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SCANDINAVIAN PULP, PAPER AND BOARD
TESTING COMMITTEE

Paper and board

Surface roughness and surface compressibility

Bendtsen method with pressure correction

0 Introduction

This SCAN-test Method specifies a modified procedure for measuring Bendtsen roughness. The correction for the pressure drop to the measuring head gives a more accurate but also a significantly higher value than that obtained according to the withdrawn SCAN-P 21 (12.1). A wider useful measuring range is also obtained.

> *Note* – Traditional Bendtsen testers with variable area flow meters can be used provided they are equipped with an updated measuring head and an additional pressure gauge.

This SCAN-test Method gives an indirect measure of the roughness of a paper surface using an air-leak technique. Although no attempt is made in this Method to convert the measured air-flow rate into a physical measure of the roughness, air-flow rates determined by this procedure have been found to be useful as measures of surface roughness.

1 Scope

The Method is applicable to all kinds of paper and board having a Bendtsen roughness in the range 50 ml/min to 5000 ml/min.

2 Reference

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

> *Note* – SCAN-test has withdrawn a number of test methods and refers instead to the corresponding ISO and/or EN Standards.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 *Surface roughness* – The volume of air that, under a specified pressure difference, passes in unit time between the surface of the paper and a flat metal ring which rests on the paper and exerts a specified pressure on it.

> *Note* – The paper is backed by a plane-ground glass plate, see *Figure 1.*

3.2 *Surface compressibility, K* – The percentage decrease in surface roughness when measurements are made consecutively without moving the test piece at the two standard contact pressures specified in this Method, i.e.;

$$K = 100\frac{G_1 - G_2}{G_1} \qquad [1]$$

where

G_1 is the surface roughness value obtained under a contact pressure of 98 kPa;

G_2 is the surface roughness value obtained under a contact pressure of 490 kPa.

4 Principle

The roughness of paper or board is assessed by measuring the flow of air which passes between the edge of a measuring head and the surface of the material under specified conditions *(*see *Figure 1)*.

5 Apparatus

5.1 *A Bendtsen surface-roughness tester, Figure 1,* including:

5.1.1 *A compressed-air-supply system,* that is capable of delivering a sufficient amount of compressed air (depending on the type of instrument used) at a sufficient pressure.

5.1.2 *A pressure regulator*, or other means, to create a steady and repeatable measuring pressure of (1,47 ± 0,3) kPa in the measuring head.

Note 1 – Alternative pressures (e.g. 0,74 kPa and 2,20 kPa) are often available and can be used to further increase the measuring range of the instrument. Their use is not, however, in accordance with this Method.

5.1.3 *A measuring head, Figure* 2, having an air inlet tube and a flat ring (the measuring edge) made of acid-proof steel. The edge has a mean thickness of (0,15 ± 0,01) mm and an inner diameter of (31,5 ± 0,2) mm. The variation range of the thickness readings should not exceed 0,02 mm.

The measuring nip between the measuring head and a flat glass plate (see 5.2 and figure 2) shall be designed so that the contact pressure between the ring and the paper is 98 kPa ± 15 %, when the buoyancy of the air at the specified air pressure is taken into account.

5.1.4 *An extra weight* or other device to enable a contact pressure of 480 kPa ± 15 % to be achieved between the ring and the paper when the surface compressibility is to be measured.

5.1.5 *An air-flow meter,* having a measuring range of between 20 ml/min and 3000 ml/min, that allows the air flow to be determined with an error of less than ±5 ml/min or ±5 % of the reading whichever is the greater.

5.1.6 *A pressure meter*, that allows the air pressure in the measuring head to be determined with an error of less than 50 Pa.

Note 2 – Care must be taken to ensure that the pressure meter is fitted in a manner which does not affect the contact pressure.

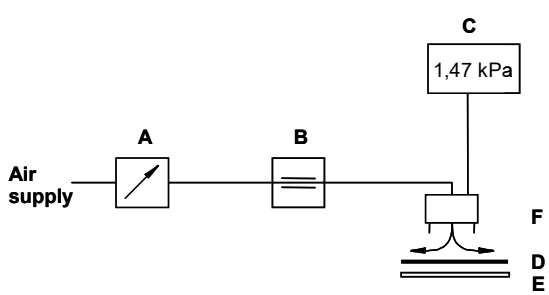

Figure 1. Principle of the Bendtsen tester

A Pressure regulator
B Flow meter
C Pressure meter for actual pressure in the measuring head
D Paper
E Glass plate
F Measuring head

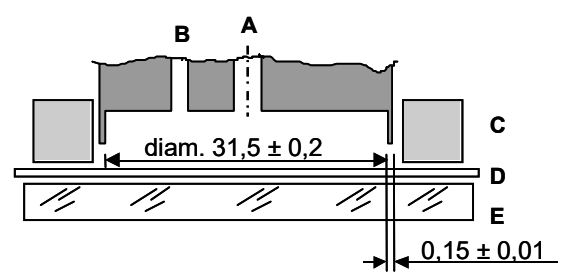

Figure 2. Principle of measuring head (dimensions in millimetres)

A Measuring air inlet
B Pressure measurement connection
C Loading device to flatten the test piece
D Paper
E Glass plate

5.2 *A plane float-glass plate,* such that when the measuring head is placed directly in contact with the glass plate under the pressure prescribed in 5.1.3, the air flow shall not exceed 5 ml/min.

