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SCANDINAVIAN PULP, PAPER AND BOARD
TESTING COMMITTEE

Paper and board

Structural thickness and structural density

0 Introduction

This SCAN-test Method has been developed in order to specify the conditions for determining the structural thickness and structural density of single sheets of paper and board.

The Method has been developed primarily for use in applications such as paper physics e.g. the use in engineering calculations of strength and stiffness, studies of wet pressing and calendering, where the thickness and surface unevenness need to be separated and for the calculation of the structural density, related to the optical and mechanical properties of the paper.

> *Note* – The Method may also be used for local thickness measurements and for thickness profile determinations across or along a paper web where the thickness signal may be analysed, e.g. by Fourier analysis, but such a measurement is not in accordance with this SCAN-test Method.

In this SCAN-test Method the sheet thickness is determined from the distance between two spherical probes when the sheet is fed into the nip with a constant speed. The feeding speed of the sheet, as well as the force and diameter of the probes, are specified in this Method and fulfil the requirements for a useful thickness value to be used in engineering calculations of paper.

This Method differs from other standardized procedures for single sheet thickness and from bulking thickness according to ISO 534 and comparable methods where the sheet thickness is determined as the distance between two parallel plates resting on a single sheet or a pack of sheets with a specified force. In these standardized methods, the surface unevenness causes an overestimation of the thickness for most papers for the engineering applications mentioned above.

1 Scope

This SCAN-test Method describes a procedure for measuring the structural thickness and for the calculation of the structural density of paper and board.

The Method is applicable for all kinds of papers and boards having a thickness between approx. 30 µm and 500 µm. It is not applicable for corrugated board and certain soft papers such as tissues which are creped or embossed.

2 References

ISO 187 Paper, board and pulps – Standard atmosphere for conditioning and testing and procedure for monitoring the atmosphere and conditioning of samples (EN 20187)

ISO 536 Paper and board – Determination of grammage (EN ISO 536)

> *Note* – SCAN-test has withdrawn a number of test methods and refers instead to the corresponding ISO and/or EN Standards.

3 Definitions

For the purpose of this Method, the following definitions apply:

3.1 *Structural thickness*, t_s – The mean value of the distance between two probes when, one by one, test pieces from a specimen are fed through a nip between the spherical probes at a constant speed, using the Method of test.

> *Note* – The Method of test requires that the measurements shall be performed on a stated minimum distance and shall be based on a stated minimum number of data points.

3.2 *Structural density,* ρ_s – The grammage divided by the structural thickness.

4 Principle

A test piece is fed through a nip between two spherical probes. The distance between the probes is continuously recorded. The structural thickness is calculated.

The structural density is calculated from the average grammage divided by the structural thickness.

5 Apparatus

5.1 *Structural thickness apparatus,* having the principle of measurement as illustrated in *Figure 1*.

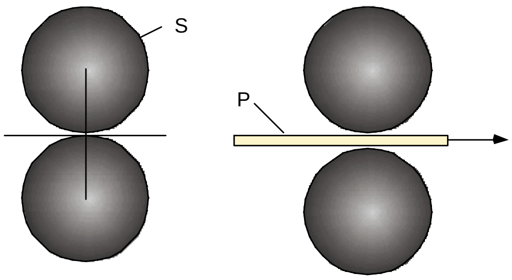

Figure 1. The principle of measuring the structural thickness.
S = Probes
P = Paper

Two non-rotating, hard, polished, spherical probes, *S*, with a radius of (2,0 ± 0,1) mm are touching each other in a point with a constant force comparable to a weight of (10 ± 2) g.

> *Note* – Steel ball bearing spheres are suitable for this purpose.

An imaginary line through the centres of the probes is perpendicular to an imaginary plane through the touching point of the probes, *figure 1*.

This position of the probes defines zero thickness. A paper sheet, *P*, is fed at a constant speed of (20 ± 5) mm/s through the nip between the probes. The feeding shall be carried out in such a way that the tangent to the surface of a representative area of the paper in the feeding direction and the tangent to the surface perpendicular to the feeding direction of the same area remains perpendicular to the line connecting the centres of the probes. The probes move along this line.

The apparatus shall be fitted with a thickness gauge, which provides a measurement of the distance between the probes at any given time with a resolution of 1 µm, and a means of recording these continuously in order to make possible the calculation of a mean value.

The lower probe shall counteract the weight of the upper probe by a spring mechanism. The probe must be able to follow the unevenness of the paper surface within the specified weight range (10 ± 2) g. In order to do this, the spring shall be flexible. A weight of 10 g on the spring shall result in a deflection exceeding 0,1 mm. Normally this is factory set.

5.2 *Calibrated feeler gauges* in a range of suitable thickness with values assigned by an accredited laboratory and traceable to a suitable national standard.

6 Calibration and adjustment of apparatus

The apparatus shall be calibrated according to the instructions given by the manufacturer of the testing instrument.

The following checks shall be carried out at regular intervals:

6.1 Check the thickness reading of the apparatus by inserting calibrated feeler gauges (5.2) that are representative for the measuring range of the samples to be tested in the following way:

6.1.1 Let the probes touch each other. This position of the probes defines zero thickness.

6.1.2 Put one feeler gauge in the nip between the probes with thickness approximately 50 % to 100 % of the desired measuring range and check the reading.

