HYGROEXPANSION OF NEWSPRINT AS A RESULT OF WATER ABSORPTION IN A PRINTING PRESS

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ABSTRACT

A method has been developed to investigate lateral dimensional changes in paper webs. The paper is printed in the GFL Lito-Tester using wet offset in the first printing unit and dry offset in the second unit. The print consists solely of two rows of register marks carefully aligned between the two printing units. The discrepancy between the register marks after the second printing unit is a measure of the lateral expansion. This is quantified using a microscope and camera to project the register marks onto a video screen where the misregister can be measured with an ordinary ruler. The degree of misregister can be assessed with an accuracy of ±0,018 mm, which is sufficient to establish and quantify differences between newsprint from different paper machines and between different rolls from the same paper machine. Tests have been carried out with seven different paper rolls and significant differences have been established. The expansion recorded was between 0,11 and 0,25 mm over a 250 mm wide measurement area, i.e. almost 0,1 %. In a full-scale press with a web width of 1500 mm, this means an expansion of 0,66 - 1,5 mm which gives an unacceptable large register error. A register error of 0,1 mm can be seen by the naked eye. These results are based on measurements made after only one printing unit, but in a situation where all of the surface, with the exception of the register marks, has been covered with fountain solution. It is not possible to relate the expansion of the different rolls simply to the paper machine in which they have been manufactured or to their pulp furnish. The difference in expansion between edge and middle rolls was significant for one mill but not for another.

The influence of the printing pressure was investigated in the absence of fountain solution. A low printing pressure gave practically no expansion at all whereas a high printing pressure gave an expansion of 0,041 %. The expansion data obtained by the new procedure for this limited number of paper samples correlated fairly well with the measured hygroinstablity of the paper samples. No other test method gave data which correlated with this press expansion.

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INTRODUCTION

In the lithographic offset process, the dimensions of the paper are sensitive to the water transferred in the process. Both longitudinal and transverse changes take place in the paper web in a web-fed press, but this study has been restricted to the transverse expansion. A consequence of the increase in width is that it is difficult to maintain satisfactory register during multicolour printing. Since more and more four-colour work is printed in newspapers today, the problem is becoming increasingly acute.

The primary aim of this study has been to develop a method of measurement in order to show and quantify the expansion of the paper web in a printing press and to provide data for a comparison between different rolls of paper, with special emphasis on newsprint. A constant expansion can be compensated for, but if the tendency of the paper web to show lateral hygroexpansion is different in different papers, it is not possible to compensate for the expansion either in the reprodepartment or in the printing press.

Measurements have been made by Trollsås and Larsson (1987a, 1987b) in a full-scale press, but apart from their reports, the literature apparently contains nothing directly concerned with the dimensional changes of paper as a result of water absorption in a press roll nip.

THE PRINTING OF NEWSPAPERS

In the printing of newspapers, transverse expansion of the paper web causes problems only in those presses where the web runs freely between the printing units. In satellite presses, the contact between the web and the common impression cylinder inhibits expansion. The discussion in this report is thus concerned only with presses in which the web is free between the printing units. See figure 1.

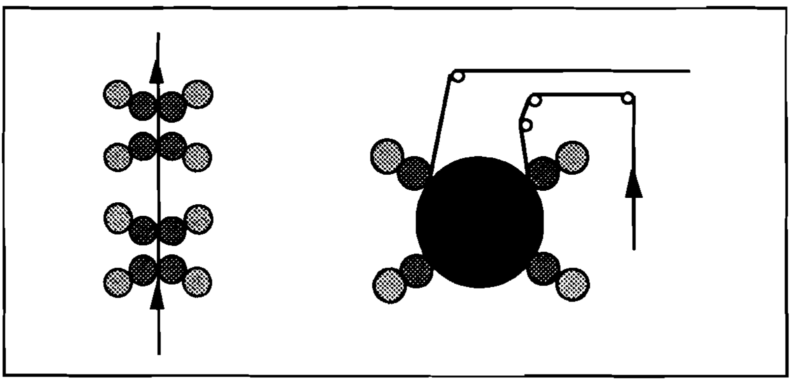

Figure 1. Examples of press configurations.
a/ Press with free web between the printing units.
b/ Satellite press.

