control variables and tension can be found.

3. Performance of the test program. Measurements of web tension profile in the paper machine and possibly again in the winder. Data collection from the control variables and from the control system in the paper machine, including CD-profiles of basis weight, moisture and caliper.

4. Additional measurements in the laboratory.

5. Calculation of the new target profiles of the process variables.

6. Verifying the response between the new target profiles and web tension by repeating the measurements. If the profiles are not satisfactory, repetition of stages 3 to 5 with new input parameters.

These tests can be used to produce a more even tension profile at the same time as the other profiles are within the tolerances. As a result of the tests, also the effect of process variables on the web tension can be seen.

VTT and Valmet Paper Machinery are now studying the paper machine performance to produce more even profiles and a better roll quality. In conjunction with the trouble-shooting tests basic information can be collected to be utilized later in developing a closed-loop web tension control system. In the future the tension control system might be a universal part in the paper machine control system. It is already known that tension defects reflect through the whole process causing runnability problems in all process stages up to the printing press.

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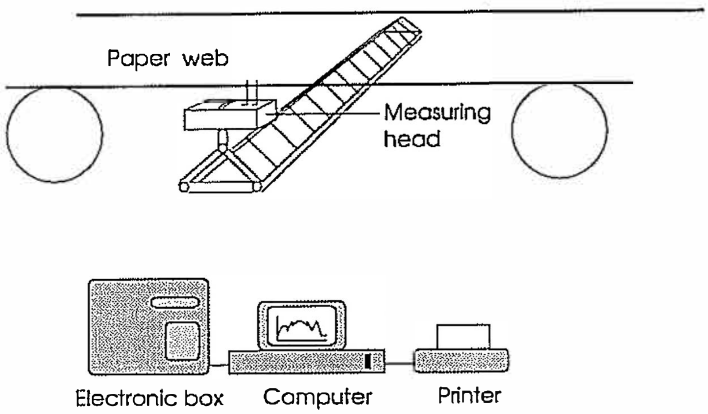

Figure 1. The measuring equipment for cross-web tension measurements.

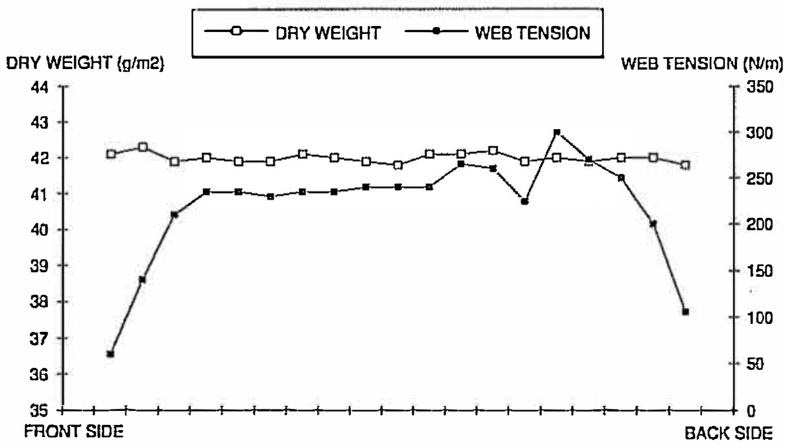

Figure 2. Dry weight and web tension profiles in a MF paper machine.