6.1.3 Put in another feeler gauge in the nip with a thickness approximately half that of the feeler gauge specified in 6.1.2. Check the reading. The thickness reading shall not deviate more than ±2 µm in the thickness range from 30 µm to 250 µm, not more than ±5 µm in the thickness range from 250 µm to 500 µm and not more than ±10 µm for thickness values exceeding 500 µm.

If the reading deviates more than the values specified above, this indicates two possible sources of error:

1) The probes are contaminated. Action: clean the probes

2) The alignment of the probes is in error. Action: The adjustment is normally a task for the manufacturer of the apparatus.

6.2 Check that the speed is (20 ± 5) mm/s.

Note 1 – Normally this speed is factory set. There are however several ways of controlling the speed. One way is to make marks on a paper strip 1 m apart. Run the paper through the nip and check the time between the marks by a stopwatch.

6.3 Check that the weight is (10 ± 2) g.

Note 2 – If the force between the probes is based on the weight of the upper probe and supplementary attachment, this is factory set by the construction of the gauging system. The manufacturer is responsible for the precision of the weight of the upper gauge and there is no requirement for a regular control of the weight.

7 Sampling and preparation of test pieces

7.1 Sampling and conditioning

The sampling procedure is not covered by this Method. Make sure that the test pieces taken are representative of the sample received.

Condition the specimens as specified in ISO 187. Keep them in the prescribed conditioned atmosphere throughout the test.

This test, like other mechanical tests, is very sensitive to changes in the moisture content of the test piece. Handle the test pieces carefully and never touch with the bare hand the region of the test piece to be tested. Keep the test pieces away from moisture, heat and other influences that may change their moisture content.

7.2 Preparation of test pieces

From specimens of undamaged paper and board, cut test pieces with a width and length suitable for the thickness measurement, avoiding watermarks, folds and wrinkles.

8 Procedure

Carry out the test in the atmospheric conditions at which the samples were conditioned.

Ensure that the thickness apparatus is placed on a vibration-free surface and that it is calibrated.

Feed the sheet through the nip and record the distance between the probes at regular intervals. An example of a thickness profile for liner is shown in *Figure 2*.

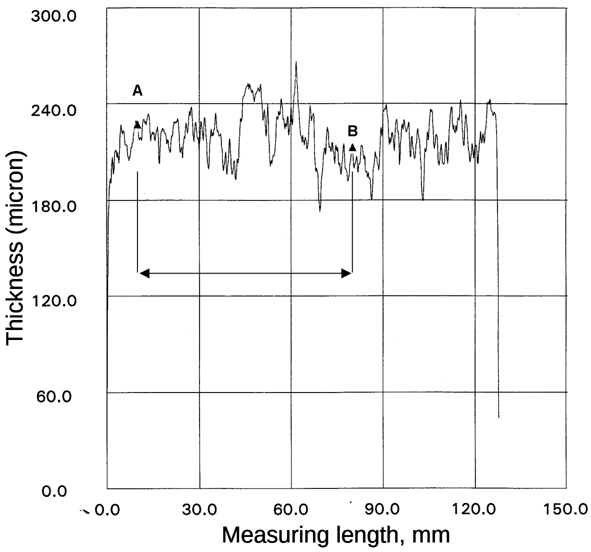

Figure 2. A thickness profile for liner. The distance between A and B in the figure is a part of the total measuring distance.

Reject all thickness results measured less than 5 mm from the edges of the sheet.

The mean structural thickness must be based on a total measuring distance not less than 100 mm and since data points are normally recorded every 0,2 mm this gives at least 500 data points. Use a representative number of test pieces from the sample.

For certain measurement purposes, other total measurement distances may be used. This must, however, be stated in the report.

Note 1 – For machine-made papers, it is recommended to perform the measurement in CD if the purpose of the test is to determine the thickness variations across the paper machine. If measurement is performed in MD there is a risk of following a single non-representative streak in the paper.

Note 2 – For laboratory sheets, the following procedure is recommended: Make two measurements in mutually perpendicular directions through the centre of the sheet and calculate the average thickness value from the two measurements.

If the structural density of the paper or board is to be calculated, determine the grammage of the sample in accordance with ISO 536.

9 Calculation

9.1 Structural thickness

Calculate the structural thickness t_s from all the thickness readings of one or several test pieces in the sample.

Report the structural thickness to the nearest 1 µm.

9.2 Structural density

If required, calculate the structural density ρ_s from the expression:

$$\rho_s = \frac{w}{t_s} 1000 \qquad [1]$$

where

ρ_s is the structural density, in kilograms per cubic metre;
w is the grammage, in grams per square metre;
t_s is the structural thickness, in micrometers.

Report the structural density to the nearest integer.

10 Report

The test report shall include reference to this SCAN-test Method and the following particulars.

