euspen's 15th International Conference & Exhibition, Leuven, Belgium, June 2015
www.euspen.eu

Concept of a correction mechanism to prevent the drift of a drill bit for micro deep hole drilling

Adam Sanders[1], Jens Wulfsberg[1]

[1]*Helmut Schmidt University, University of the Federal Armed Forces Hamburg, Germany*

adam.sanders@hsu-hh.de

Abstract
Machining of micro parts is very demanding in terms of accuracy and precision of tools and machine components. Concepts for miniaturization of machine tools continuously drive various research fields of engineering. Some of these concepts cannot be realized by simply scaling down existing macro machine tools. In contrast, other concepts can only be realized by the small size itself. In that case the small size acts as an enabler for certain applications [1]. This is especially true in the production of micro deep hole bores, due to the high aspect ratio of hole depth to diameter.
In this paper a machine concept for a micro machine to perform axial deep hole drilling in transparent polymethylmethacrylate (PMMA) round stock is presented. Target diameters of the round stock of < 400 µm and bore diameters down to 200 µm result in a very thin wall thickness of < 100 µm. Therefore the drilling course has to be coaxial to the round stock. Due to the high aspect ratio of up to fifty, initial tests have shown that the drill tends to drift in the material out of the round stock causing damage to the material and the chuck. For this reason, the central part of the machine concept consists of a correction mechanism that prevents the drift of the drill in the material. Because of scaling effects for small machine tools and small work pieces and due to the material properties the active correction mechanism is implemented on the side of the work piece. The concept of this correction mechanism will be explained and formulated in detail in this paper.

Keywords: Micro Deep Hole Drilling, Micro Manufacturing, Machine Concept, Polymethylmethacrylate (PMMA)

1. Introduction

The increasing demand for micro components in the electronic and medical device industry, favored by the trend of product miniaturization, has resulted in the development of novel manufacturing technologies by researchers all over the world. An effect of this downsizing trend is the increasing importance of deep holes with small diameters and high aspect ratios of length to diameter. This field of research is widespread [2, 3]. One of the challenges of micro deep hole drilling is to ensure a coaxial boring course. This is even more important when the work piece is a transparent PMMA round stock with a diameter that is not much larger than the diameter of the drill.

In this paper a concept to ensure a coaxial boring course for micro deep hole drilling in transparent round stock is proposed. Aside, the problems occurring by drilling in absence of a correction mechanism are discussed. Therefore results of initial tests which were performed without a correction mechanism are presented. It is discussed what opportunities arise from this specific production process which leads to the introduction of a concept of a correction mechanism.

2. Drilling transparent PMMA round stock without a correction mechanism

Initially the drilling process is performed without a correction mechanism. Various round stock with different diameters are machined. Therefore different drill bits with varied diameters are used. The aim is to get a drilled round stock with a remaining wall thickness in the range of 75 µm to 200 µm. Figure 1 shows various used drill bits with different diameters.

The smallest used drill bit has a diameter of 200µm with a corresponding round stock of 400 µm. This combination results in a very thin wall thickness of 100 µm. The desired drilling depth is 10 mm which follows in an aspect ratio of fifty. The drilling process is performed with an initial pilot hole of 600 µm length. This is needed to get a reasonable drilling start and is a basic procedure in deep hole drilling [3]. Thus the pilot hole drives the longer drill bit in the correct direction. If there is no pilot hole drilling will not be possible because the actual drill bit to perform the deep hole does not enter the material. The drill bit drifts off the surface of the round stock due to the high aspect ratio.

Figure 1. Drill bits with different diameters

Due to the pilot hole the drill course in the depth of 4 mm - 5 mm is coaxial to the round stock. In the following the drill bit tends to drift in the material thus the drill course abandons the coaxial course. This behaviour of the drill bit is illustrated in figure 2. A specimen of a drilled PMMA round stock is pictured

as well where the shift can be identified. Due to the thin wall thickness of the remaining round stock the drifting drill bit leaves the material. This causes damage to the work piece and the chuck. The direction where the drill bit drifts to is not specified and varied between the experiments.

