International Standard ISO 4288

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

Rules and procedures for the measurement of surface roughness using stylus instruments

Règles et procédures pour le mesurage de la rugosité de surface avec des instruments à palpeur

First edition — 1985-05-01

UDC 620.179.118 **Ref. No. ISO 4288-1985 (E)**

Descriptors : surface condition, roughness, roughness measurement, inspection.

Price based on 6 pages

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work.

Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council. They are approved in accordance with ISO procedures requiring at least 75 % approval by the member bodies voting.

International Standard ISO 4288 was prepared by Technical Committee ISO/TC 57, *Metrology and properties of surfaces.*

Rules and procedures for the measurement of surface roughness using stylus instruments

0 Introduction

This International Standard is intended to assist in obtaining correct and comparable results when inspecting workpieces during manufacturing processes and also for finished products with respect to their surface roughness.

1 Scope and field of application

This International Standard specifies rules and procedures for the measurement of surface roughness parameters R_a, R_y and R_z using stylus instruments of consecutive profile transformation and measuring systems with computers in which these instruments are used.

NOTE — Surface roughness parameters S_m, S and t_p will be dealt with after rules and procedures for their measurement are agreed upon.

2 References

ISO 468, *Surface roughness — Parameters, their values and general rules for specifying requirements.*

ISO 1879, *Instruments for the measurement of surface roughness by the profile method — Vocabulary.*

ISO 1880, *Instruments for the measurement of surface roughness by the profile method — Contact (stylus) instruments of progressive profile transformation — Profile recording instruments.*

ISO 2602, *Statistical interpretation of test results — Estimation of the mean — Confidence interval.*

ISO 2632, *Roughness comparison specimens —*

Part 1 : Turned, ground, bored, milled, shaped and planed.

Part 2 : Spark-eroded, shot-blasted and grit-blasted, and polished.

Part 3 : Cast surfaces.

ISO 3274, *Instruments for the measurement of surface roughness by the profile method — Contact (stylus) instruments of consecutive profile transformation — Contact profile meters, system M.*

ISO 4287/1, *Surface roughness — Terminology — Part 1 : Surface and its parameters.*

3 Definitions

For the purposes of this International Standard, the terms and definitions given in the standards referred to above shall apply where relevant.

4 General

In order to decide whether or not a particular manufacturing process gives the required surface finish, it is necessary to compare the values of the roughness parameters of the workpiece surface with the requirements specified on the drawings or in technical documents.

The surface roughness of the workpiece being inspected can appear homogeneous or be quite different over various areas. This can be seen by visual examination of the surface. In cases when the surface roughness appears homogeneous, roughness parameter values determined along the whole surface shall be used for comparison with the requirements specified on the drawings or in technical documents.

If there are separate areas with obviously different surface roughness, the surface roughness parameter values which are determined on separate areas shall be used for comparison with the requirements specified on the drawings or in technical documents.

For requirements specified by the upper limit of the surface roughness parameter, those separate areas of the surface shall be used which appear to have the maximum roughness, i.e. the maximum values of the surface roughness parameter. For requirements specified by the lower limit of the surface roughness parameter, those separate areas of the surface shall be used which appear to have the minimum roughness. If the roughness of the surface being inspected or of some of its areas differs substantially from the value specified on the drawings, then the method of visual evaluation or the method of comparison with roughness specimens in accordance with ISO 2632/1, ISO 2632/2 and ISO 2632/3 can be used for the surface roughness inspection. In these cases the above methods can give single-valued results. In other cases methods of measurement using instruments should be used.

For requirements specified by the upper limit of the surface roughness parameter, the surface is considered acceptable if not more than 16 % of all the measured values of the surface roughness parameter exceed the value specified on the drawings or in technical documents. In cases where the lower limit is specified, the surface is considered acceptable if not more than 16 % of all the measured values of the surface roughness parameter can be exceeded by the specified value.

For requirements specified by the maximum value of the surface roughness parameter during surface roughness inspection, none of the measured values of the surface roughness parameter of the whole surface being inspected shall exceed the value specified on the drawings or in technical documents.

If the roughness requirements are not specified for a surface, the roughness of that surface should not be inspected.

