International Standard 438

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION•МЕЖДУНАРОДНАЯ ОРГАНИЗАЦИЯ ПО СТАНДАРТИЗАЦИИ•ORGANISATION INTERNATIONALE DE NORMALISATION

Paper — Determination of bulking thickness and apparent density

Papier — Détermination de l'épaisseur moyenne et de la masse volumique

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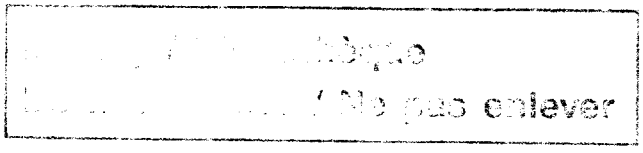

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Paper — Determination of bulking thickness and apparent density

1 Scope and field of application

This International Standard specifies a method of measuring the bulking thickness of paper of grammage up to 224 g/m^2. It also specifies a method of calculating the apparent density of the paper.

The method of measurement is not suitable for measuring the bulking thickness of certain soft papers, such as some felts and tissues which are crêped and/or embossed, due to the slow or excessive compression which takes place when measurements are made on such materials.

It should be noted that two alternative pressures are permitted (see table 1); the pressure of 100 ± 10 kPa is preferred.

NOTE — It is stressed that the bulking thickness of paper, obtained by the method specified in this International Standard, is not necessarily identical with the thickness of a single sheet of paper, obtained by the method specified in ISO 534 using the same apparatus.

2 References

ISO 186, *Paper and board — Sampling for testing.*

ISO 187, *Paper and board — Conditioning of samples.*

ISO 534, *Paper and board — Determination of the thickness of single sheets and the apparent density of board.*

ISO 536, *Paper and board — Determination of grammage.*

ISO 5725, *Precision of test methods — Determination of repeatability and reproducibility by interlaboratory tests.*

3 Definitions

3.1 bulking thickness : The thickness of a single sheet of paper, calculated from the thickness of several superimposed sheets (termed a pack), measured under an applied static load, using the standard method of test.

3.2 apparent density : The mass per unit volume of the paper, calculated from its grammage and bulking thickness, and expressed in grams per cubic centimetre.

4 Principle

4.1 Measurement of the thickness of a pack of sheets of paper over a specified area and under a specific static load by means of a high precision micrometer. Expression of results in terms of the bulking thickness per sheet.

4.2 Calculation of the apparent density of the paper from a knowledge of its grammage and bulking thickness.

5 Apparatus

5.1 Micrometer, provided with two plane parallel circular pressure faces, between which the paper is placed for measurement.

The pressure exerted between the pressure faces during the thickness measurement shall be as given in table 1. A dead weight shall be used, to ensure that the pressure between the faces is uniform within the limits stated.

Table 1 — Pressure between pressure faces

Pressure, kPa	Status of value
100 ± 10	Preferred
50 ± 5	Alternative

The pressure faces, two in number, shall form an integral part of the micrometer, such that one face is fixed and the second face is capable of movement in a direction perpendicular to the plane of the fixed face.

One face shall be 16,0 ± 0,5 mm in diameter, and the other face shall be of at least that diameter. Thus, a circular region of a test piece, nominally 200 mm^2 in area, is subjected, during the thickness measurement, to the pressure exerted between the faces.

The whole area of the smaller face shall be in contact with the larger face when the micrometer reading is zero.

The performance requirements of the micrometer shall be such that, when calibrated according to the method given in the annex, the micrometer complies with the requirements given in tables 1 and 2 (see also 9.1).

Table 2 — Micrometer performance requirements

Micrometer characteristic	Maximum permitted value
Indication error	± 2,5 µm or ± 0,5 %
Error of parallelism between pressure faces	5 µm or 1 %
Repeatability of measurement (as a standard deviation)	2,5 µm or 0,5 %

NOTES

1 The maximum permitted value of a micrometer characteristic is the greater of the two values quoted for it in the table.

2 Where a tolerance is expressed in the form of a percentage, it is based upon the thickness of the test piece undergoing test. Thus, it is possible for a given micrometer to comply with the requirements of the table for some materials, but not for others.

3 For measurements on very thin papers, an instrument with better performance than that specified may be required.

5.2 **Thickness gauges,** corresponding to approximately 10, 30, 50, 70 and 90 % of the full scale reading of the micrometer. Each gauge shall be accurate to 1 µm.

6 Sampling

Sample in accordance with ISO 186.