PAPER EXPANSION AND REGISTER ERROR

In multicolour printing, any change in dimensions of the web makes it difficult to obtain complete register agreement between the colours. Trollsås and Larsson (1987a, 1987b) have shown that the web expands to approximately the same extent after each colour; i.e. after each exposure to fountain solution. In four-colour printing, the first printed colour is therefore subjected to three successive expansions, and the largest register error can thus be found between the first and last printed colours.

In 4+4 printing, i.e. four colours on each side, the web absorbs moisture from eight printing units. In this case, it is theoretically possible to distinguish two extremes according to whether the four inks are printed first on one side and then on the other or whether they are printed simultaneously on both sides. In the first case, the hygroexpansion associated with printing on the first side does not affect the register error on the side which is printed last. When both sides are printed simultaneously, on the other hand, there may be a greater expansion between each colour since approximately twice as much fountain solution is transferred to the paper.

The fact that the paper is subjected to compression forces in the printing ink may also lead to some expansion even in the dry state, although the fact that water acts as a softener for the paper may in fact mean that, at least in the second and subsequent printing units, the tendency for the paper to expand laterally under the action of the compressive nip forces may increase.

THE RESOLUTION OF THE EYE

In any discussion of register errors, it is of course important to consider the sensitivity of the human eye. The eye has a resolution of 0,1 mm at a normal reading distance, and it may be assumed that a register error of 0,1 mm is certainly visible to the naked eye, although it is not certain that this represents the limit for how large a register error needs to be before it is visually discernible.

NUANCE VARIATIONS

A register error may not only produce a blurred print but may also give rise to variations in nuance. This is a consequence of the fact that the printing inks are not ideal, they are not completely transparent, so that a screen dot printed in later unit may partly cover an earlier printed dot. This means that the colour can change markedly as a result of a register error in multicolour printing if the relative alignment of the screens for the different colours is altered.

COMPENSATION IN A PRINTING PRESS

In a double-width newspaper press, four plates are fitted beside each other on the printing cylinder. To compensate for the transverse expansion, the daily newspaper printers displace the outermost plates outwards slightly in the second, third and fourth printing units. This is only a partial solution to the problem, however, since the hygroexpansion gives a register error which is distributed over the whole width of the web.

The expansion can also be compensated for in the reprodepartment by progressively increasing the width of the printing picture through the four colours. This technique is in fact used when newsprint is printed in heat-set presses where a single printing plate covers the whole width of the press. It would of course be possible to carry out the same procedure in a newspaper press with several printing plates beside each other. Unfortunately, different papers show different expansion tendencies, and the tendency can vary from roll to roll. Although desirable, to adjust the printing plates after each roll change is hardly feasible in practice.

TEST PROCEDURE

In order to simulate true lithographic offset printing as closely as possible, the test method involves printing in GFL's laboratory Lito-Tester, one printing unit of which is used for wet-offset and the second for dry, water-free offset, as indicated in figure 2. Similar printing forms with register marks and a test strip are fitted in both printing units. During printing in the first unit, the paper web absorbs water and expands, so that the

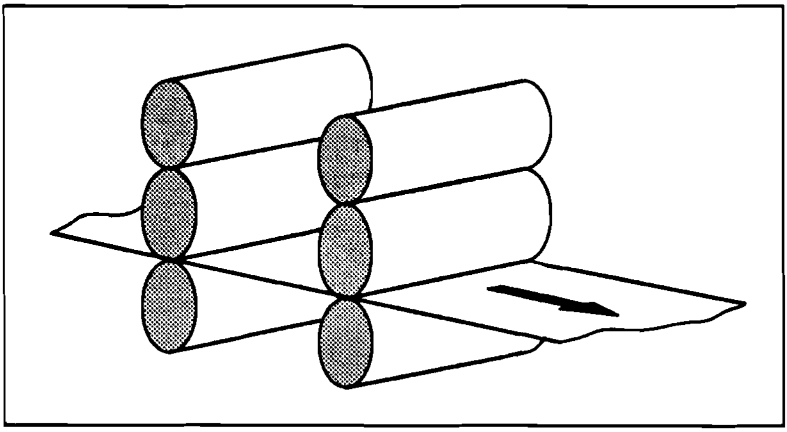

Figure 2. Sketch of GFL's laboratory press. The press has two printing units. In the first printing unit, register marks are printed with wet-offset and in the other with water-free offset.

register marks are not printed in exactly the same place when the web reaches the second unit. The degree of misregister is then a measure of the expansion of the web. When measurements are being made, the press is not adjusted so that it prints in as good register as possible. An intentional register error is introduced in both the longitudinal and transverse directions in order to simplify the measurement procedure. The use of different colours in the two printing units makes the measurement procedure still easier.

