# CHANGES IN WEB TENSION PROFILES AND PAPER PROPERTIES DURING REPEATED REWINDING

by

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## ABSTRACT

Newsprint rolls with a diameter of about 125 cm have been run six times through a rewinder. The changes in the CD web tension profile have been recorded during the rewindings. The roll hardness has been measured before and after each rewinding. Paper samples have been taken out and measured in order to determine the change in paper properties such as surface roughness, surface compressibility, thickness, air permeance, and friction coefficient. Tensile testing has also been made and values of tensile stiffness, tensile strength, tensile energy absorption, and strain to failure have been derived.

The CD web tension profile remained almost the same. The tensile properties changed also very little. The roll hardness increased after the first rewinding, but in the following rewindings it did not change very much. The thickness, surface roughness, and surface compressibility declined significantly.

Significant changes of the paper properties are recorded after the first rewinding. Thereafter very small changes take place when the roll is repeatedly rewound.

## INTRODUCTION

In paper production the properties of the paper are determined by on-line measurements and laboratory tests. Traditionally the lab tests are made on paper samples taken from the top of the machine roll. To secure the quality of the product it is important to know how the properties of the paper are changed by the winding process.

The tension distribution in the paper web, which is important for the runnability, can be changed if the thickness and the tensile stiffness are changed in the winding process. The surface of the paper is also likely to be changed, which can affect the printability of the paper.

The compressibility in the z-direction is an example of another paper parameter, which is likely to be changed. The compressibility has an influence on the roll structure and the printing properties.

## TENSION MEASURING EQUIPMENT

Changes in the CD (Cross Direction) web tension profile has been measured with a so-called CTSensor (Cross Tension Sensor), which is described by Kilmister and Malinen (1). The geometrical configuration of the one used in this investigation is given in (2), together with details about data collection, data presentation, and calibration procedure.

## MEASUREMENTS

The measurements reported below have, with one exception, been made on one newsprint roll with a grammage of 45 $g/m^2$ (roll A). The exception is the comparison between roll hardness and tension profile, for which a 42.5 $g/m^2$ roll (roll B) was used. The diameter was about 125 cm, and the web length was 17 500 and 19 250 m, respectively.

The rolls were rewound six times. They were made from TMP with some added kraft pulp, and without recycled fibres.

The rewinder used is of the two-drum type, fig 1. The rewinding operation is performed so that the same side of the paper web is kept outwards all the time. The web speed of 1000 m/min and the web tension were kept constant, except for short sections at the beginning and the end of the process.

Before and after each rewinding, paper samples were taken from the roll for testing the changes of the paper properties. All tests on the paper were carried out with room conditions at 23 deg C and 50 % RH.

### CD Tension Profiles.

Fig 2 shows the tension profiles as measured during the repeated rewinding. The difference between the recorded tension profiles is quite small. One conclusion is that the way in which the changes of the various paper properties take place in different width positions is balanced, so that the load carrying characteristics of the running web is unchanged.

### Tensile Properties.

In order to check in more detail how the tensile properties change, we have also made measurements with a standard tensile testing machine. Samples have been taken before the initial rewinding, after the first, and after the last. The following parameters have been measured both in the machine direction and in the cross direction: Tensile stiffness, tensile strength, tensile energy absorption, and strain to failure, see fig 3, 4, 5, and 6.

Examples of recorded stress-strain curves are shown in fig 7. The paper is subject to stress both wound-in in the paper roll, and in the winding operation.

However, in some of these parameters there is a slight tendency to change, for example the tensile energy absorption is somewhat decreased, fig 8.

**Thickness.**

The thickness changes with the successive rewindings can be seen in fig 9. During the winding the paper is densified because of the radial pressure inside the roll. The effect is largest after the first and the second rewinding operation. The thickness then varies slightly, but seem to have reached a limit corresponding to the pressure in the roll.

**Air Permeance.**

Air permeance for the paper has been measured according to the Bendtsen method. The result is shown in fig 10. The change of the air permeance is analogous to the change of the thickness. When the paper is compressed, some of the pores are closed and the air permeance is decreased.

**Surface Roughness and Surface Compressibility.**

When the pressure is applied to the layers inside the paper roll by the wound-in tension, there is a significant change of volume and surface roughness. A certain amount of this change is irreversible, and can be measured on paper samples taken from the roll.

To study the permanent changes of the surface roughness and the surface compressibility the Bendtsen instrument has been used. The measurement is based on air leakage between the measuring head and the surface of the paper. The surface compressibility is defined as

$$K_b = dR/dP,$$

where R is the surface roughness and P is the clamp pressure. The measurement of the roughness is also time-dependant due to the visco-elastic behaviour of the paper.