7 Conditioning

Condition the sample in accordance with ISO 187.

8 Preparation of test pieces

Prepare test pieces, each comprised of the same number of sheets, of at least five and preferably ten sheets. Note the number of sheets in each test piece.

Carry out the preparation in the standard atmospheric condition at which the sample was conditioned.

Cut each sheet from a specimen taken at random from those selected in accordance with clause 6. Ensure that each sheet is cut to dimensions of 200 mm × 250 mm if possible, the 200 mm dimension being in the machine direction (see the figure). If this is not feasible, prepare smaller test pieces at least 150 mm × 150 mm.

Superimpose the sheets to form the test piece, ensuring that the sheets all face the same way, for example, the wire side of one sheet rests against the top side of its neighbour. Each sheet shall be independent of the remainder; for example, one sheet folded and inserted into the test piece to form two or more sheets shall not be permitted.

Prepare at least 4 test pieces.

NOTE — In special circumstances, such as for thick or very thin sheets or when agreed between the manufacturer and the user, a smaller or larger number of sheets or a smaller or larger size of sheet may be used. The number of sheets used and their size shall be reported.

9 Procedure

9.1 Verification and calibration of micrometer

At appropriate intervals of time, calibrate the micrometer and verify its performance using the method given in the annex.

For micrometers in frequent use, determine the indication error and repeatability of measurement daily. Determine the pressure exerted between the pressure faces and their error of parallelism at monthly intervals.

When measurements are to be made on very thin papers, it may be necessary to verify the performance of the micrometer at the temperature at which it is to be used.

9.2 Determination

9.2.1 Bulking thickness

Carry out the test in the standard atmospheric condition at which the sample was conditioned.

Place the micrometer on a horizontal vibration-free surface and interpose the test piece between the open pressure faces of the micrometer. Permit the test piece to be held by the pressure faces by very carefully allowing the moveable pressure face to move steadily and slowly, at a velocity less than 3 mm/s, towards the fixed pressure face so that any punching effect is avoided. Record the micrometer reading as soon as its value becomes steady but before any "bedding-down" of the paper can occur. Avoid imposing any manual stress on the test piece or micrometer while a reading is being made.

Make one measurement at each of the five positions on the test piece that are indicated in the figure, that is, situated between 40 and 80 mm from the sides of the test piece and distributed along the two sides which are in the cross direction of the paper.

Dimensions in millimetres

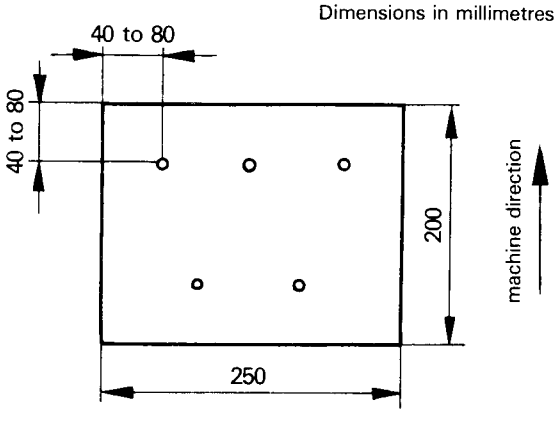

Figure — Positions of measurement on test piece

Carry out measurements on at least four test pieces.

9.2.2 Apparent density

If the apparent density of the paper is to be calculated, determine the grammage of the sample by the method specified in ISO 536.

10 Expression of results

10.1 Bulking thickness

10.1.1 Calculate the mean value of the readings (not fewer than 20). Divide it by the number of sheets comprising each test piece to obtain the bulking thickness of a single sheet of paper and express the result, in micrometres, to three significant figures.

10.1.2 Calculate the standard deviation of the bulking thickness.

10.1.3 Calculate the precision of the mean at the 95 % confidence level.

10.2 Apparent density

Calculate the apparent density, in grams per cubic centimetre, from the formula

$$\frac{g}{\delta}$$

where

δ is the bulking thickness of the paper, in micrometres;

g is the grammage of the paper, in grams per square metre.

Report the result to two decimal places.

11 Precision

11.1 Repeatability

Under routine laboratory conditions, repeatability varies from 0,1 µm to 0,5 µm, with a mean value of 0,31 µm, or from 0,1 % to 0,9 %, mean value 0,5 %.

The difference between the two single test values found on identical test material by one operator using the same micrometer within a short time interval will exceed the repeatability on average not more than once in 20 instances in the normal and correct operation of the method.