5.3 *A loading device*, with a hole for the measuring head, which acts on the test piece to flatten stiff paper or board against the glass plate. This shall be designed so that it exerts a flattening force on the paper without disturbing the contact pressure within the measuring nip.

6 Calibration and adjustment of apparatus

Place the Bendtsen tester (5.1) in a vibration-free environment or use a vibration-damping foundation. Make sure the instrument is level. Use a precision spirit level and adjust the instrument, or the table, if necessary. Check and, if necessary, calibrate the tester with traceable tools and in accordance with the manufacturer's instructions.

Note – The readings from the instrument are strongly influenced by vibrations. It is therefore important to eliminate this source of error as far as possible.

7 Preparation of test pieces

Condition the specimens as specified in ISO 187 and keep them in the conditioning atmosphere throughout the test. Select test pieces from undamaged paper, free from watermarks and from folds, wrinkles or other defects not normally inherent in the paper.

Cut test pieces, at least 10 test pieces for each side of the sample, having a minimum size of 50 mm × 50 mm. Mark the test pieces to identify the two sides. Do not handle that part of the test piece, which will become the test area.

8 Procedure

8.1 Surface roughness

Make the instrument ready for use and select, if applicable, a measuring range for the air-flow meter.

Carefully bring the measuring head and the glass plate (5.2) into contact and check that the pressure is (1,47 ± 0,3) kPa.

Carefully follow the manufacturer's instructions and introduce a test piece into the measuring nip between the measuring head (5.1.3) and the glass plate (5.2), taking care to avoid excessive manual pressure or twisting.

Check whether the use of the loading device (5.3) will influence the result level or the coefficient of variation. If this is the case, the loading device must be used.

Note – Extreme care must be taken to ensure that the measuring head is not damaged by contact with the loading device.

Record the flow, V_m, after (4 ± 1) s. At the same time, record the pressure, P_m, on the measuring head pressure gauge.

Repeat the test with the remaining test pieces until in total 10 approved results for the same side of the sample have been obtained. If desired, repeat the test on the other side of the sample until at least 10 approved results from that side of the test pieces have been obtained.

Note – Normally, it is the field of application of the product that determines if the surface roughness shall be measured on both sides of the sample, and if those results shall be reported separately for the two sides.

8.2 Surface compressibility

Follow the instructions in 8.1. For electronic instruments, see the manufacturer's manual for advice on settings etc. Record the first measurement value, G_1, and then carefully add the additional mass (5.1.4) to the head and record the result, G_2, after (4 ± 1) s.

9 Calculation

9.1 Surface roughness

In instruments that automatically correct for the pressure drop to the measuring head, use the values as reported.

If no pressure correction is made, calculate the corrected flow from the expression:

$$V_{corr} = V_m \cdot \frac{P_o}{P_m} \qquad [2]$$

where

V_{corr} is the corrected flow, in millilitres per minute;
V_m is the measured flow, in millilitres per minute;
P_o is the nominal pressure, in kilopascals (1,47 kPa);
P_m is the measured pressure at the measuring head, in kilopascals.

Calculate the mean roughness separately for each side of the paper. Report the results to the nearest ml/min.

9.2 Surface compressibility

Calculate the surface compressibility for each measurement position of the paper using equation [2]. Calculate the mean surface compressibility from each side of the paper and report it with two significant figures.

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 of the material tested;
(c) the side of the material tested;
(d) the test results as specified above;
(e) the standard deviation or coefficient of variation;
(f) any departure from the procedure described in this Method and any other circumstances that may have affected the results.

11 Precision

Sets of test pieces taken from the same gross samples of five different paper grades were tested at five different laboratories. Each test result is based on 20 test pieces. The results are presented in *Table 1*, the papers being presented in order of increasing mean roughness.

Table 1.

Sample	Surface roughness, ml/min	Within-test CV, %	Between-labs CV, %
Newsprint 1, 45 g/m^2	88	9	6
Newsprint 2, 45 g/m^2	103	14	12
Fine paper, 100 g/m^2	311	12	9
Sack paper 1, 70 g/m^2	928	8	7
Sack paper 2, 70 g/m^2	1284	7	11
Mean	543	10,3	9,3

CV is the coefficient of variation, i.e. the standard deviation expressed as a percentage of the mean. CV is fairly constant among the samples, and mean coefficients of variation have thus been calculated as the root mean squares of the coefficients for the different materials. The reproducibility limit, *R,* calculated as $R = t\sqrt{2}\,s$ where $t_{(n=5)}$=2,776, is thus 36,5 %. This means that there is a 95 % probability that the means of measurements made at two different laboratories will not differ by more than this amount.

12 Literature

12.1 SCAN-P 21 – Roughness of paper and paperboard determined with the Bendtsen tester (withdrawn 2006, ISO 8791-2 is recommended)

12.2 ISO 8791-2 – Paper and board – Determination of roughness/smoothness (air leak methods) – Part 2: Bendtsen method

13 Additional information

The Bendtsen tester, but not the measuring head, is the same as that described in SCAN-P 85 Paper and board – Air permeance – Bendtsen method with pressure correction.

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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