(a) date and place of testing;
(b) identification mark of the material tested;
(c) mean structural thickness and, for machine-made paper; the measurement direction;
(d) if required, the structural density;
(e) if required, the standard deviation of the structural thickness (based on the number of collected data points);
(f) if not as stated in this Method, the total measuring distance and the number of collected data points;
(g) any departure from the procedure described in this SCAN-test Method and any other circumstances that may have affected the results.

11 Precision

Six laboratories tested seven papers under normal laboratory conditions using test pieces from the same gross sample. The laboratories evaluated the repeatability of the structural thickness by running the seven papers five times in the same thickness apparatus. The results were as follows:

Sample	Structural thickness, t_S µm	CV within lab, %	CV between labs, %
Newsprint, 45 g/m^2	61	4,4	5,6
LWC, 60 g/m^2	48	4,3	4,0
Copy paper, 80 g/m^2	96	4,3	3,0
Sack paper, 90 g/m^2	102	6,6	2,4

CV = the Coefficient of Variation.

12 Literature

12.1 Fellers, C., Andersson, H. and Hollmark, H. The definition and measurement of thickness and density. In: Paper. Structure and Properties. (Ed: J. A. Bristow and P. Kolseth). p. 151-167 (1986). Marcel Dekker. New York, Basel

12.2 Schultz-Eklund, O., Fellers, C. and Johansson, P-Å. Method for the local determination of the thickness and density of paper. Nordic Pulp and Paper Research Journal 7:*3*, p. 133-139, 154 (1992)

12.3 SCAN-G 2 Statistical treatment of test results

12.4. SCAN-P 9 Paper and board – Identification of machine and cross direction

Annex
Comparison with other thickness methods

Six laboratories tested seven papers under normal laboratory conditions using test pieces from the same gross sample. The structural thickness was determined according to this SCAN-test Method, the single sheet thickness was determined according to ISO 534 and the bulking thickness for a given number (b) of sheets according to ISO 534. Average values and the relations between the different thickness results are given.

Paper type	Structural thickness, t_s, µm	Single sheet thickness, t_1, µm	Bulking thickness, t_b, µm	$\frac{t_1 - t_s}{t_s}$, %	$\frac{t_b - t_s}{t_s}$, %	No of sheets for bulking thickness, (b)
Newsprint, 45 g/m²	64	74	73	16	15	10
LWC, 60 g/m²	48	53	52	11	9	10
Copy paper, 80 g/m²	92	99	97	9	6	10
Sack paper, 90 g/m²	102	115	108	13	6	10
Kraftliner, 300 g/m²	371	403	388	9	5	5
Fluting, 150 g/m²	218	268	235	23	8	5
Carton board, 240 g/m²	292	299	299	3	2	5

A.1 Precision, single sheet thickness

A.1.1 Repeatability

Six laboratories tested seven papers under normal laboratory conditions using test pieces from the same gross sample. The laboratories evaluated the repeatability of the single sheet thickness by testing the seven papers five times in the same thickness apparatus. The results for single sheet thickness, t_1, were as follows:

Paper type	CV within labs, %
Newsprint, 45 g/m²	1,5
LWC, 60 g/m²	2,0
Copy paper, 80 g/m²	1,6
Sack paper, 90 g/m²	2,7
Kraftliner, 300 g/m²	2,1
Fluting, 150 g/m²	4,3
Carton board, 240 g/m²	0,8

A.1.2 Reproducibility

The reproducibility was also determined. The results for single sheet thickness, t_1, were as follows:

Paper type	CV between labs, %
Newsprint, 45 g/m²	0,7
LWC, 60 g/m²	0,7
Copy paper, 80 g/m²	0,6
Sack paper, 90 g/m²	1,0
Kraftliner, 300 g/m²	0,6
Fluting, 150 g/m²	2,5
Carton board, 240 g/m²	0,3

CV = the Coefficient of Variation.

A.2 Precision, bulking thickness

A.2.1 Repeatability

Six laboratories tested seven papers under normal laboratory conditions using test pieces from the same gross sample. The laboratories evaluated the repeatability of the bulking sheet thickness by testing the seven papers five times in the same thickness apparatus. The results for bulking thickness, t_b, were as follows:

Paper type	CV within lab, %	Number of sheets, (*b*)
Newsprint, 45 g/m^2	0,5	10
LWC, 60 g/m^2	0,6	10
Copy paper, 80 g/m^2	0,6	10
Sack paper, 90 g/m^2	0,7	10
Kraftliner, 300 g/m^2	0,8	5
Fluting, 150 g/m^2	1,4	5
Carton board, 240 g/m^2	0,4	5

A.2.2 Reproducibility

The reproducibility was also determined. The results for bulking thickness, t_b, were as follows:

Paper type	CV between labs, %	Number of sheets, (*b*)
Newsprint, 45 g/m^2	0,4	10
LWC, 60 g/m^2	0,5	10
Copy paper, 80 g/m^2	0,2	10
Sack paper, 90 g/m^2	0,4	10
Kraftliner, 300 g/m^2	0,6	5
Fluting, 150 g/m^2	0,5	5
Carton board, 240 g/m^2	0,3	5

SCAN-test Methods are issued and recommended by KCL, PFI and STFI-Packforsk for the pulp, paper and board industries in Finland, Norway and Sweden.
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