In practice $K_b$ can be determined by measuring the roughness values at different pressures. Bristow (4) has shown that the surface roughness of paper measured with a Parker Print Surface (PPS) instrument declines as the logarithm of the clamp pressure. As the Bendtsen values are proportional to the cubic of the PPS-values, the surface compressibility has been calculated according to the formula

$$K_b = (B_5^{0.33} - B_1^{0.33}) \,/\, {}^{10}\log 5,$$

where $B_1$ and $B_5$ are the Bendtsen values at 0.1 and 0.5 MPa, respectively.

From the diagram in fig 11 it can be seen that the absolute value of the surface compressibility is reduced during the rewinding. This is implied by the changes measured in surface roughness. There is a small difference between the top and the wire side of the paper in fig 11.

**Friction.**

The friction coefficients of the paper surfaces have been measured with an apparatus built at STFI (3). The friction force on a moving sled was measured with a pressure between the slide and the sled of 2.6 kPa. Static and kinetic friction have been recorded as shown in fig 12. The measurements have been made in the machine direction. Especially the kinetic friction coefficient is lower and more uniform after the sixth rewinding, fig 13.

**Paper roll hardness.**

The hardness of the paper rolls has been measured with an instrument called PAROtester™. The measuring principle is as follows: An impact body is launched by a spring force against the test surface from which it rebounds. The impact and rebound velocities are measured. A hardness value is calculated according to the formula

$$L = 1000 \cdot (B/A),$$

where A is the impact velocity and B is the rebound velocity.

The measured hardness profiles from six succesive rewindings are presented in fig 14. The tension profile measured in the rewinder from the same experiment is shown in fig 15. Here the scattering of the values is larger than in the experiment shown in fig 2.

Fig 16 shows how the mean value of the measured hardness of the roll changes during the repeated rewindings. The largest hardness change takes place during the first rewinding; thereafter it remains fairly constant.

## DISCUSSIONS AND CONCLUSIONS

The largest changes take place during the first rewinding. Examples of this are the increase in roll hardness, fig 16, and the decrease in paper thickness, fig 9. Other parameters such as the absolute value of the surface compressibility continue to decrease in subsequent rewinding operations, fig 11. The CD tension profile, on the other hand, remains almost constant, fig 2 and fig 15.

The changes in the tensile properties are small, which can be seen both from the tension profiles of the running web and from the properties measured in the tensile test. Changes are seen in surface properties and thickness. The rewinding process seem in this respect to be similar to a light calendering. Changes due to calandering has been investigated by Sunnerberg (5).

The roll hardness profile depends, among other things, on the thickness profile. A relation between the roll hardness profile and the measured tension profile cannot be found in the present measurements.

One conclusion is that if the paper roll has been rewound once, the paper properties do not change very much if it is rewound again.

The time dependence of the induced changes has not been studied.

## ACKNOWLEDGEMENTS

We are very grateful to Mr T. Rönnqvist and his staff at the rewinders in the paper mill of SCA Ortviken AB, where this experiment took place.
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Dr C. Fellers of STFI (Swedish Pulp and Paper Research Institute) gave us the opportunity to use the newly developed paper friction meter, which is gratefully acknowledged.

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4. Bristow, J.A., The Surface Compressibility, a Printing Property, Proceedings of the IARIGAI 15th International Conference on Printing Research Institutes, Lillehammer, Norway, 1979.

5. Sunnerberg, G., Structural Changes in Newsprint during Machine Calendering, Swedish Newsprint Research Centre, Report No. 90:8, Djursholm, Sweden, 1990. (In Swedish.)

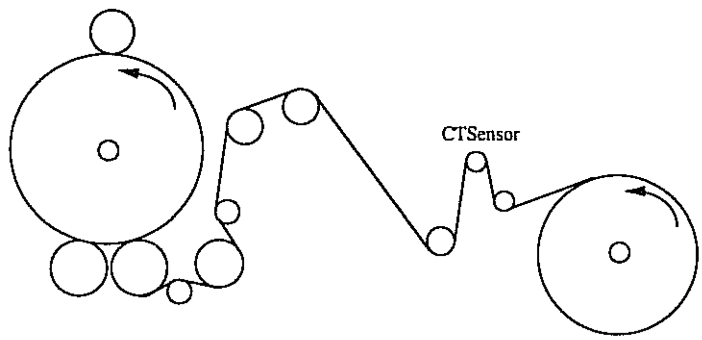


Fig 1. Outline of the rewinder used in this investigation.