EQUIPMENT

PRINTING PRESS

The printing press is a laboratory press which prints from reel to reel and was developed by GFL. The maximum web width is 300 mm and the maximum printing speed is 5 m/s. The press may be used in four different printing modes: offset, direct litho, letterpress and indirect letterpress, using any material combination from news-inks on newsprint to heatset inks on coated paper.

It is possible to use either an IR-dryer or a hot-air dryer. The first inking unit can be controlled with the help of a traversing densitometer which measures print density on-line on the running web. There is also a meter which measures the flow of fountain solution to the dampening unit.

TEST FORM

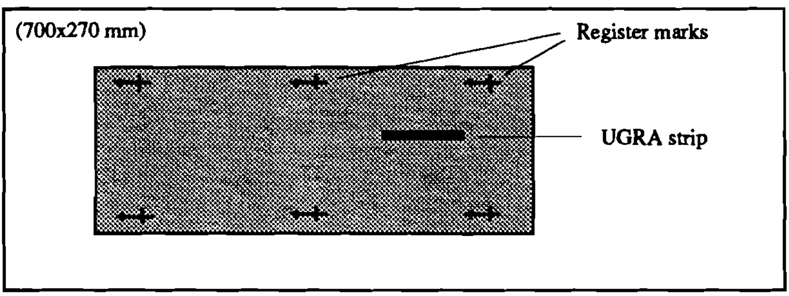

Figure 3. The test form used in the test method.

For this test, a special test form is used with six register marks positioned in pairs in the longitudinal direction, as indicated in figure 3. In order to facilitate control of the ink/ fountain solution balance (during wet-offset), the printing pressure and plate exposure, the test form also includes an UGRA-strip.

To ensure that the paper absorbs moisture directly from the fountain solution and not indirectly via the printing ink, the test form has no large printing surfaces. The risk that the ink itself affects the expansion of the paper is thus eliminated.

MEASUREMENT EQUIPMENT

To measure the distance between two register marks, a microscope with camera and video equipment is used, which makes it possible to make a recording on a tape and measure the degree of misregister on a colour monitor on a later occasion. The magnification on the screen is 260 times and the distance between the register marks is measured simply with a transparent ruler, as indicated in figure 4. Reading takes place with respect to estimated centre lines on the register marks.

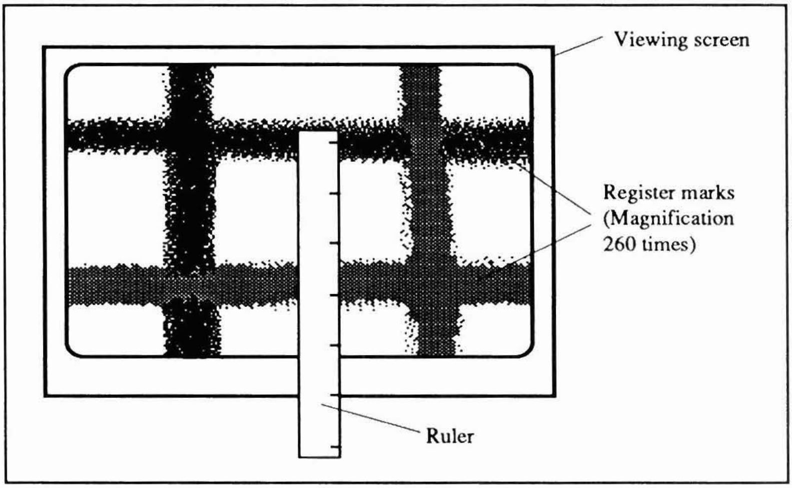

Figure 4. Register marks in strong magnification on viewing screen. The distance between them is measured with a transparent ruler.

