Measurement and Evaluation Processes for Inner Micro Structures

T. Krah[1], A. Wedmann[1], K. Kniel[1], F. Härtig[1]
[1]*Physikalisch-Technische Bundesanstalt, Braunschweig und Berlin, Germany*

thomas.krah@ptb.de

Abstract

Inner micro structures can be found in a growing number of products, especially in medical equipment. Frequently, the quality requirements are very high, whereas the metrological possibilities are limited. The new T-shaped micro probe presented in this article forms an approach to solve this discrepancy. It allows high accurate tactile measurements at internal micro structures such as inner threads. First verification measurements are performed with the new probe applied in a 3D coordinate measuring machine (CMM). Furthermore, an approach for a laminar evaluation of the measured thread flanks is presented.

1 Introduction

In economic terms, a constant growth of the market for technical and medically functional components from the micro systems technology sector can be observed. These components are moulded by complex structures, whose accessibility frequently poses problems, especially when it comes to the employment of measurement devices. It is e. g. not uncommon for inner micro threads that inner micro structures with a dimension of less than 0.2 mm can be found. However, calibrations traceable to the SI units can only be performed until a minimal thread size of M3, the main reason being the lack of micro probing processes to facilitate a way of probing the complex inner structures. To eliminate this problem, a complete process chain for the calibration of complex inner micro structures has been developed by the Physikalisch-Technische Bundesanstalt (PTB), comprising the development and the implementation of innovative, robust T-shaped micro probes, their adaptation into a coordinate measuring machine (CMM) by means of especially designed calibration processes, and the performance of laminar analyses.

2 Design and fabrication of new T-shaped micro probes

The innovative T-shaped micro probes are characterised by the fact that the probe spheres are basically clamped and not, as hitherto common, glued or brazed to the shaft. By using this new method, not only a high stability, but also the possibility to replace spheres once they are worn out, and to reuse the shaft can be obtained. The original design of the micro probe is based on the patent [1] (Figure 1). The ideal stylus designs for different probe sphere diameters were identified with the help of FEM analyses, taking into consideration the stylus length, the elasticity, and the processibility. The objectives behind the design optimization were a maximization of the clamping force on the probe sphere and the avoidance of stress peaks.

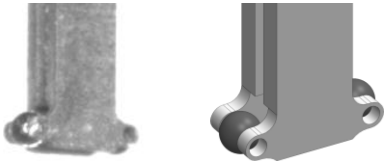

Figure 1: Design of a T-shaped micro probe (photograph and corresponding sketch)

Different probes were manufactured via micro wire cut EDM and die sinking. Special assembly jigs for the insertion of the probe spheres were developed and produced. Based upon this functional principle, it is currently possible to implement T-shaped micro probes with a probe sphere diameter of down to 120 µm. The geometric dimensions can be varied in a wide range. For probes with a probe sphere diameter of 120 µm the length of the shaft is set to 1.82 mm, its cross-section to 200 x 250 µm and the stylus constant (length between the spheres' outside [2]) to 490 µm.
Due to its design the T-shaped micro probe shows a highly anisotropic probing behavior. In order to get proper measurement results it is important to have a good knowledge of the probe's mechanical behavior. A universal characterization method for 3D tactile probing systems that is also suited for microprobes is described in [3].

3 Measurement and evaluation of inner micro structures

3.1 Measurement setup

The new T-shaped micro probe was adapted to a standard CMM. System parameters such as probing force and dynamics were adjusted to get reliable measurement results and simultaneously not do damage the probe. First verification measurements were carried out on a calibrated thread measurement standard with the dimension M3 x 0.5, which barely can be calibrated with common probes. Further measurements were carried out with so far uncalibrated micro threads with the dimensions M10 x 0.175, M0.9 x 0.175, and M0.7 x 0.175.

3.2 Standard conform evaluation

The measurements of the micro threads were carried out in the same way as measurements of macroscopic thread measurement standards [2]. The diameters were calculated by subtracting the x- respectively y-components of three measured points on opposite sides of the thread. For the calculation of the pitch diameter it is important that the probe sphere touches the thread on both sides of the gaps. Special attention was paid to the touch behavior of the micro probe in gaps. In microscopic dimensions parameters such as the roughness of surfaces, particles and fluidic layers have a much stronger impact on getting in contact on both sides of the thread gap than in macroscopic dimensions. The visual observation and the analysis of repeated measurements showed that a reliable contact of both flanks in the gap was performed.
The measurement results of the micro threads are in excellent accordance with the calibration results within the respective measurement uncertainties. Harmonious results were also achieved with first measurements of micro threads of the sizes M10, M0.9 and M0.7, each with a pitch of 0.175 mm, after applying the standard conform measurement strategy and evaluation of the customary thread parameters pitch, pitch diameter as well as inner or outer diameter.

3.3 Laminar evaluation

The laminar analysis of flank areas by dint of least squares algorithms may form the basis to a future evaluation of thread geometry in its entirety. For this purpose, measurement points spread all over the thread flank were recorded with an increased density. By applying an innovative laminar evaluation process for the first time a complete 3D analysis of the functional areas can be carried out. Based on this, it is now possible to make statements with regard to factors such as periodic pitch errors, convexities of the flank areas or local defects.
The laminar evaluation is executed in three steps. First, the flank areas are unwinded. Since threads have a linear profile and pitch the unwinded surface is a plane.

Depending on the used measuring device and yielded presentation of the coordinate points an additional coordinate transformation may become necessary. In a second step, a plane is fitted into the measured points. In a last step, all desired parameters are calculated and compared to nominal values. Figure 2 shows the example of a laminar evaluation for a plug thread gauge of the size M64 x 6. From this figure it is possible to extract a clear periodic pitch error, a slight error of the flank angle and a very small pitch error, whereas formerly through the application of a standard conform evaluation to the measured plug only the pitch error could be recognized.

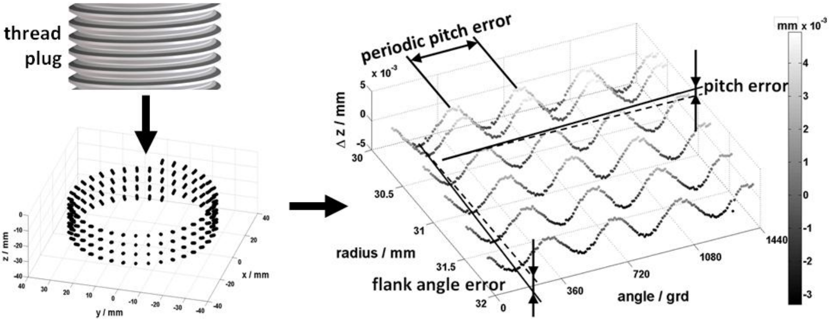

Figure 2: Laminar evaluation of threads using the example of a plug thread gauge of the size M64 x 6

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