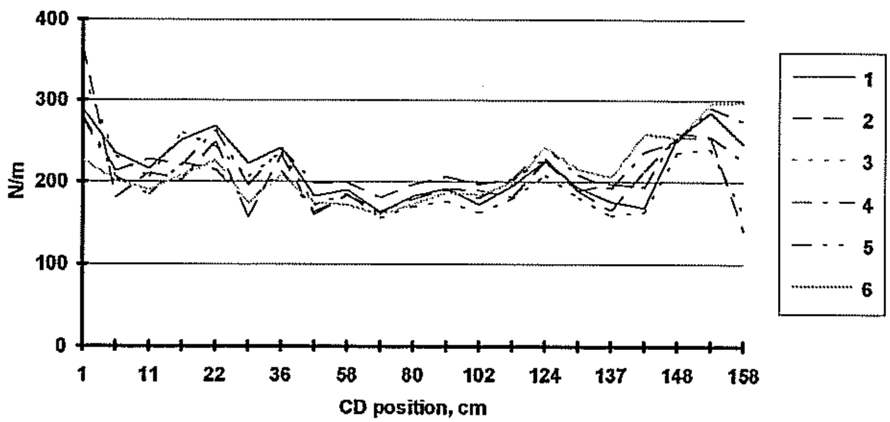


Fig 2. Tension profiles measured during six successive rewindings (roll A).

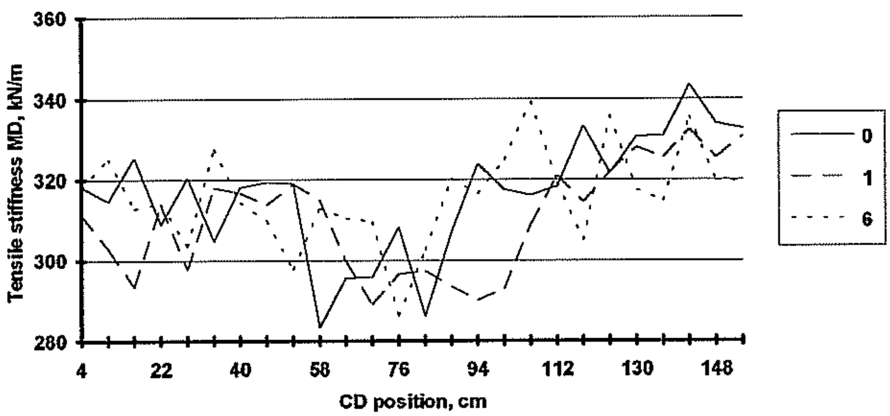


Fig 3. Tensile stiffness profiles measured before rewinding, after the first and after the sixth rewinding.
a) MD (Machine Direction).

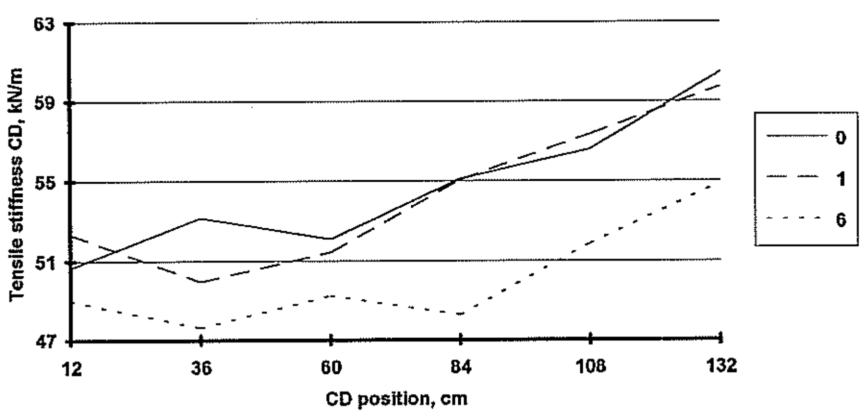


Fig 3. b) CD (Cross direction).

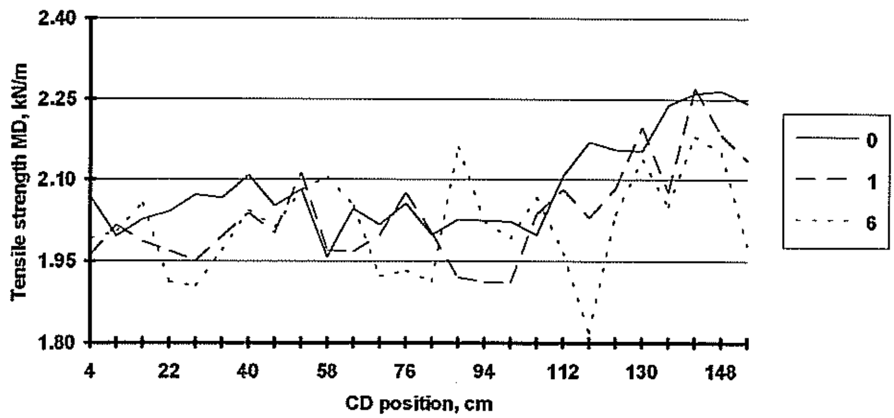


Fig 4. Tensile strength profiles measured before rewinding, after the first and after the sixth rewinding.
a) MD.

