EAL European cooperation for Accreditation of Laboratories

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Calibration of Stylus Instruments for Measuring Surface Roughness

PURPOSE

This document has been produced by EAL to improve the harmonisation in surface roughness measurement. It provides guidance to national accreditation bodies to set up minimum requirements for the calibration of stylus instruments and gives advice to calibration laboratories to establish practical procedures.

Authorship

This publication has been written by EAL Committee 2 (Calibration and Testing activities).

Official language

The text may be translated into other languages as required. The English language version remains the definitive version.

Guidance Publications

This document represents a consensus of EAL member opinion and preferred practice on how the relevant clauses of the accreditation standards might be applied in the context of the subject matter of this document. The approaches taken are not mandatory and are for the guidance of accreditation bodies and their client laboratories. Nevertheless, the document has been produced as a means of promoting a consistent approach to laboratory accreditation amongst EAL member bodies, particularly those participating in the EAL Multilateral Agreement.

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1 Introduction

1.1 The purpose of this technical guideline is to improve the harmonisation within EAL for surface roughness measurement. It provides guidance to national accreditation bodies to set up minimum requirements for the calibration of stylus instruments and gives advice to calibration laboratories to establish practical procedures. The guideline is based on a national calibration guideline [ref. 1]. In the first part (sections 2, 3 and 4), the general definitions, the reference standards to be used and the technical requirements for the calibration of stylus measurement instruments are given. The second part of this guideline is of procedural nature and gives practical advice to calibration and testing laboratories. In section 5 an example of a typical calibration procedure is presented. It may be amended or modified to meet the specific requirements of accreditation.

2 Scope and field of application

2.1 This guideline applies to the calibration of stylus instruments for the measurement of surface roughness by the profile method as defined in ISO 3274 [ref. 2]. The calibration shall be carried out with the aid of reference standards. The guideline is intended only for instruments with pick-ups with independent datum.

2.2 Components: The stylus instrument comprises the basic equipment (indicator, evaluation and control units), a traverse unit, a probe (pick-up) with the stylus and a profile recorder. Only complete combinations of instruments are qualified for calibration. If the basic equipment is used with several traverse units and pick-ups, each of these instrument combinations shall be calibrated separately.

2.3 Site of calibration: The stylus instrument shall be calibrated at the place of use, so that all the ambient conditions which will influence the instrument in service, are taken into consideration.

Note: General requirements for the accreditation of laboratories and organisations performing site calibrations are given in Publication EAL-R3 [ref. 3].

3 Terminology

3.1 The surface roughness parameters are defined in ISO/DIS 4287-1.2 [ref. 4]:

P_t total height of profile over evaluation length

R_a arithmetical mean deviation of roughness profile over five sampling lengths

R_z average height of roughness profile over five sampling lengths

R_{z1max} maximum height of roughness profile over one sampling length

The measuring conditions are described in ISO/DIS 4287-1.2 [ref. 4] and ISO 4288 [ref. 5] using a profile filter according to ISO 11562 [ref. 6].

4 Reference standards

4.1 The stylus instrument shall be calibrated by means of reference standards. Among other standards of similar type, the following proved to be appropriate:

(a) Optical flat. Reproduces the residual profile; the effects of external datum straightness, environmental conditions and instrument noise can be established.

(b) Depth measurement standard, type A1 or A2 according to ISO 5436 [ref. 7] (Fig.1): Reproduces the profile depth P_t; ensures the traceability of the vertical profile component to the unit of length.

(c) Roughness measurement standards, preferably type D according to ISO 5436 [ref. 7] (Fig. 2): Reproduce the arithmetic mean deviation R_a and the maximum height of profile R_z and R_{z1max} establishing an overall check of the instrument.

4.2 Dependent on the type and the metrological characteristics of the instrument to be calibrated, the following standards may be used as well:

(a) inclination standard

(b) sphere

(c) wavelength measurement standard type C according to ISO 5436 [ref. 7].

4.3 The depth and roughness measurement standards should be calibrated by a national metrology institute or an accredited laboratory capable of delivering the measurement uncertainty required for the specific application in question. The calibration interval should not exceed 5 years.

5 Example of a calibration procedure

5.1 The following procedure is taken from a national calibration guideline [ref. 1]. It refers to specific reference standards. Both the guideline and the reference standards have proven to be very useful and to lead to excellent agreement among accredited laboratories [ref. 8, 9]. Other standards of similar or different type are available from several manufacturers.

5.2 Preparation for calibration

5.2.1 Before calibration, check that the stylus instrument operates correctly as described in the manufacturer's operating instructions. Additional information can be taken from [ref. 8] if necessary.

5.2.2 Before calibration the following preparations have to be made:

(a) Establish the effects of external datum straightness, environmental conditions and instrument noise by measuring R_a and R_z of an optical flat. The measuring conditions are in accordance with those applied for the corresponding roughness standards (usually five sampling lengths over a total evaluation length of l_n = 4 mm and a cut-off wavelength of l_c = 0,8 mm for the filter). The measured R_a and R_z values must be indicated in the calibration certificate.

(b) Align the plane of the depth measurement standard to the datum axis in the best possible way, align the plane of the roughness measurement standard to within 10 % of the measuring range.

(c) Always select the smallest possible measuring range.

(d) Take measurements in the middle of the measuring range each time.

5.3 Calibration by means of a depth measurement standard

5.3.1 Measure each groove in five profile sections (Fig. 5.1). Probe the grooves individually in succession and determine the P_t value of the unfiltered profile (without automatic alignment). Indicate the deviation of the mean value (obtained from the 5 measured P_t values) from the value given in the calibration certificate of the depth measurement standard, in percent and in micrometers.