The accuracy of a single measurement on the screen is estimated to be ±2,5 mm which corresponds to approximately ±10 μm on the print. The maximum expansion measurable on the screen with this magnification is 1 mm on the paper, i.e. up to circa 0,5 % expansion on a 250 mm wide measurement surface, which is fully sufficient.

The magnification is so great that there is no space for a whole register mark on the screen. During printing, care is therefore taken to check carefully that the register marks are at a suitable distance from each other, and to ensure that the print quality is sufficient for measurement. Care is also taken to see that the ink/water balance is correctly adjusted.

PLATEMAKING

During platemaking, the plate and film have been placed in the middle of the printing frame in order to avoid problems due to oblique illumination of the plate. The distance between the register marks has then been measured with a ruler directly on the plate. This has also been done when the plates have been fitted in the press. No difference in distance between the register marks has ever been observed.

It is important that the alignment between film and plate is the same for both plates. If there were an angular discrepancy, the transverse distance between pairs of register marks would not be the same on both plates and the method would indicate transverse differences which are not in fact associated with any expansion phenomenon. For a given sample of paper, the method would give a greater or less expansion depending on whether the incorrectly printed plate were in the first or second printing unit.

If the film were displaced obliquely by 1 mm in the longitudinal direction, which is much greater than is likely to occur, the error is of the order of 3 µm which cannot be detected by the method. It is thus concluded that the platemaking is achieved with sufficient accuracy.

PLATE FITTING

It is also important that the plates are similarly aligned in the press. An angular error in the fitting would affect the distance between the register marks across the paper web in the same way as if the film were placed obliquely on the plate during the platemaking.

As before, an error of 1 mm over the length of the plate due to oblique fitting would lead to an error in the register measurement of only 3 µm, and so large an error in fitting is unlikely to occur.

PRINTING CONDITIONS

The press speed was 1 m/s and the length of the free web between the printing units was 0,4 m. The time between the first and second printing units was therefore 0,4 s.

This may be compared with the conditions in a full-scale press which often runs at a speed of 10 m/s. If the distance between the printing units is 2 m, the time between two subsequent printings is then 0,2 s.

Both web tension and printing pressure have been kept constant to avoid uncontrolled changes in the dimensions of the web. The press room was conditioned to 22°C and 65 % r.h.

THE EFFECT OF PRINTING PRESSURE

The effect of the printing pressure on the width of the paper was studied in a preliminary test, in which the paper was printed in two nips using water-free offset to separate dry expansion under pressure from hygroexpansion due to absorbed water. The width was indeed found to increase with increasing printing pressure, as shown in figure 5, which confirms that it is important to keep the printing pressure constant during printing and also to check that it does not vary from one printing to another. The printing pressure considered to be "normal" for the GFL Lito-Tester was used in these tests.

The fact that a low dry expansion was recorded when the printing pressure was reduced to a minimum is confirmation that the plates were well made and properly aligned on the rollers.

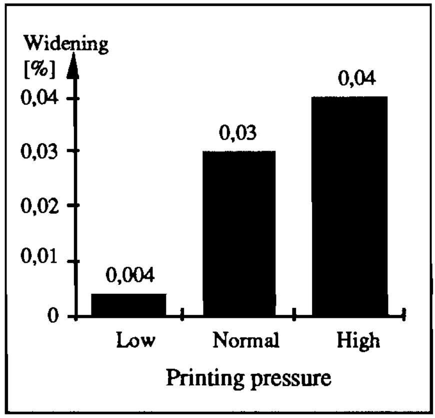

Figure 5. The widening of the paper web under different printing pressures. The measurement width was 250 mm.

THE EFFECT OF WEB TENSION

The web tension affects the width of the paper web in that a high web tension counteracts the tendency of the web expand, since the more a material is elongated, the narrower it becomes. The Poisson ratio for paper is approximately 0,3.

It is therefore necessary to keep the web tension at a constant level during a test printing and also to check that it does not vary between two test printings. Since it is not desirable in this test to inhibit the hygroexpansion, as low a web stress as possible without operational problems is used.