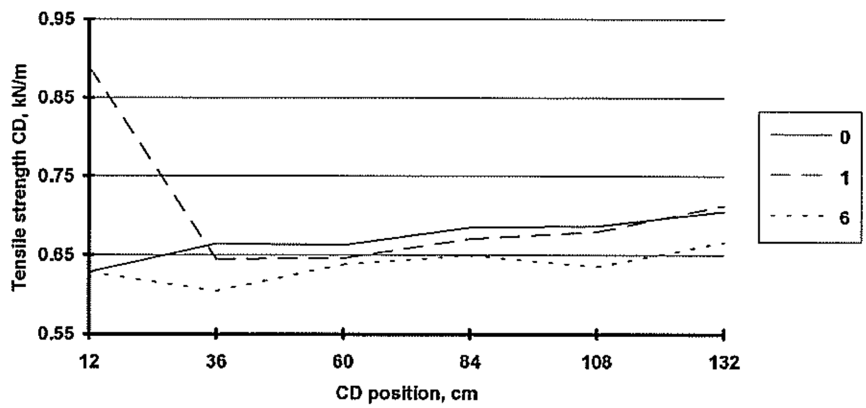


Fig 4. b) CD.

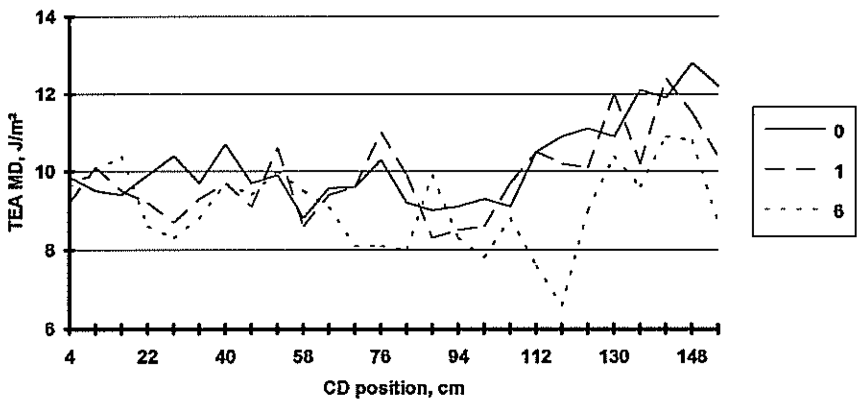


Fig 5. Tension energy absorption (TEA) measured before rewinding, after the first and after the sixth rewinding.
a) MD.

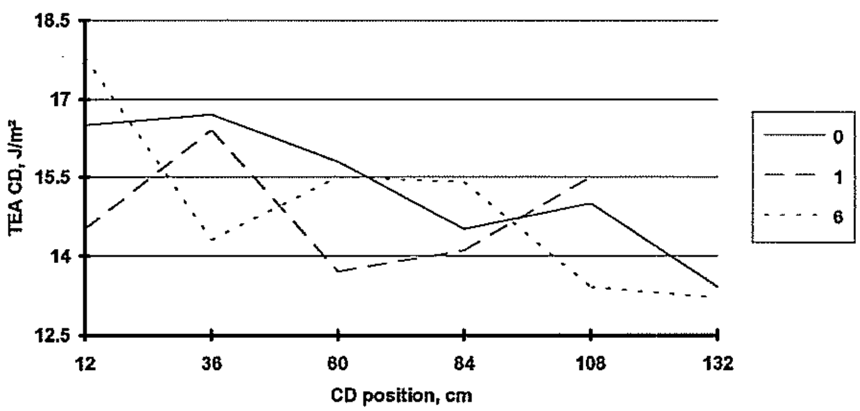


Fig 5. b) CD.

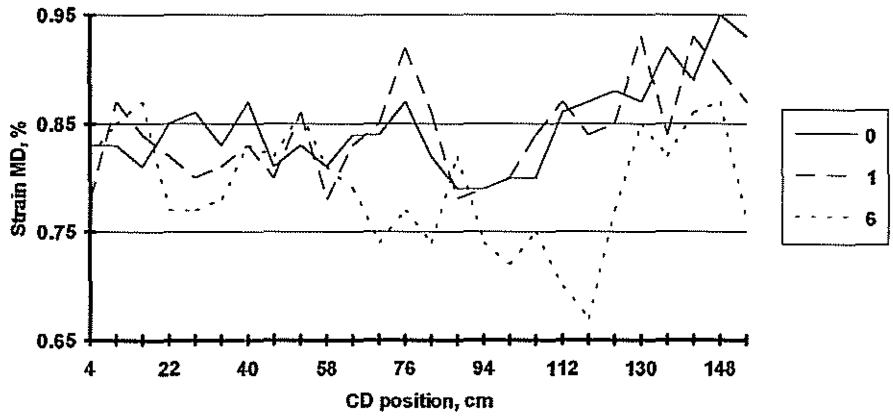


Fig 6. Strain to failure measured before rewinding, after the first and after the sixth rewinding.
a) MD.