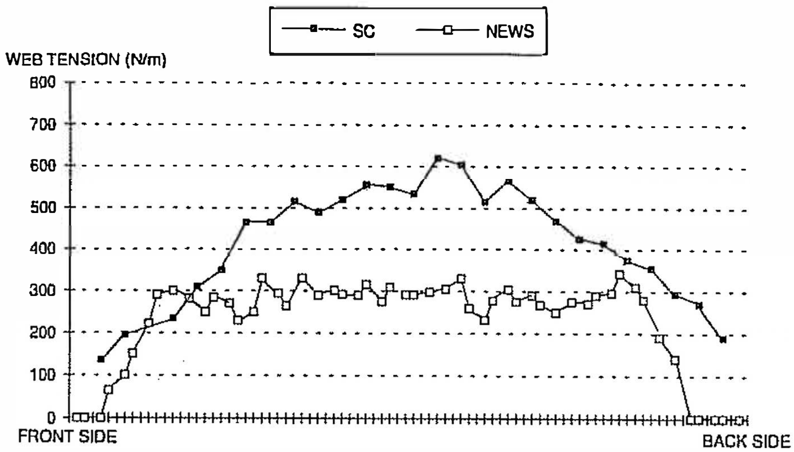

Figure 3. Web tension profiles across the web in a SC and in a newsprint machine.

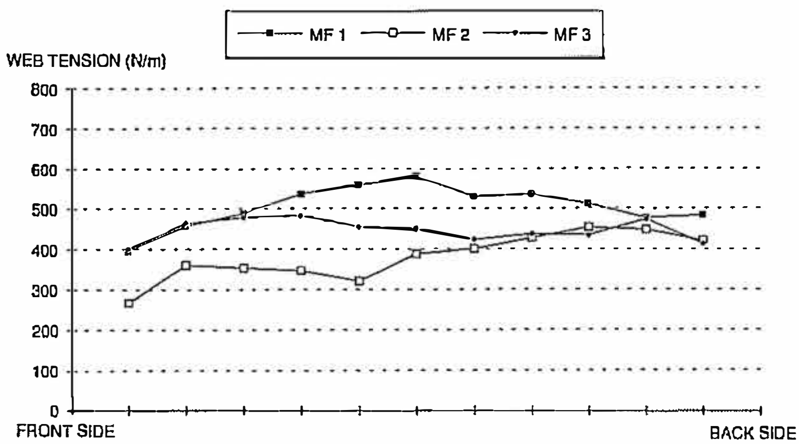

Figure 4. Web tension profiles across the web in three MF paper machine.

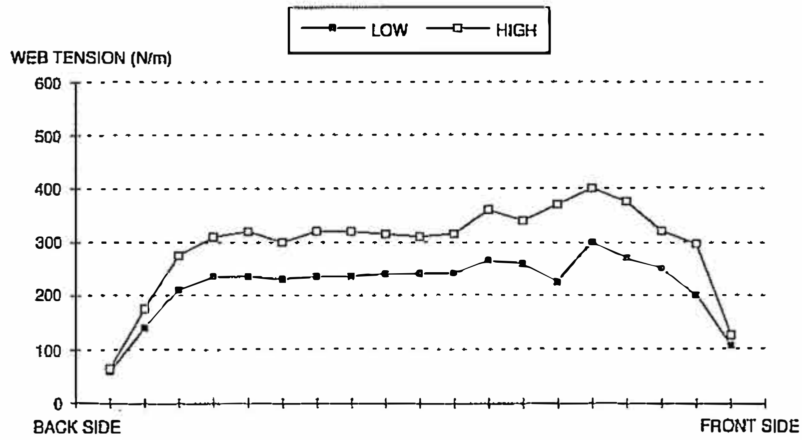

Figure 5. Influence of paper draw on web tension profile.

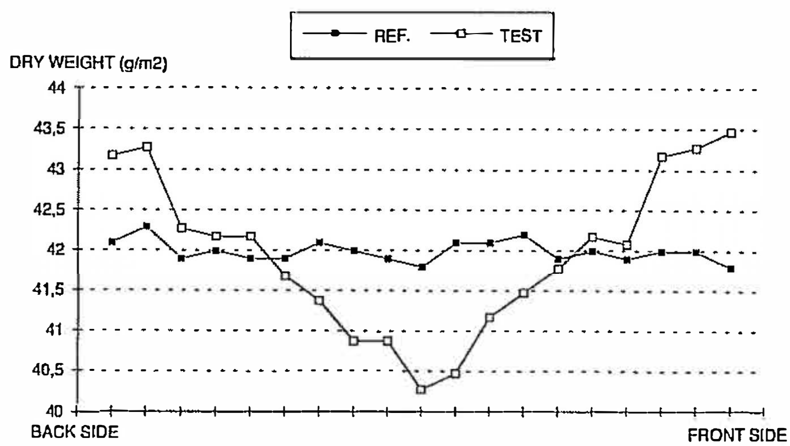

Figure 6. Dry weight profiles in normal condition and after the slice lip profile was changed.