NOTES

1 To designate the maximum permissible value of the surface roughness parameter, Technical Committee ISO/TC 57 has recommended the use of the symbol of the surface parameter with the "max" index (for example, $R_{y\,max}$). To designate the upper and the lower limits of this parameter, the use of the symbol of the surface roughness parameter without the "max" index is recommended. A final decision on this matter will be made by Technical Committee ISO/TC 10, *Technical drawings*.

2 In cases when the values of the roughness parameter of the surface being inspected are distributed according to the normal law, the determination of the upper limit as a limit which may be exceeded by 16 % of the measured values of the surface roughness parameter conforms with the limit, determined by the value $\mu + \sigma$, where μ is the arithmetic mean value of the surface roughness parameter, and σ is the standard deviation of the values. The greater the value of σ, the further from the specified limit (the upper value) is the mean value of the surface roughness parameter. See figure 1.

5 Evaluation length

To decide whether or not a workpiece surface is in accordance with the specification, a set of single values of the surface roughness parameter, each determined from a number of sampling lengths constituting one evaluation length, shall be used.

Using these measured values, the mean value of the surface roughness parameter can be determined in accordance with ISO 4287/1.

The reliability of the decision as to whether or not the surface being inspected meets the specification and the precision of the mean value obtained for the surface roughness parameter of the same surface depend on the number of sampling lengths within the evaluation length along which the single value of the surface roughness parameter is obtained and also on the number of evaluation lengths, i.e. the number of measurements along the surface. The minimum evaluation length is equal to the sampling length. The evaluation length including five consecutive sampling lengths (cut-offs) is taken as the standard.

The greater the number of measurements along the surface and the evaluation length, the greater is the reliability of the decision as to whether the surface being inspected meets the specification and the higher is the precision of determination of the roughness parameter mean value.

However, an increase in the number of measurements leads to an increase in the measurement time and the costs of measurement. Therefore the inspection procedure shall necessarily reflect a compromise between reliability and cost. A description of one of the possible procedures of the workpiece surface roughness inspection is given in the annex.

6 Rules and procedures for inspection using stylus instruments

6.1 Measurement of single values of surface roughness parameters

The cut-off is to be chosen equal to the sampling length specified in the requirements for the surface roughness of the workpiece being inspected.

In the majority of cases it is not necessary to specify the values for sampling lengths on drawings or in technical documents; in these cases, when measuring the R_a, R_y and R_z parameters, the values given in tables 1, 2 or 3 shall be used.

However, in special cases which require the choice of values of sampling length other than those specified in the tables, sampling and evaluation lengths shall be stated.

Table 1 — Sampling lengths for the measurement of R_a of non-periodic profiles
(for example ground profiles)

R_a µm over	R_a µm up to (inclusive)	Sampling length l mm	Evaluation length l_n mm
(0,006)	0,02	0,08	0,4
0,02	0,1	0,25	1,25
0,1	2,0	0,8	4,0
2,0	10,0	2,5	12,5
10,0	80,0	8,0	40,0

Table 2 — Sampling lengths for the measurement of R_z and R_y of non-periodic profiles
(for example ground profiles)

R_z, R_y µm over	R_z, R_y µm up to (inclusive)	Sampling length l mm	Evaluation length l_n mm
(0,025)	0,10	0,08	0,4
0,10	0,50	0,25	1,25
0,50	10,0	0,8	4,0
10,0	50,0	2,5	12,5
50,0	200,0	8,0	40,0

Table 3 — Sampling lengths for the measurement of R_z, R_y and R_a of periodic profiles
(for example turned profiles)

Values in millimetres

S_m over	S_m up to (inclusive)	Sampling length l	Evaluation length l_n
(0,01)	0,032	0,08	0,4
0,032	0,1	0,25	1,25
0,1	0,32	0,8	4,0
0,32	1	2,5	12,5
1	3,2	8,0	40,0

NOTE — Although the S_m parameter in table 3 is defined in ISO 4287/1, for practical use of table 3 it is necessary for this parameter to be determined either from the surface itself or graphically.

With routine measurements a skid can be used, the radius of curvature of which should be not less than 50 times the sampling length (cut-off).

Since the radius of curvature of the skid can cause distortion of the trace of the profile being measured, in measurements where high accuracy is required, on complex workpieces and also when the sampling length is 2,5 mm and greater, it is preferable to use an independent datum.