NUMBER OF MEASUREMENTS

Preliminary trials were carried out in order to determine how many measurements were required in order to obtain statistically significant results.

DEVIATION WITHIN A TRIAL

Figure 6 shows a series of 20 successive but independent measurements made at 70 cm intervals during a single run. There is no evidence of any trend, and the standard deviation σ is of the order of 0,02 mm. The standard deviation of a series of 100 successive measurements is 0,024 mm. It was concluded that 10 independent measurements would be sufficient to characterise a paper.

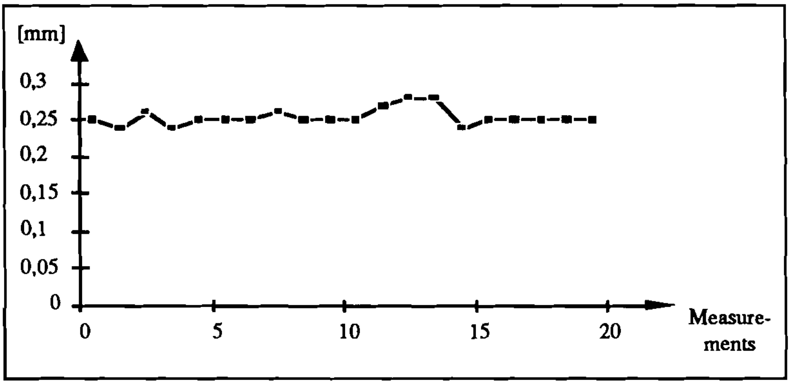

Figure 6. A series of 20 independent measurements of the lateral expansion of the web.

Deviations between separate trials

The standard deviation of means σ_m of 10 measurements was found to be 0,008 mm according to the expression

$$\sigma_m = 0,024/\sqrt{10} = 0,008 \text{ mm}$$

which gives an accuracy of the method with a 95 %-confidence interval of ±0,018 mm. Since it was found that the distribution of expansion values on a single paper was approximately normal and since the means of separate sets of measurements on such a distribution are known to be normally distributed, it was calculated that the difference Δbetween two means must exceed a value Δ>0,024 mm for the results to be significantly different at the 95 % confidence level, according to the expression

$$\Delta = 2,101 \text{x} 0,008 \text{x} \sqrt{2} = 0,024 \text{ mm}$$

MEASUREMENTS OF DIFFERENT PAPERS

The method has been used on several different newsprints from three different mills.

In order to investigate the expansion without moisture in the printing process, water-free offset (Toray) was printed in both printing units. The different papers showed no differences. In all cases the dry expansion for a measurement width of 250 mm, on a 300 mm wide web, was 0,076 mm.

THE SAMPLES

Seven different paper samples were used; designated P1, P2, P3, P4, P5, P6 and P7.

P1, P2 and P3 were papers from the three mills. One of the papers had a fairly high content of recycled fibre (40-50 %), one had a low content (<10 %) and the third had no recycled fibre at all.

P4 and P5 were papers from the same mill as P1. P4 was an edge roll taken from the edge of the web of the paper machine and P5 was a middle roll taken from the middle of the web.

P6 and P7 are edge and middle rolls respectively from the same mill as P3. It is not known exactly where the edge and middle rolls have been taken from the paper web. Nor is it known whether the rolls have been taken close to the core or farther out towards the periphery of the machine roll in the paper mill.

All paper rolls have been stored for about a month at GFL in an air-conditioned room prior to testing.

Thickness, grammage, surface roughness and density were measured on all papers.

RESULTS

Figure 7 shows the total expansion in mm and as a percentage for all papers included in the test. The paper web was 300 mm wide. The distance between the register marks which were measured was 250 mm.

The dry expansion was 0,076 mm and was the same for all the papers. The greatest expansion noted was 0,25 mm, and the least 0,11 mm. The resolution of the eye is 0,10 mm which means that even the smallest expansion is visible to the naked eye. An expansion of 0,25 mm would give an unacceptable register error in a sensitive four-colour picture.