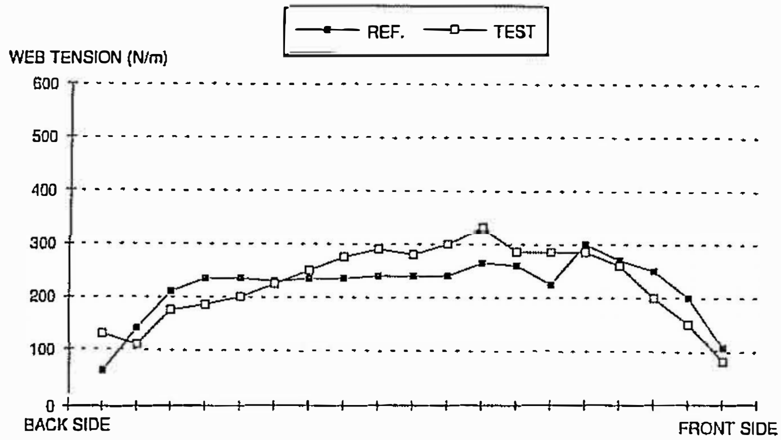

Figure 7. Influence of the headbox slice profile on web tension profile.

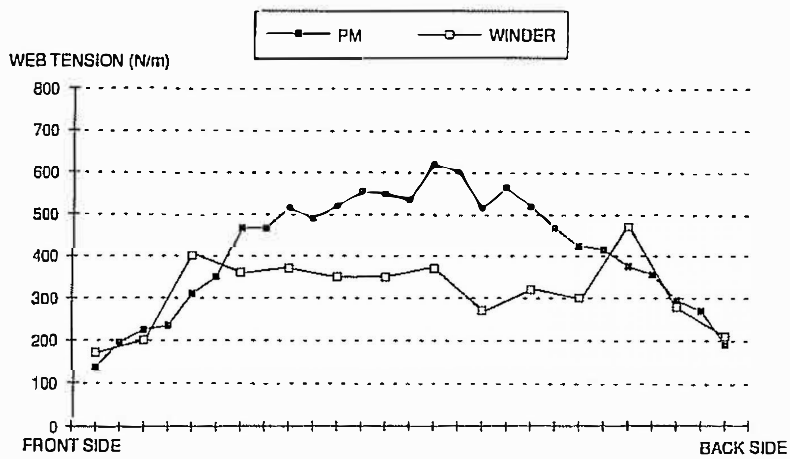

Figure 8. Web tension profiles measured from the same roll in a paper machine and in a winder.

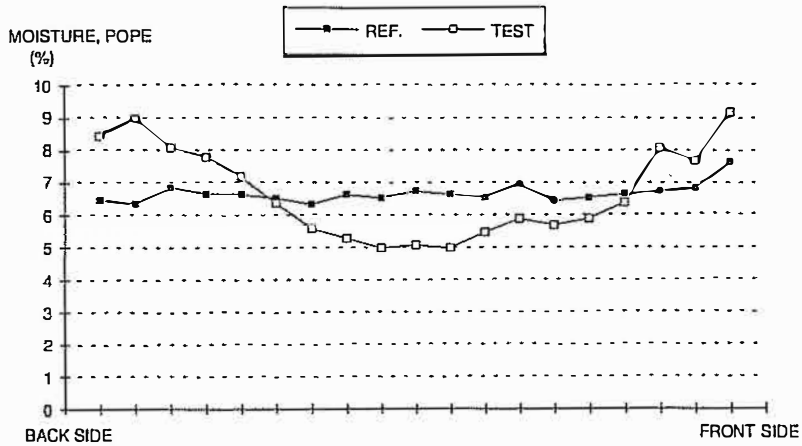

Figure 9. Moisture profiles in normal condition and after the slice lip profile was changed.