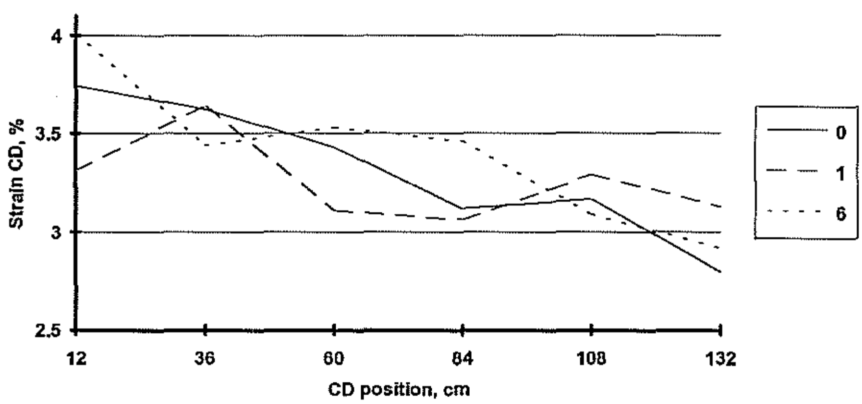


Fig 6. b) CD.

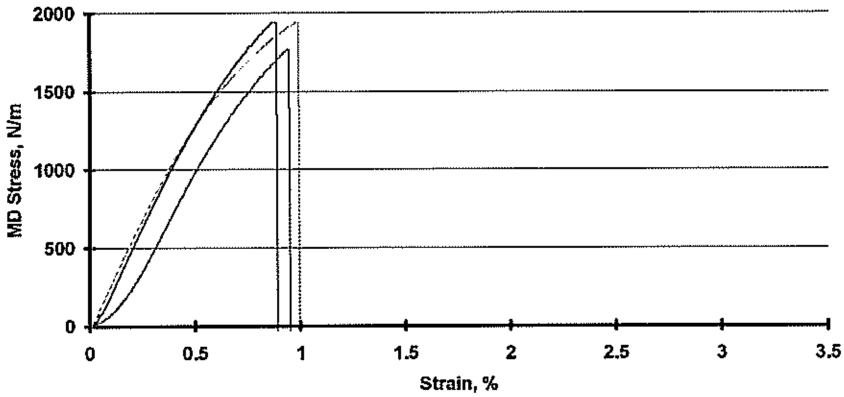


Fig 7. Stress-strain curves recorded during standard tensile testing.
a) MD.

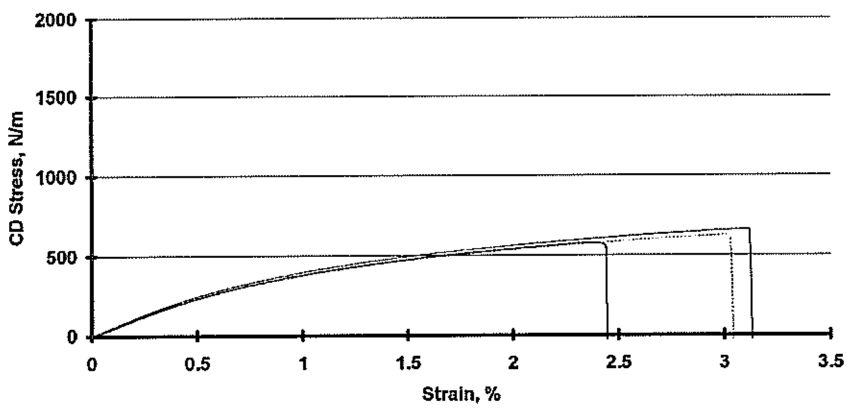


Fig 7. b) CD.