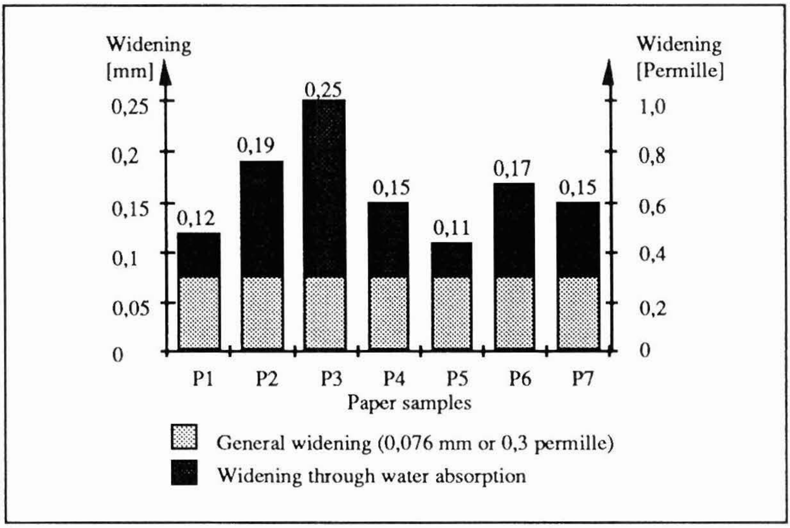

Figure 7. The widening for all samples P1-P7 in mm. On the axis to the right, the widening is shown in permille of the width between the register marks at 250 mm. The general widening is equal for all papers (0,076 mm).

From our tests so far, it is not possible to relate the expansion tendency of the different papers to the pulp content of the paper or to the mill where the paper was made.

Results which differ by more than 0,024 mm are significantly different, according to section "Deviation between separate means". There is for example a significant difference between P4 and P5 where the edge roll expands more than the middle roll. There is, on the other hand, no significant difference between P6 and P7. The material is too small, however, to permit general conclusions to be drawn about differences between edge and middle rolls.

MOISTURE TRANSFER

A certain concentration of a salt containing a tracer substance was added to the fountain solution before printing. The quantity of tracer substance in the paper was measured by activation analysis, to determine exactly how much fountain solution was transferred to the paper during the printing.

In the printing with papers P1, P2 and P3, a manganese salt was used as tracer substance, but the paper itself contained too much manganese to enable the amount added via the fountain solution to be measured. During printing of the other papers, europium was used as tracer substance, and this gave reliable values. The values shown in table 2 indicate some degree of correlation between the expansion and the amount of water absorbed.

FULL-SCALE PRESS

Assuming that there is a linear relation between expansion and web width, our results indicate that on a full-scale newspaper press, without satellite unit, with a web which is 1500 mm wide, an expansion between 0,66 and 1,50 mm can be expected.

It has been shown by Trollsås and Larsson (1987a, 1987b) that the expansion increases linearly during printing with four colours. The expansion should thus be three times greater in four-colour printing than in printing with only two printing units. No such tests have however yet been carried out at GFL.

It is important to remember that the register is often adjusted at the middle of the web, so that the real register error is at most half the total expansion. If, on the other hand, an important advertisement picture lies at one edge of the web, the printer probably sets the register according to this picture, which means that the register error at the other edge is as large as the total expansion.

PAPER PROPERTIES

Table 1 lists data for the grammage, thickness, surface roughness and density of the papers.

Sample	Grammage [g/m ^{2}]	Thickness [μm]	Surface roughness [ml/min]	Density [kg/m ^{3}]	Widening [Permille]
P1	47,0	68	50	691	0,48
P2	47,0	64	31	734	0,76
P3	48,0	72	50	667	1,0
P4	45,0	70	41	643	0,6
P5	44,0	66	36	667	0,44
P6	44,0	65	48	677	0,68
P7	44,0	64	40	688	0,6

Table 1. Table over grammage, thickness, surface roughness and density of the paper samples. The widening is shown in the right column.

The property which correlated best with the expansion is the surface roughness, measured in a Bendtsen apparatus with a measurement pressure of 0,5 MPa.

The difference in thickness was too small to permit any direct conclusions to be drawn with regard to its effect on the expansion.

The grammage was approximately the same for all the papers.

