Investigation of a mini clamping system for micro manufacturing

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Abstract

A clamping system for micro manufacturing was investigated using a micro coordinate measuring machine, and appropriate parameters to assess this clamping system were defined. The reproducibility of the measured clamping system determined in a first step under laboratory conditions was 1.6 µm, and the repeatability was less than 0.2 µm.

1 Introduction

Typical manufacturing tolerances in micro-precision manufacture of less than 0.01 mm define, on the one hand, the requirements placed on the properties of clamping systems, and they also furnish proof of these properties. Within the scope of an industrial cooperation between PTB and the *Hirschmann GmbH* company, the properties of the mini clamping system "µ-PrisFix" [1] were investigated with a micro coordinate measuring machine (which, in the following, will be referred to as "micro CMM").

2 The mini clamping system

2.1 Set-up

Figure 1 shows the CAD representation of the mini clamping system "µ-PrisFix". This system has been developed within the scope of a BMBF project [1]. The clamping fixture is fastened to the manufacturing machine. The workpiece can be clamped onto the changing pallet via threaded holes. The position of the pallet with respect to the clamping fixture is determined by four centering prisms (1a) and their counter pieces (1b) as well as by four height supports (2a, 2b). The system is, therefore, overdetermined several times in its position. The zero point of the system lies in the intersection of the four centering prisms (1a) at the level of the height

supports (2a). The distance between the upper side of a pallet and this level is 10 mm. The pallet is pneumatically fastened in the clamping fixture. Cleaning of the centering prisms and of the height supports is carried out with compressed air during the changing of a pallet.

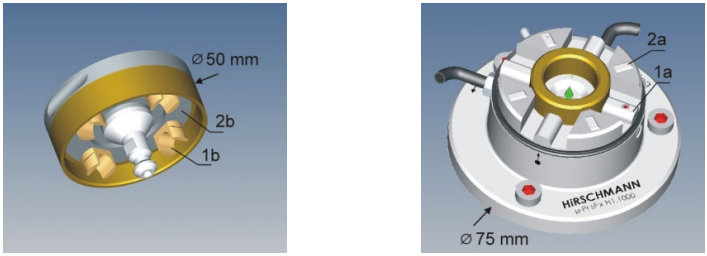

Figure 1: Mini clamping system with clamping fixture (right) and pallet (left). 1a, 1b: centering prisms; 2a, 2b: height supports, total height of the clamping system: 50 mm.

2.2 Parameters for the assessment of the clamping system

For the assessment of clamping systems, no standardized parameters have been available so far. Therefore, the following parameters were agreed according to [2]: *Repeatability:* The reproducibility of the position of a pallet when repeatedly changing in a clamping fixture. The repeatability thus describes the accuracy with which a workpiece can be repositioned in a manufacturing or measuring machine by means of the clamping system, e.g. after an inspection or after cleaning. *Reproducibility:* The difference between the positions of a pallet when it is changed from one clamping fixture to the other. The reproducibility is specified in [1] as "*changing accuracy*". The reproducibility thus describes the accuracy with which a workpiece can be positioned, for example, between a manufacturing machine and a measuring machine.

3 Measurements carried out on the clamping system

3.1 Measuring device

For the investigations, a micro coordinate measuring machine of the type Carl Zeiss F25 was used. The micro CMM has a measuring volume of 130 mm x 130 mm x 100 mm (*x,y,z*), air-bearings, linear drives and Zerodur® scales. The microprobe used had a stylus length of approx. 2 mm and a contacting sphere 300 µm in diameter. Essential for the investigations were the very stable ambient conditions in the

measurement room of PTB, with maximum temperature drifts of the micro CMM in measuring operation of 0.02 K/h.

3.2 Measuring set-up and measuring strategy

The investigations were carried out on two clamping fixtures and three pallets. The pallets were changed from one clamping fixture to the other by hand. Therefore, it was necessary to reduce the thermal influence of the operator as far as possible by means of a suitable measuring strategy. Figure 2 shows the measuring set-up.

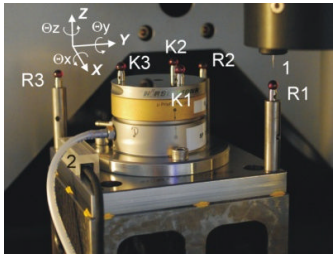

Figure 2: Measuring set-up for the investigation of the clamping system. 1: micro-probe; 2: temperature sensor; R1-R3: reference spheres; K1-K3: spheres on the pallet.

The clamping fixture is fastened to an adapter plate on which three reference spheres, R1-R3, (∅ 5 mm), are fixed. These three spheres define the reference coordinate system. On the upper side of the pallets, three spheres each, K1-K3 (∅ also 5 mm), are arranged. In a measuring sequence, the positions of each of the spheres were measured, and the position of the pallet spheres K1-K3 with respect to the reference coordinate system was determined. From the *xyz*-positions of the spheres, the following parameters are derived: displacement Δx, Δy, Δz of the pallet, rotation Θz of the pallet around the *z*-axis, tilting Θx and Θy of the pallet around the *x*-axis and around the *y*-axis.

4 Results

4.1 Repeatability

The repeatability lies in the range of ± 0.2 µm for the displacement (Δx, Δy, Δz), ± 0.5´´ for the tilting (Θx, Θy), and ± 0.7´´ for the rotation (Θz). Depending on the size of the workpiece and the clamping, the tilting or rotation leads to an additional

displacement in the position of the workpiece. For micro-workpieces, a processing volume of 20 mm above the pallet surface and ± 10 mm outside the centre can be assumed. For this volume, the resulting position changes amount to $\Delta = 0.07$ µm for maximum tilting $\Theta x = 0.44''$ and $\Delta = 0.04$ µm for maximum rotation $\Theta z = -0.68''$.

4.2 Reproducibility

From the measurements described above, the positions of the pallet spheres K1-K3 in the reference coordinate system and the respective angles were determined for the two clamping fixtures and for each of the three pallets. Then, the differences of these positions and of the angles between the clamping fixtures were determined for each pallet. From these differences, the common mean was determined and the deviations from this mean were determined for each pallet. The reproducibility is the maximum deviation of the parameters *displacement*, *rotation* and *tilting* having occurred. The determined reproducibility is 1.6 µm for the displacement, 1.1´´ for the rotation and 0.5´´ for the tilting. Related to the processing volume described in Chapter 4.1, the position changes due to the tilting or rotation are smaller than 0.1 µm.

5 Summary

In a cooperation between PTB and the *Hirschmann GmbH*, a mini clamping system "µ-PrisFix" was investigated according to appropriate parameters under laboratory conditions, and their high precision was confirmed. Thereby, the repeatability of the clamping systems in the range of 0.2 µm and below made high demands on the measurement procedure and on the ambient conditions. The reproducibility determined amounted to 1.6 µm for the displacement and to 1.1´´ for the rotation of the pallets. In addition, the investigations furnished starting points for a further optimization of the clamping systems. For the future it is planned to supplement the present results by carrying out investigations on clamping systems that have been further optimized and – also – under manufacturing conditions.

References:

[1] http://www.hirschmanngmbh.com

[2] JCGM 200:2012, International Vocabulary of Metrology – Basic and General Concepts and Associated Terms