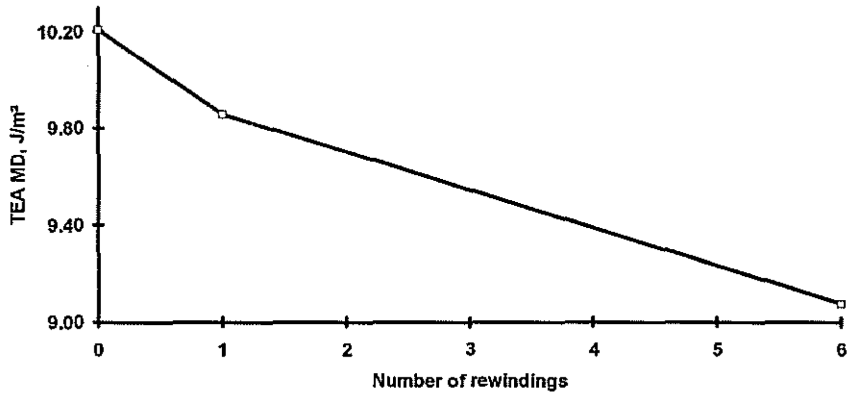


Fig 8. The variation of the tensile energy absorption (TEA) with increased number of rewindings.
a) MD.

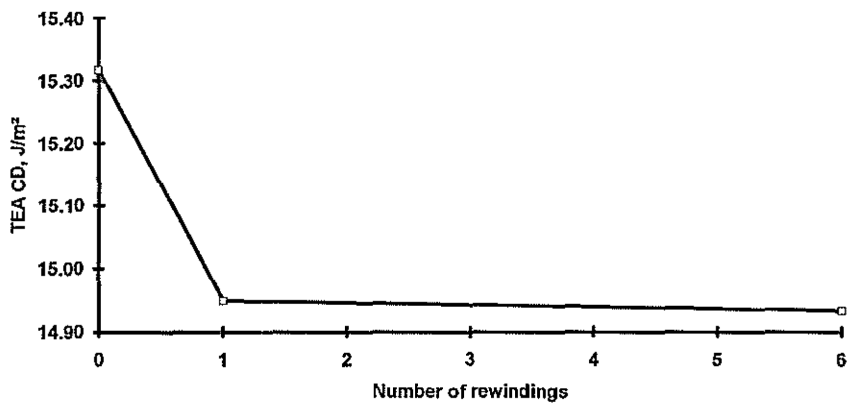


Fig 8. b) CD.

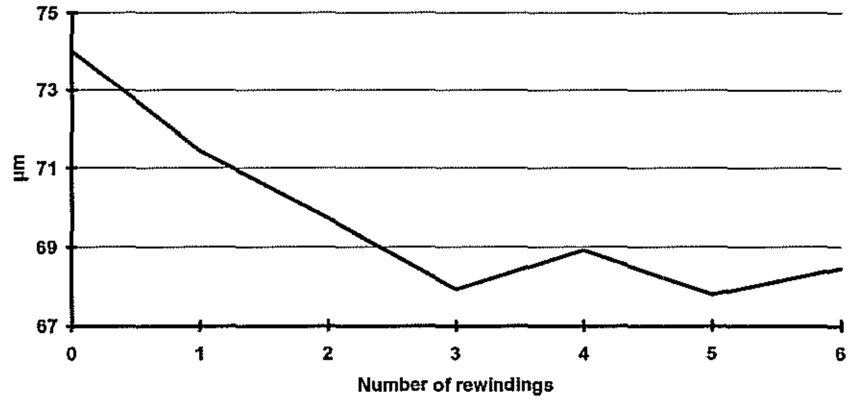


Fig 9. The change of the thickness with increased number of rewindings.

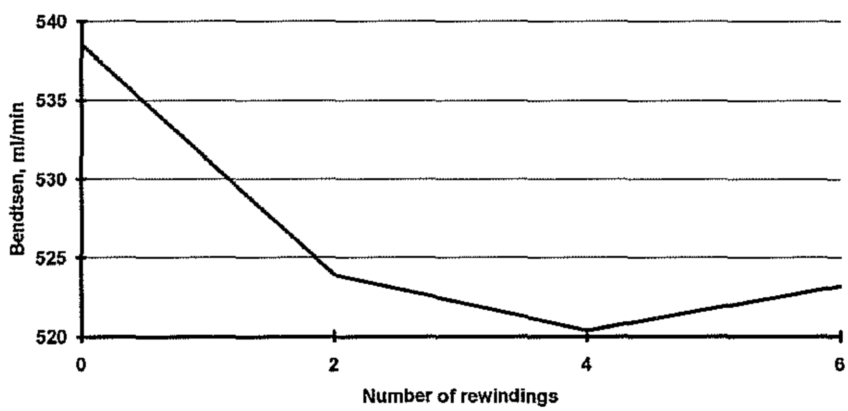


Fig 10. The change of the air permeance with increased number of rewindings.