When the direction of measurement is not specified, the workpiece should be positioned so that the direction of the section corresponds to the maximum values of height parameters of the surface roughness (R_a, R_y or R_z). This direction will be normal to the lay of the surface being measured. For isotropic surfaces the direction of the section can be random.

Measurements should be carried out on that part of the surface on which critical values can be expected; this can be assessed by visual examination. Separate measurements should be distributed equally over this part of the surface to obtain independent measurement results.

6.2 Defining the mean line

When using profile meters with electric wave filters (see ISO 3274), the mean line is defined by the instrument itself.

In measuring systems with computers, the mean line is determined using the relevant programs (software).

6.2.1 Drawing of the mean line on a graph

When the instrument does not provide the mean line, it may be determined using the graph by one of the following simplified methods. The methods cannot be used in measuring systems with digital computers.

If the graph is recorded without electrical filters, the mean line should be drawn within the limits of the sampling section $l_p = l \cdot V_h$, where V_h is the horizontal magnification.

If the graph is recorded using an electrical filter with a given cut-off, the mean line can be drawn within the limits of the evaluation length section l_{np}.

6.2.1.1 Visual method

Within the limits of the representative lengths (sampling length of graph or evaluation length of graph) the mean line is drawn visually such that it is parallel to the general direction of the profile and that the areas between this line and the profile above and below the mean line are equal.

It is not necessary to draw the mean line to evaluate the R_y value. In this case the line of peaks and valleys should be drawn parallel to the general direction of the profile.

6.2.1.2 Averaging method

A straight line is drawn through points a_1 and a_2 on the graph within the representative length (sampling section or the evaluation section) : see figure 2. Coordinates of points a_1 and a_2 are determined using the formulae :

$$h_{a1} = \frac{2}{N} \sum_{i=1}^{N/2} h_{pi} ; \qquad x_{a1} = \frac{1}{4} N \cdot \Delta x \cdot V_h$$

$$h_{a2} = \frac{2}{N} \sum_{i=\frac{N}{2}+1}^{N} h_{pi} ; \qquad x_{a2} = \frac{3}{4} N \cdot \Delta x \cdot V_h$$

where

N is the number of discrete points on the graph, the distance between which is Δx (the sampling interval);

l_p is the sampling section on the graph;

$l_p = l \cdot V_h$

l_{np} is the evaluation length section on the graph;

$l_{np} = l_n \cdot V_h$

l is the sampling length;

l_n is the evaluation length;

V_h is the horizontal magnification of the graph;

$N = \frac{l_p}{\Delta x \cdot V_h}$ for a graph recorded without filtration;

$N = \frac{l_{np}}{\Delta x \cdot V_h}$ for a graph recorded with filtration;

h_{pi} are the ordinates of the graph in the reference system of coordinates.

6.2.2 Mean line for measuring systems with computers

Programs (software) employ the following formula for the determination of the mean line :

$$m = a + \text{tg}\,\alpha\,(x - \bar{x})$$

where $\bar{x}$ is the point lying in the middle of the sampling length l.

The angle α can be determined from the following formula :

$$\text{tg}\,2\alpha = 2\,\frac{\Delta x\left[\sum_{i=1}^{N} i\,h_i - a\,\frac{N(N+1)}{2}\right]}{(\Delta x)^2\,\frac{N(N^2-1)}{12} - \sum_{i=1}^{N} h_i^2 + a^2 N}$$

Coefficient a should be determined from the formula :

$$a = \frac{1}{N}\sum_{i=1}^{N} h_i$$

where

h_i are the profile ordinates in discrete points; the distance between these points is equal to the sampling interval Δx;

N is the number of points within the selected section;

i is the ordinate number;

Δx is the sampling interval.

6.3 Evaluation of the standard deviation of the mean value of surface roughness parameter

The standard deviation of surface roughness parameter should be determined, if necessary, according to the statistical methods given in ISO 2602.

