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Comparising measuring methods of pitch diameter of thread gauges and analysis of influences on the measurement results

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ABSTRACT

In this article, the differences between three calibration methods of the thread ring pitch diameter are being presented. Two of these methods are classical methods (executed on a 1D-length measuring machine with a two-ball stylus for mechanical probing and on a coordinate measuring machine also with a two-ball stylus for mechanical probing); the third method is a modern one, executed on a profile scanner to calculate the pitch diameter with an adjustment technique (least square fit).

To improve the measurement uncertainty of calibration of the thread ring pitch diameter for classical calibrations the methods were compared, by analyzing the influences on the measuring uncertainty and numerous measurements.

The thread ring pitch diameter measurements, which are the main topic of this article, were also incorporated into the international intercomparison, where the same thread ring was used as mentioned in this article.

1. Introduction

The calibration of the pitch diameter of thread rings has been significantly improved during the last years due to improvements in the field of calibration equipment used for calibration of threads. The classical methods and procedures for calibration of a pitch diameter of a thread ring, such as the two balls method, are well known since the 19th century and are executed by means of universal measuring machines [1], and in the last two decades even by means of coordinate measuring machines. More modern methods deal with scanning of the profile and the mathematical processing of the received data. These methods are executed on optical as well as on mechanical scanning machines.

In the last years the thread ring has been subject to comparative measurements at the annual international intercomparison LABCOM. The gained results were different, which means that the calibration results gained from different machines of individual laboratories did not match.

The influences on the uncertainty differ from method to method. The most common influences are the form deviation, and there is the influence of the mechanics of the measuring machine as well as the mechanical probing by means of the machine, which are considered to be less controllable. By comparing calibrations of the thread performed with different methods and by changing the influences of an individual method as well as statistical processing of gained results, the impact of the influences on uncertainty of the calibration of the thread ring pitch diameter could be reduced. The guidance for accreditation of the procedure and the calculation of the measuring uncertainty of all three calibration types is the Euramet document EURAMET/cg-10/v.01 [2].

2. Thread ring

If a point travels in a circle and in the same time performs a vertical move up or down, which is proportional to the

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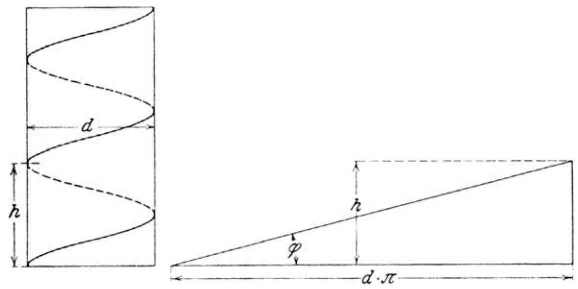

Fig. 1. Formation of the thread.

individual rotation angle than this point describes a thread (see Fig. 1). The easiest way of getting such a thread is to wind up a rectangular triangle around a round cylinder (with a diameter *d*), whereas the baseline of the triangle should be equal to the circumference of the cylinder ($d \cdot \pi$) – in this way its hypotenuse represents the screws line.

The cylinder, which is now equipped with a thread, represents the bolt; however, should the inner side of the cylinder be equipped with a thread, then it represents a ring.

The main parameters of a thread ring are: the maximum diameter (*D*), the lead (P), the flank angles (β, γ), thread angle (α), where $\alpha = \beta + \gamma$, the lead angle (ψ), the pitch thread diameter (*D*2). Fig. 2.

3. Categories of the thread ring calibrations

In this article three of altogether eight calibration categories will be compared, which deal with techniques of mechanical probing and are also described in chapter [2]. They describe the extent of measurements and refer to defining the pitch diameter of a thread, which we want to determinate.

3.1. Measurement of the diameter

The simple pitch diameter of a thread is calculated from the measured diameter, for which the incline and the measurement force must be corrected, and from the assumed nominal values of the lead and the angle of the thread.

3.2. Measurement of diameter and lead

The pitch diameter of a thread is calculated from the measured diameter and the measured lead, for which the incline and the measurement force must be corrected, and from the assumed nominal values of the distance and the angle of the thread.

3.3. Measurement of the 2D axial profile

The measurement of the whole profile allows a much more precise characterization of the thread as if measuring only certain points of it, because the profile of the thread ring is scanned and the desired parameters are mathematically calculated.

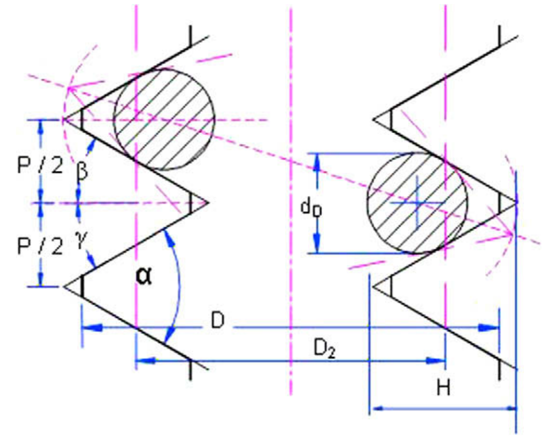

Fig. 2. Main parameters of a thread ring with an inserted measuring ball.

4. Basic considerations about the uncertainty of pitch diameter calibration

The already mentioned document [2] is used as guidance for all three compared types of calibration of the thread ring pitch diameter. Because of a wide range of thread ring types we decided to analyse the measuring uncertainty of metrical thread rings.

The calibrations differ in the used measuring machine, which determines D_2, or which parameters of the thread ring can be determined with this machine and how accurately they can be determined, which is even more important. The measuring uncertainty of the pitch diameter calibration of the thread ring also depends on the number of measured parameters of the thread ring and on the number of parameters, for which we assume to have nominal values. Influential contributions and coefficients (recommended to be considered by the EURAMET) which are needed to calculate the measuring uncertainty of the pitch diameter, are presented in Table 1.

Besides, the guidance claims the fact that the values are independent among each other. This is true, but D_2 is calculated out of nonlinear function and for that very reason we checked in what extent the links of the second degree influence the measuring uncertainty of the measurement.

5. Expanded approach to uncertainty evaluation of pitch diameter calibration

5.1. Mathematical model of the measurement

Bias (calibration result) is calculated by the expression according to [3]:

$$D_2 = \Delta L + C + d_D\left(\frac{1}{\sin(\alpha/2)} - 1\right) - \frac{P}{2}\cot(\alpha/2) + \frac{d_D}{2} \times \tan^2\psi \cdot \cos\frac{\alpha}{2} \cdot \cot\frac{\alpha}{2} - 4 \cdot \sqrt[3]{\frac{1}{d_D}} \cdot a_2 + \delta B \quad (1)$$

and a_2 is short expression for

$$a_2 = \sqrt[3]{\frac{9F^2}{8}\left(\frac{(1-\upsilon_1^2)}{E_1} + \frac{(1-\upsilon_2^2)}{E_2}\right)^2}, \quad (2)$$