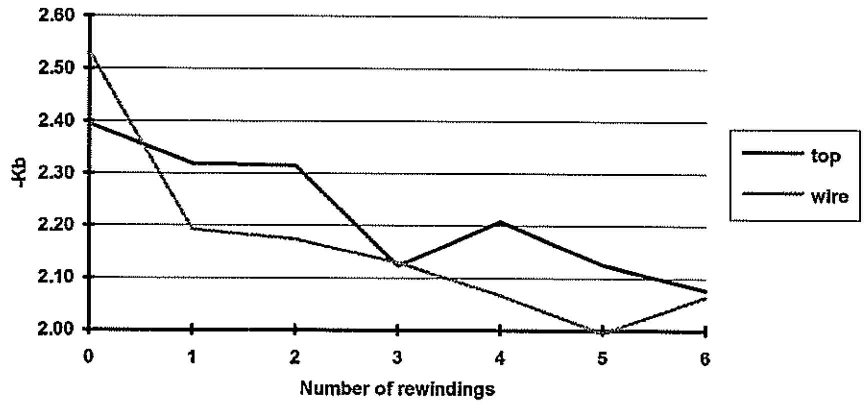


Fig 11. The change of the surface compressibility with increased number of rewindings.

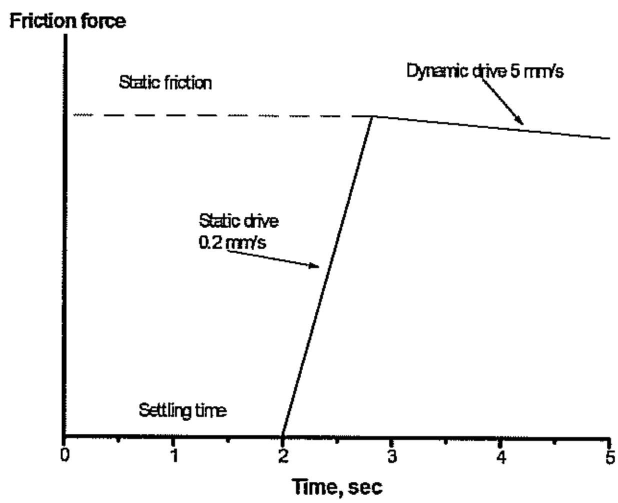


Fig 12. The friction force vs. time during a friction test.

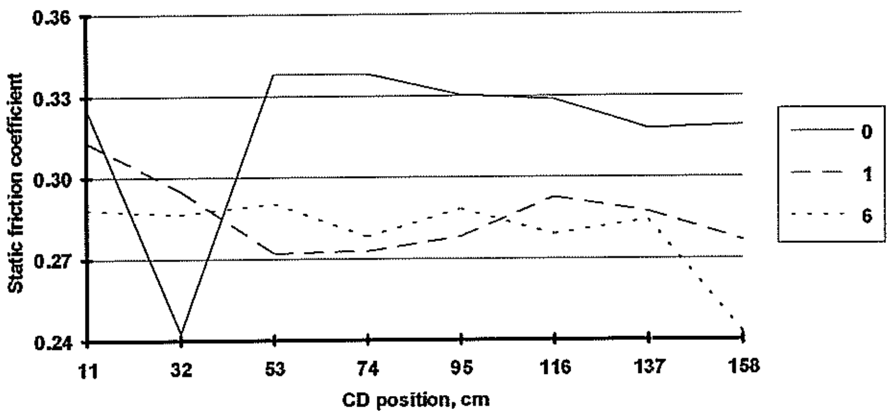


Fig 13. Friction coefficient CD profiles. The friction is measured in MD.
a) Static friction coefficient.

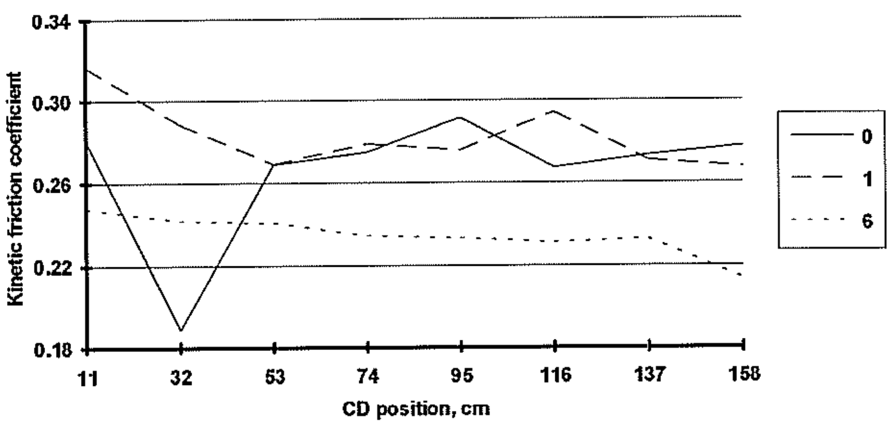


Fig 13. b) Kinetic friction coefficient.