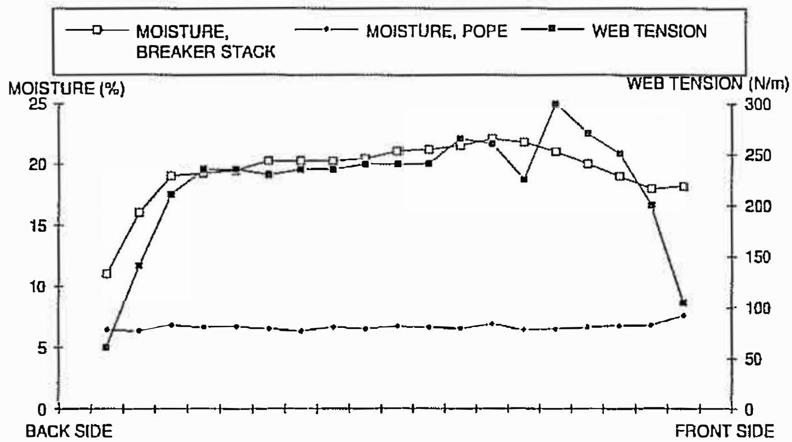

Figure 10. Web tension profile and moisture profiles: one before the remoisturizing unit at the breaker stack, another at the pope.

WEB TENSION MEASUREMENTS IN THE PAPER MILL
H. Linna

Were all your tension profiles measured with the same system? Can you explain the sensing principle used in the tension measurement system?
Karl Reid, OSU

We have used this Tenscan device in all the measurements I have shown here. The method of this measuring device has been described in my paper. In fact, the Tenscan measures the sound velocity in the web. There is a loud speaker in the sensor and it puts a sound wave to propagate in the paper web. There are some lasers which detect the propagation of this sound wave. Propagation speed depends only on paper basis weight and web tension. As we know basis weight we can calculate tension.

How long does an individual tension measurement take?
Roger Whitfield, DuPont

If you mean one individual measurement, it takes about 20 milliseconds, but if you mean how long it take to measure the whole tension profile in the paper machine, it depends on the scanning speed of the sensor. With the speed we have normally used one measurement across the web which takes about one minute.

Is it possible to have irreversible strain differences that cause tension differences across the width of the web?
Roger Whitfield, DuPont

Yes I'm certain there will also be irreversible strain differences as there will be reversible strain differences across the web. We do not know which one is the most dominant, but together all strain properties and tensile stiffness properties seems to be very important in web tension.

Papermakers intentionally distort edge profiles to maintain runnability in the dryer section. How have you used tension profile measurements to create new operating strategies which combine good machine runnability and good edge roll performance?
Brian Penttila, Weyerhaeuser Paper Co.

Our method is based on the principle that we should have an even tension profile across the width from the beginning of the dryer section in the paper machine. We do not know what it needs but it is possible that the machine should be equipped with a remoisturing unit and at least new places for measuring the web moisture profile before the pope reeler is needed. We have not tested this method enough yet, but at this time we believe that it is very important to manage the moisture profile in the whole drying section.

What is the rank of importance of CD profiles (basis weight, moisture, caliper, modulus of tension) for control?
Brian Penttila, Weyerhaeuser Paper Co.

I do not know the ranking order. Today at least a tension profile is not even but normally caliper basis weight moisture are quite even. Uneven tension sometimes causes problems in winding or in printing but I do not believe that tension should be even and other profiles not. Tension should be more controlled than it is nowdays in the normal paper making process.

What is the minimum web solids content for which this device would give reliable tension values?
Dave McDonald, Pulp and Paper Research Institute of Canada

This instrument is possible to use right after the press section in paper machines, where the solids content is high enough. Space is normally the problem in the drying section because we need 50 cm in machine direction to install the instrument. That is why tension is measured between the drying section and the calender stack