The values quoted above compare with a value of about 0,3 % calculated according to ISO 5725 from the specified micrometer performance requirements. The difference arises from the inherent variability of paper.

11.2 Reproducibility

Under routine laboratory conditions, reproducibility varies from 1,7 µm to 3,4 µm, with a mean value of 2,7 µm, or from 2,4 % to 6,2 %, mean value 3,7 %.

The difference between two single and independent results found by two operators working in different laboratories on identical test material will exceed the reproducibility on average not more than once in 20 instances in the normal and correct operation of the method.

The values quoted above compare with a value of about 0,65 %, calculated according to ISO 5725 from the specified micrometer performance requirements. The difference arises from the inherent variability of paper.

12 Test report

The test report shall include the following particulars :

a) reference to this International Standard;

b) precise identification of the sample;

c) date and place of testing;

d) the conditioning atmosphere used;

e) the pressure exerted between the micrometer pressure faces, if other than 100 ± 10 kPa;

f) the bulking thickness of the paper, to three significant figures;

g) the standard deviation of the bulking thickness;

h) the precision of measurement of the bulking thickness, in terms of its confidence limits at the 95 % probability level;

j) if required, the apparent density of the paper;

k) the number of test pieces used for the test;

l) the number of sheets used for each test piece;

m) the number of readings taken;

n) the grammage of the sample, if determined;

p) any departure from the procedure specified this International Standard, together with any circumstances or influences that may have affected the results.

Annex

Verification of micrometer performance and calibration

A.1 General

Verify the performance of the micrometer, using the following tests in the order given.

If the micrometer performance is not within the tolerance appropriate to a particular test (see 5.1), make the necessary correction and recommence the series of tests.

A.2 Planarity of pressure faces

Carefully wipe the pressure faces, open them slightly and observe the gap against a bright light. Look along the plane of the faces in two mutually perpendicular directions and verify that the gap is quite even.

A.3 Pressure exerted between pressure faces

Any suitable means of verifying the accuracy and uniformity of the pressure exerted between the pressure faces may be used.

A.4 Indication error and repeatability of measurement

A.4.1 With the pressure faces in contact with one another, set the micrometer reading to zero. Do not reset the zero reading during the following procedure.

A.4.2 Open the gap between the pressure faces, allow it to close again (see 9.2) so that the pressure faces make contact with one another, and note the micrometer reading. Repeat this procedure at least 5 times.

A.4.3 Take one of the thickness gauges specified in 5.2, open the gap between the pressure faces, interpose the gauge, allow the faces to close upon the gauge (see 9.2), and note the micrometer reading. Repeat this procedure at least five times.

A.4.4 Repeat the procedure described in A.4.3, using, in turn, each of the remaining thickness gauges.

NOTE — The thickness gauges shall be used singly, not in combination.

A.4.5 Repeat the procedure described in A.4.2.

A.4.6 For each gauge thickness at which micrometer readings are taken, calculate :

a) the repeatability of measurement, that is, the standard deviation of the five, or more, readings taken;

b) the indication error, that is, the difference between the mean of the five, or more, readings taken and the gauge thickness.

A.5 Parallelism of pressure faces

A.5.1 Take one of the thickness gauges specified in 5.2, open the gap between the pressure faces and position the gauge in the gap, as near as possible to one edge of the faces. Allow the pressure faces to close upon the gauge (see 9.2), and note the micrometer reading.

A.5.2 Open the gap between the pressure faces and position the thickness gauge in the gap, as near as possible to the edge of the faces and diametrically opposite the edge used in A.5.1. Allow the pressure faces to close upon the gauge (see 9.2), and again note the micrometer reading.

A.5.3 Repeat the procedure described in A.5.1 and A.5.2, using positions as near as possible to the edge of the pressure faces and on a diameter perpendicular to that passing through the points referred to in A.5.1 and A.5.2.

A.5.4 Repeat the procedure described in A.5.1, A.5.2 and A.5.3, using, in turn, each of the remaining thickness gauges.

NOTE — The thickness gauges shall be used singly, not in combination.

A.5.5 For each gauge thickness at which micrometer readings are taken, calculate the error of parallelism from the formula

$$0{,}5\sqrt{d_1^2 + d_2^2}$$

where

d_1 is the difference between the readings corresponding to opposite ends of a diameter of the pressure faces;

d_2 is the difference between the readings corresponding to opposite ends of a diameter of the pressure faces perpendicular to that used to obtain d_1.