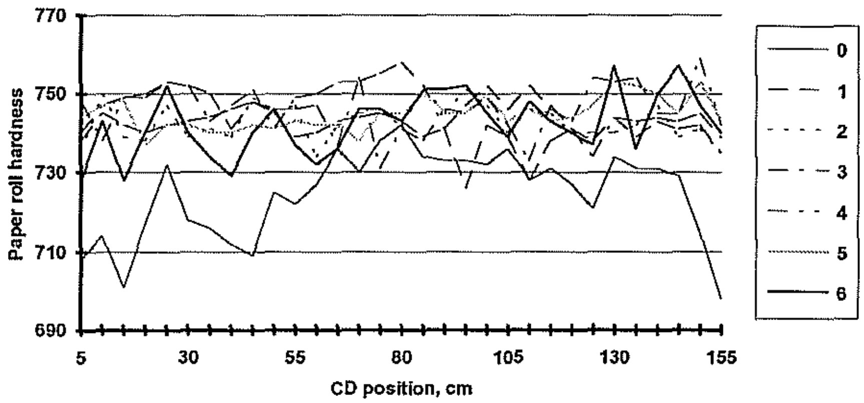


Fig 14. Hardness profiles of a paper roll before and after the rewindings (roll B).

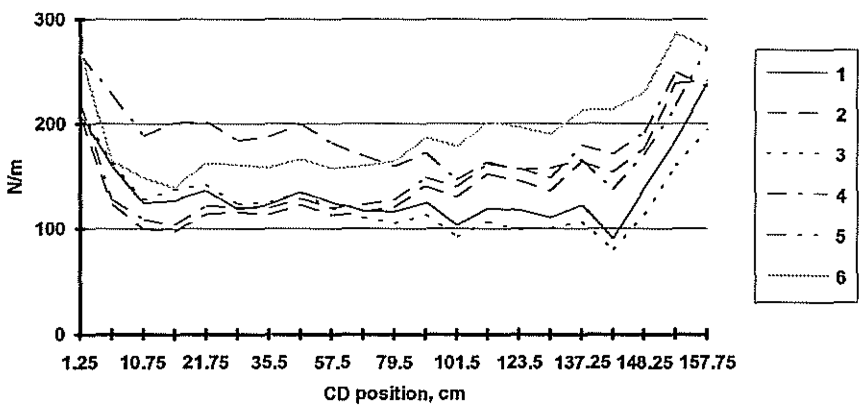


Fig 15. CD tension profiles measured during the rewindings (roll B).

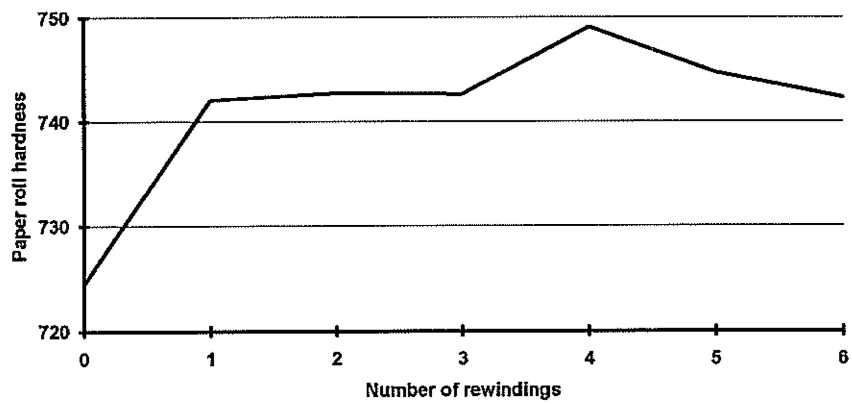


Fig 16. The change of the roll hardness with increased number of rewindings.

## QUESTIONS AND ANSWERS

Q. Is the thickness variation across the web included in Fig. 9?

A. Fig. 9 shows the mean value of the thickness across the web. When the roll was rewound several times, the thickness changed from 74 to 68 mm. This change was larger than the variation across the web, which was within ±0.5 mm.

Q. Why does the reel hardness decrease after the fourth rewinding?

A. Fig. 16 shows the mean value of the reel hardness across the paper roll. After two rewindings, the reel hardness is almost constant. The decrease after the fourth rewinding is due to scattering of the data.

Q. From which part of the paper roll were the paper samples taken?

A. The paper samples were taken from the top of the roll after each rewinding.

Q. What is the maximum radial deflection of the rotors of the CTSensor?

A. About 5 mm.

Q. Has the winding on the paper machine had any effect on the paper properties?

A. Yes, in fact, the major changes of the properties in the paper take place during the first winding on paper machine and the second on the slitter winder.

Q. What is the practical conclusion of the investigation?

A. The data presented shows that only minor changes take place during the winding processes after the first rewinding. Therefore, in practice, it doesn't matter if you rewind a paper roll three or more times.