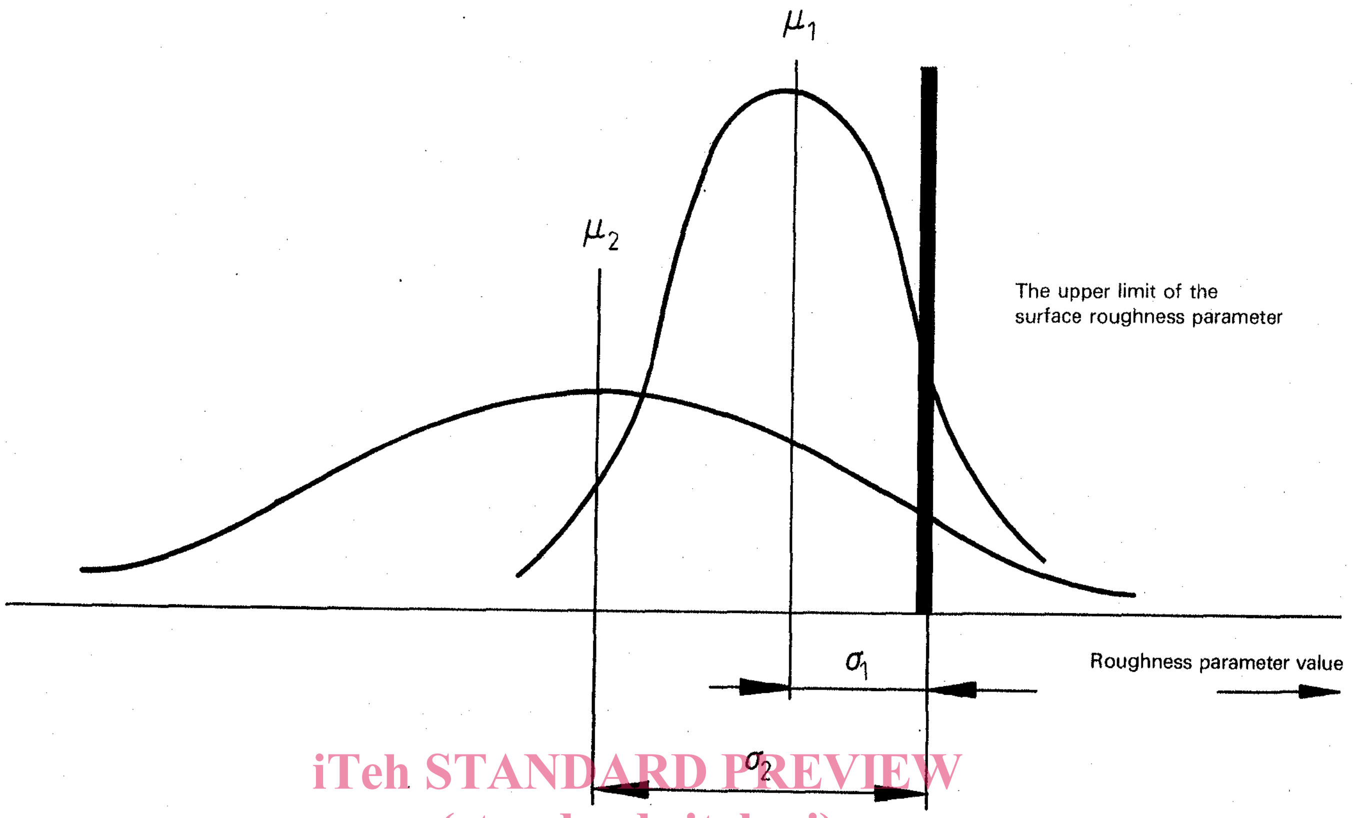

Figure 1

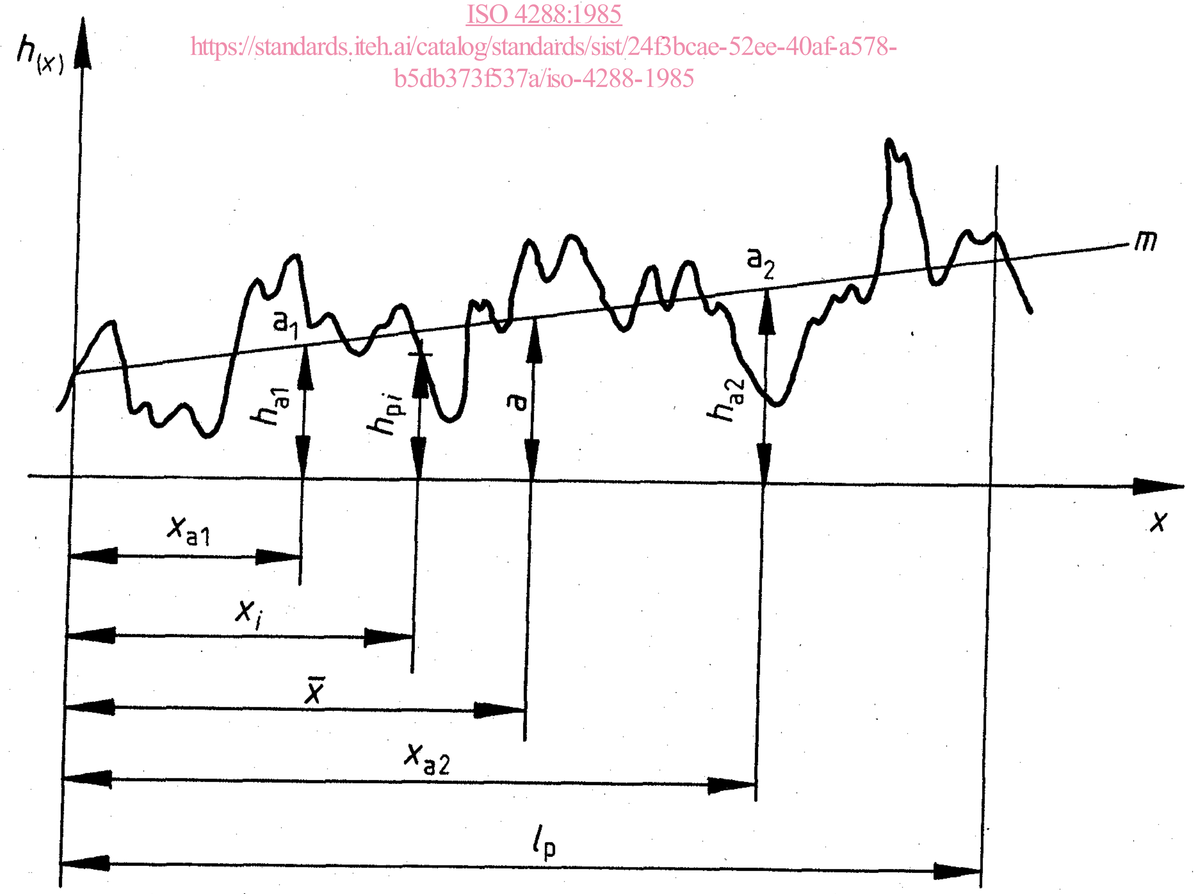

Figure 2

Annex

A procedure for surface roughness inspection

(For information purposes only.)

A.1 Inspection

The following example illustrates one of a number of methods of workpiece surface roughness inspection.

A.2 Visual test

Visually inspect workpieces to select those where it is obvious that inspection by more precise methods is unnecessary, for example because the roughness is obviously better or obviously worse than that specified, or because a surface defect which substantially influences the function of the surface is present.

A.3 Comparison test

If the visual test does not allow a decision, tactile and visual comparisons with roughness comparison specimens should be carried out : see ISO 2632/1, ISO 2632/2 and ISO 2632/3.

A.4 Measuring inspection

If the comparison test does not allow a decision to be taken, measurement should be performed as follows.

The measurements should be carried out on that part of the surface on which the critical values can be expected, according to visual examination.

A.4.1 Where the indicated parameter symbol does not contain the index "max" initially, the surface will be accepted and the test procedure stopped if :

- the first measured value does not exceed 70 % of the specified value (indicated on the drawing);
- the first three measured values do not exceed the specified value;
- not more than one of the first six measured values exceed the specified value;
- not more than two of the first twelve measured values exceed the specified value.

Sometimes, for example before rejecting high value workpieces, more than 12 measurements may be taken, for example, 25 measurements with up to four exceeding the specified value.

A.4.2 Where the indicated parameter symbol does contain the index "max", usually at least three measurements are taken from that part of the surface from which the highest values are expected (for example, where a particularly deep groove is visible), or equally spaced if the surface gives the impression of homogeneity.

The most reliable results of surface roughness inspection are achieved with the help of measuring instruments. Therefore, rules and procedures for inspection of the most important details can be followed with the use of measuring instruments from the very beginning.