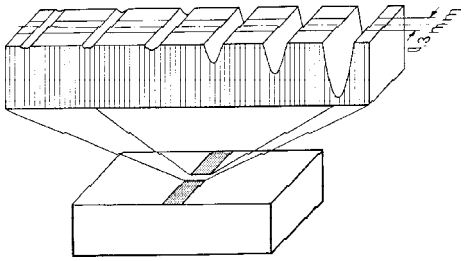

Figure 5.1. Depth setting standard (type A2) with enlarged area of measurement

5.4 Calibration by means of roughness measurement standards.

5.4.1 Carry out 12 measurements on each roughness measurement standard, distributed over the measurement surface as shown in the measurement location pattern (Fig.5.2). Measuring conditions: 5 sampling lengths over a total evaluation length of l_n = 4 and a cut-off wavelength of l_c = 0,8 mm for the filter. Calculate the arithmetical mean and the standard deviation for each roughness parameter. The deviations (in percent and in micrometers) of the mean from the value stated in the calibration certificate of the standard and the standard deviations are to be indicated in the certificate.

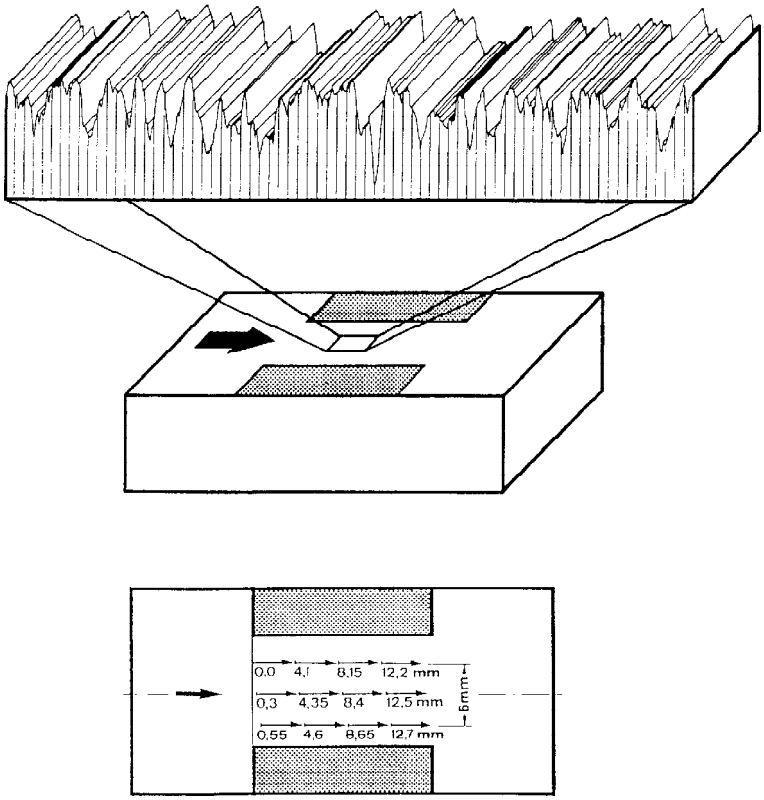

Figure 5.2. Roughness standard (type D) with enlarged area of measurement (above) and measurement location pattern with starting points and measurement lengths (below).

6 Uncertainty of measurement

6.1 The uncertainty of measurement shall be calculated according to EAL-R2 [ref. 10]. This means that all quantities (input estimates) contributing to the measurement result are treated as random variables. The square of the combined standard uncertainty is obtained by summing the variances of the input estimates. The expanded uncertainty is given with a coverage factor $k = 2$.

6.2 The uncertainty of the stylus instrument calibration consists mainly of the two components u_n and u_e :

(a) u_n is the standard uncertainty of the measured value of the standard as it is taken from the calibration certificate of the standard. It contains the uniformity of the reference standard.

(b) u_e is the standard uncertainty estimated by experience for transferring the measured value of the standard to the stylus instrument. It contains the instrument's repeatability on the same measurement length.

6.3 The total expanded uncertainty is given by:

$$U = 2\sqrt{u_n^2 + u_e^2}$$

The values rounded to an integer percent for the measured roughness parameters and rounded to integer hundredths of a micrometer for the groove depths are to be indicated in the calibration certificate.

Note: Since the surface of the roughness measurement standard is not perfectly uniform, the results of the measurements will scatter, resulting in a random component of the uncertainty, expressed by its experimental standard deviation. This random component, which is caused by the roughness standard, is already included in the uncertainty u_n of the roughness standard. It must therefore not be added to the component u_e once more, though this scattering of the measurement results is found again when the stylus instrument is calibrated.

7 Calibration certificate

7.1 The certificate of calibration shall be in conformance with EAL-R1 [ref. 11]. In particular it has to contain the following information:

(a) Identification of all relevant components of the complete instrument combination according to section 2 of this document.

(b) Site of calibration.

(c) Method of calibration.

d) Type of standards used, including their calibration value.

(e) Measuring conditions (measuring range, traverse speed applied, length probed, wavelength cut off, filter type, stylus tip radius).

(f) Results of the R_a and R_z measurements on the optical flat.

(g) The mean measured profile depth for each groove of the depth measurement standard and the deviations from their calibration values.

(h) The mean measured R_a and R_z values for each roughness measurement standard, their experimental standard deviation and the deviations from their calibration values.

(j) Each result has to be given with its uncertainty of measurement.

8 References

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