The density of the paper does not seem to influence the expansion during printing either. There is here no indication, for example, that high density leads to less expansion of the paper.

CORRELETION WITH OTHER TEST METHODS

The papers have been subjected to a number of other test methods to seek some correlation with this method.

The expansion of paper during printing is special because the water is applied in a press roll nip with a certain linear load. In most test methods, in which moisture and dimensional changes are involved, moisture is added in the form of water vapour or liquid but not in a press roll nip.

OTHER TEST METHODS

RATE OF WATER ABSORPTION

The rate of water absorption was measured by the method developed by Bristow (1967) in which the paper is drawn with different speeds past a slit through which a known quantity of liquid is absorbed. The length of the liquid trace for different speeds gives an absorption coefficient and a surface roughness contribution.

The test was performed on all papers P1 - P7. The results shown in table 2 indicate no significant correlation.

HYGROINSTABILITY

The dimensional stability was measured according to SCAN-P 28:69, the elongation of paper strips being measured and recorded as percentage of the original length for a given change in relative humidity.

The results from the dimensional stability measurements on papers P4 - P7 are shown in table 2. The dimensional stability of the paper shows the clearly best correlation against the expansion of the paper in a printing press.

TENSILE STRENGTH ANISOTROPY

The tensile strength was determined according to SCAN-P 16.65 as the stress necessary to break a 1,5 mm wide strip at a speed of 10 cm/min. Measurements were made on papers P4 - P7 in both the machine and cross-directions (MD and CD).

The anisotropy of the paper samples for the tensile strength show no correlation with the expansion for the papers tested, table 2.

DROP TEST

The time for a drop of water with circa 12 % isopropanol to be absorbed by the paper was measured. A drop of liquid is placed on the paper and filmed with a video camera. The contact angle of the drop and the time it takes for the drop to be absorbed into the paper are measured.

The test was carried out on papers P4 - P7 on both sides of the web. The results of the measurements on that side of the paper which was printed are shown in table 2. There was practically no difference between the two sides of the papers except for one middle roll which showed a longer absorption time on the outside (the side printed) than on the inside.

RESULTS

The results from the test methods which have been compared with our test method are shown in table 2. The test method which correlates best with the widening is measurement of dimension stability.

Sample	Rate of water absorption [cm^3/m^2]	Activation analysis [$mg\ H_2O/dm^2$]	Dimension stability [%]	Anisotrophy [MD/CD]	Drop test [Seconds]	Widening [Permille]
P1	10,2	—	—	—	—	0,48
P2	5,7	—	—	—	—	0,76
P3	4,9	—	—	—	—	1,0
P4	10,7	4,0	16,5	2,28	8,9	0,6
P5	9,5	2,7	13,2	2,26	15,3	0,44
P6	11,7	6,8	21,7	3,26	14,8	0,68
P7	9,4	2,0	16,0	3,27	13,3	0,6

Table 2. Rate of water absorption according to Bristow. Activation analysis. Dimension stability. Tensile strength anisotropy. Drop test. The widening is shown in the right column.

CONCLUSIONS

A test method has been developed for investigating the lateral expansion of paper webs. The accuracy of the method with a 95 %-confidence interval is ±0,018 mm. With this accuracy, the method can establish and quantify differences between different newsprints, both from different paper machines and between different rolls from the same paper machine.

Tests have been carried out with seven different paper rolls and significant differences have been established. It is not possible to relate the differences between rolls to the paper machine in which they have been made or to differences in furnish.

Even the smallest expansion on detected on a 250 mm wide measurement area is visible to the naked eye.

The results obtained indicate that the expansion on a full-scale press with a web width of 1500 mm would be 0,66 - 1,5 mm, which gives an unacceptable large register error. These results are measured after only one printing unit.

The difference in expansion between edge rolls and middle rolls was significant for the rolls from one mill but not from the other. The material is insufficient, however, to permit general conclusions to be drawn with regard to differences between edge and middle rolls. Further tests need to be carried out to clarify possible differences.

A low printing pressure in the absence of water gives practically no expansion, whereas a high printing pressure leads to an expansion of 0,041 %.

The test method which correlated best with the behaviour in the test printing was the dimensional stability. No other test method gave a correlation with all papers.

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