Development of a High Precision Clamping System for the Compensation of Angular Errors in Workpiece Alignments

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Abstract

This paper presents a concept for an automated positioning system which can be integrated into different machine tools. The system is designed for the compensation of angular errors at high precision part alignment. It aims at many applications to decrease the non-productive time. The design of the additional system is described considering the mechanical unit, actuators, sensors and flexure hinges.

1 Introduction

Demands on accuracy and economical manufacturing of parts machined by micro milling and micro electrical discharge machining (EDM), are increasing continuously. Especially the way of alignment has a great influence on the accuracy and the manufacturing time of precision parts. Manual adjustment of precision parts is time intensive and therefore costly. However the reduction of the non-productive time during work preparation in process chains offers huge potentials for increasing cost efficiency [1].

To fulfill these requirements a concept for an automated high precision positioning system is developed at the Fraunhofer IPK together with partners from the industry.

2 Concept

An additional system which can be placed between workpiece holders and machine tool tables is developed. The system mainly consists of a control unit and a mechanical device based on flexure hinges. It is designed for the use in different applications and machine tools. Precise milling operations of cavities where placement accuracies in the micrometer range are demanded are chosen as testing scenario. Those accuracies are still realized by time extensive manual adjusting which takes at least several minutes. Due to the presented concept secondary times can be reduced and manufacturing accuracy can be increased at the same time. The integrated measuring system of the machine tool, usually a touch probe, determines the current position of the work piece in three points and transmits the data to a control unit. The control compares the current position and the required position. The transformation of the calculated differences converted in required adjustment travel for the actuators follows, as shown in Figure 1. The stroke of three piezo linear drives is controlled in closed loops until the required position is confirmed by the measuring system of the additional system. The required position is now held by all three linear drives simultaneously. The machine tool's measuring system verifies the position of the work piece. If the required position is achieved the processing at the work piece can be initiated. Otherwise the angular error compensation starts again until the required position is finally reached.

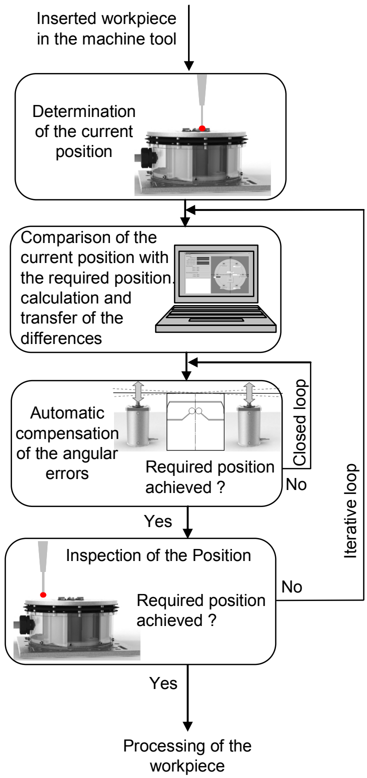
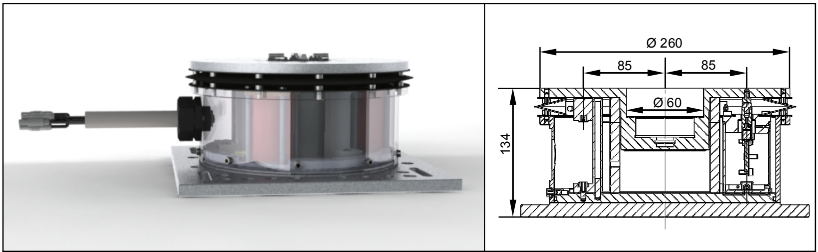


Figure 1 Adjustment process

3 Design

The dimensions of the actuation device measure 134 mm in height and 260 mm in outer diameter. The motion diameter of the actuators is 170 mm (see figure 2). The interface for a fixturing device measures 60 mm in diameter.

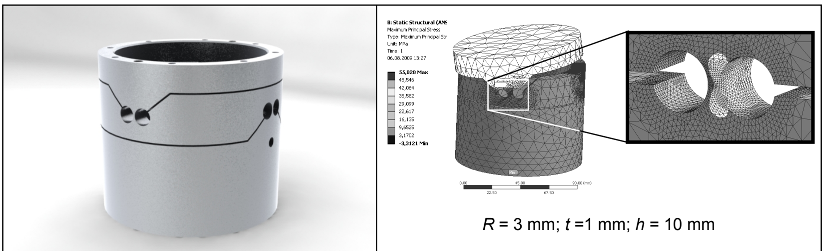


Overall clamping system	Overall system in full section view

Figure 2: left side: overview; right side: design

The actuators used for the adjustment are piezo motors with a stroke of 20 mm, a possible resolution of 1 nm and a stall force up to 450 N. The speed is adjustable from a few nanometers per second up to the maximum of 0.3 mm/s. These actuators are bridging the technical gap between traditional piezo stacks and conventional piezo legs. Closed loop controlled operation is possible with the aid of capacity sensors. These have a measuring range of 2 mm, a resolution of 0.1 µm and a bandwidth up to 8 kHz. Precision adjustment of all components enables the system to compensate angular errors of ± 0.6° with resolution of 0.3". The workpieces are clamped by an integrated conventional fixturing system with a clamping force of 1500 N. For the unclamping process compressed air is used.

To achieve a maximum of stiffness and accuracy monolithic flexures are used [3]. Assisted by FE calculations the break-even point between stiffness and tilt angle is located for high repetitive accuracy. Optimized lot width dimensions of the flexure hinges ensure overload protection.



Calculation of monolithic flexure hinge	FEM-Simulation for the detailed design

Figure 3: left side: designed of flexure hinge; right side: FEM calculation

For the design of the monolithic flexure hinges the most important characteristics such as the notch radius *R*, the ridge width *t* at the thinnest point and the height *h* with respect to the material strength are calculated [2]. Considering the expected forces and moments during manufacturing processes depending on the demanded tilt angle the bending force of the flexure hinge is calculated. Furthermore the whole system is equipped with a guard against cutting chips and liquids for the use in rough environment such as dielectric fluid in EDM-machine tools.

The system is designed to hold the position of work pieces with a weight of 5 kg and height of 50 mm during an acceleration respectively deceleration of 12 m/s^2.

4 Conclusions

The presented concept of the automated clamping device is able to compensate angular errors of ± 0.6° with an angular resolution of 0.3". Therefore it has enormous potential to reduce adjustment time for precision engineering and to enhance the repeat accuracy from 2 µm of conventional fixturing systems to 0.5 µm. First run of the system will be at the end of 2010.

Acknowledgement

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