New Hybrid Machine Tool with an Automated Clamping System for Drilling Micro Holes by Laser Helical Drilling and µEDM

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Abstract

The continuous demand concerning the enhancement of functionality and power of technical and mechanical products, such as sensors, actuators and mechatronical systems leads to a steady miniaturization. Application fields located in the automotive industry, consumer electronics, medical and biological engineering, have shown that the fabrication of micro parts as mass products have been becoming more and more common practice. Therefore, next generation products requiring a new level of precision and efficiency demand the development of novel machining processes, machine tools and peripheral equipment.

1 Hybrid Machine Tool and Automated Clamping Device

A novel hybrid machine tool for high efficient production of complex micro holes is presented. The machine tool features a Laser Helical Drilling unit (LHD) for roughing and a Micro Electrical Discharge Machining (µEDM) system for finishing. Precise alignment of both modules is provided by a camera device that is integrated into the machine tool. For compensating angular errors when drilling micro holes also an automated clamping device is provided. Through these combinations, machining and setup times are to be reduced and accuracies are to be increased.

2 Setup Hybrid Machine Tool

The machine tool´s setup is based on a gantry portal construction. For moving either the µEDM module or the LHD and camera unit two main Z-axes (Z1, Z’) are provided. Fast positioning and measuring during combined machining is realized by a linear driven X-axis. The work tank including the automated clamping device and the fixed work piece is positioned by a servo driven Y-axis that is embedded in the machine base (figure 1).

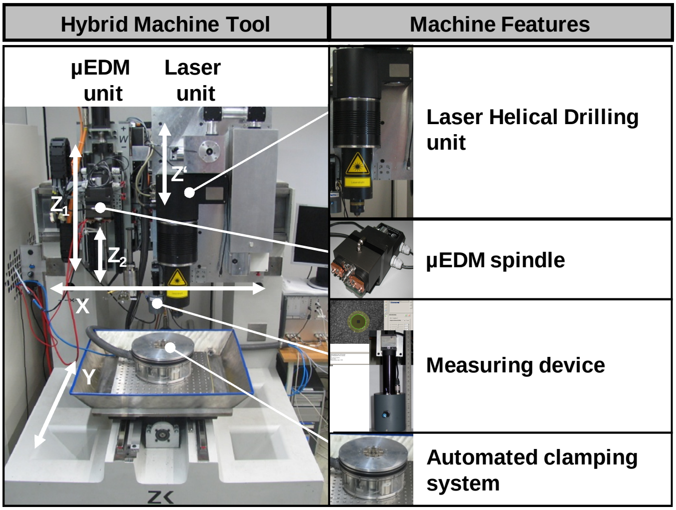

Figure 1: Hybrid Drilling machine tool and automated clamping device

The µEDM system is equipped with an air bearing spindle providing internal high pressure flushing of up to 80 bar and a maximum rotational speed of 3000 min^{-1}. For further flushing enhancement also two piezo actuators integrated in the spindle's body can be externally controlled. The spindle is mounted on a double Z-axis. The main axis (Z_1) positions the tool electrode´s ceramic guide above the work piece. The secondary Z-axis (Z_2) is integrated into the machine's adaptive feed control.

The Laser unit features an Edgewave® Innoslab IS4I-E Nd:YVO4 Laser (1064 nm wavelength) with pulse durations from 6 ns to 85 ns and a pulse frequency of up to 50 kHz with 2 mJ/pulse at maximum. The output beam is guided into a helical drilling optic developed by Fraunhofer-ILT. Maximum optical rotation speed of the system is 16.000 min^{-1}. Drill hole diameters from 40 µm to 400 µm at expansion ratios (entrance:exit) varying from 1:4 to 2:1 can be produced [1, 2].

Positioning between the roughing and finishing process of the Laser and the µEDM module is provided by a camera system. The system includes a µeye 2240 camera and an objective with a maximal magnification of 10. Fast capturing and analysis of the drill holes´ radius is realized by a special illumination unit and a recognition-software developed at the Institute of Imaging and Computer Vision/RWTH Aachen. First technological investigations showed a relevant reduction in machining time of about 50 % when using the hybrid LHD and µEDM drilling process compared to conventional µEDM [3]. This means a significant increase of efficiency in the manufacture of micro holes.

3 Setup Active Clamping System

Clamping and highly precise angular adjustment of the work piece inside the hybrid machine is done by an active clamping device developed at Fraunhofer IPK. The device is designed for being used within different application fields and machine tools. Therefore it is protected against different sorts of liquids, such as deionized water or oil, by a special casing. Clamping of the work piece is realized by a conventional fixturing system. Angular errors are adjusted by three piezo motors having a maximum stroke of 20 mm at a stall force of 300 N. Due to the additional use of capacity sensors being operated within a closed loop, angular errors of ± 34 ´ at a minimum resolution of 0,412 ´´ can be compensated.
For verification of the active clamping device's final positioning accuracy a laser interferometer being equipped with an angular optic was used. The system allows a pitch and yaw measurement at a resolution of 0.01 ´´.

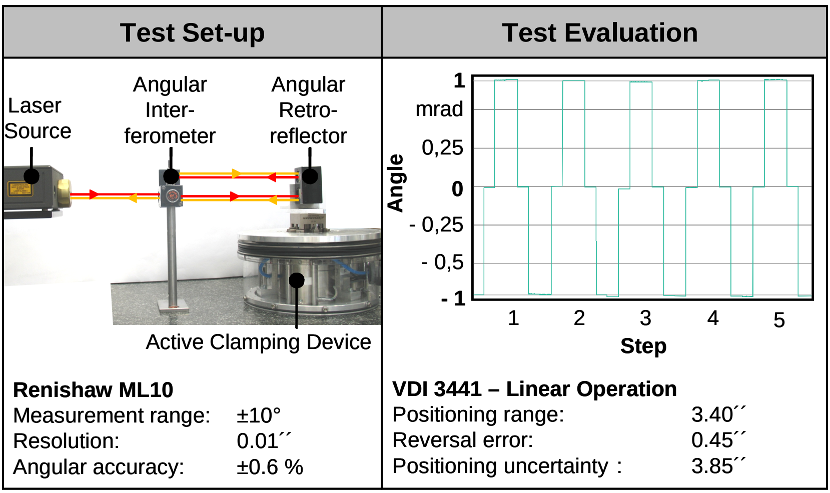

Figure 2: test set-up (left); test evaluation (right)

Figure 2 shows the test set-up for acquisition of the positioning range, reversal error, and positioning uncertainty. For statistical validation the device was moved to three positions for five times. Data analysis gave a final positioning range of 3.4 ´´, a reversal error of 0.45 ´´, and a positioning uncertainty of 3.85 ´´. With this accuracy work pieces can be adjusted very precise and efficient.

4 Conclusion

The paper presents a novel hybrid machine tool with an automated clamping device. Through this, setup and machining times are to be reduced and position accuracies are to be increased. Further research work will cover the verification of the combined system when hybrid drilling micro holes. Also an implementation of the clamping device's external control into the hybrid machine tool's axis control is planned.

5 Acknowledgements

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