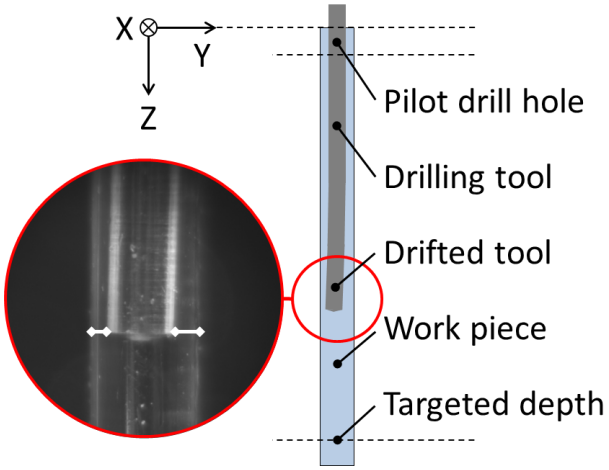

Figure 2. Illustration of the drill course

3. Concept of a correction mechanism

As a result of the problem detailed in section 2 a new methodology is needed to detect the drift of the drill bit in the material and to operate a correction movement to obtain a coaxial drilled round stock. The proposed machine settings described below are illustrated in figure 3.

To measure the position of the drill bit in the process different approaches were discussed. This includes inductive sensors, conductive drill bit, thermal recording, detecting of the resulting forces and visual detection.

Using inductive sensors to measure the position of the drill bit is not possible because the drill bit is too small to change the inductance of the induction loop of the sensor. By reason of the bad electrical conductivity of PMMA electrical approaches cannot be used either. Thermal recording and the detection of the resulting forces are also rejected because of the high responding time and the conjectured inaccuracies in the recorded data.

Considering the transparency of the PMMA the approach to visually detect the drill bit by two high resolution zoom cameras on a 90° offset is chosen. Thus the position of the drill bit can be evaluated by digital image processing. Therefore the wall thicknesses on both sides are compared. The picture which is to be processed is similar to the image in figure 2. To maintain the view of the relevant region of the round stock the work piece is clamped at two different areas. The first clamping area contains the first 3 mm of the round stock. Due to the pilot hole the drill bit does not drift on a critical level in that area. The relevant range between the first area and the targeted drilling depth lays bare to provide the vision of the round stock for the camera. In the third region the round stock is clamped again. Due to the 90° angle of the cameras it is possible to determine the drift of the drill and the direction of the drift. To maintain a correction movement of the drill bit the third area respectively the second clamping area is movable in X- and Y-direction. Thus it is possible to deform the round stock in order to keep the drill bit on track on basis of the results of the digital image processing. On consideration of the characteristics of the material this means the correction movement is executed on the side of the work piece. To provide the needed high precision the travel paths in both directions are realized by piezo actuators with a mechanical amplifier on basis of flexible mechanisms [4].

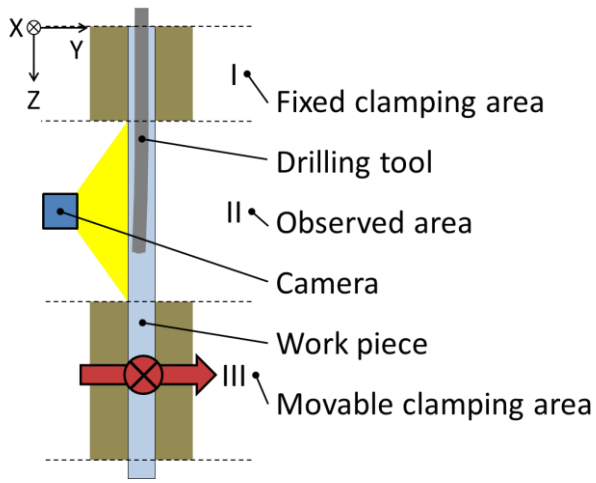

Figure 3. Concept of the correction mechanism

4. Summary and future works

This paper discusses the problem of micro deep hole drilling in transparent PMMA round stock. Results of drilling tests are presented which are initially performed without a correction mechanism with an insufficient outcome. On this basis a concept of a correction mechanism is proposed to perform a micro deep hole with the targeted dimensions and which is coaxial to the round stock. The mechanism is based on digital image processing and contains different clamping areas of the work piece. Due to the specific properties of the used material and the opportunities from the small size of the work piece the correction mechanism is implemented on the side of the work piece instead of correcting the tool.

For further research the proposed concept will be realized to obtain a coaxial drilling course. Therefore the interactions of the machine parts will be investigated. Thus more tests can be performed to further analyze the drilling process and the process parameters.

Acknowledgment

Research funded by the AIF ZIM program of the German Federal Ministry for Economic Affairs and Energy.

References

[1] Wulfsberg J P and Röhlig B 2013 Paradigm change: small machine tools for small workpieces *Production Engineering* **7(5)** 465-468
[2] Dornfeld D, Min S and Takeuchi Y 2006 Recent advances in mechanical micromachining *CIRP Annals-Manufacturing Technology* **55(2)** 745-768
[3] Heinemann R, Hinduja S, Barrow G and Petuelli G 2006 Effect of MQL on the tool life of small twist drills in deep-hole drilling *International Journal of Machine Tools and Manufacture* **46(1)** 1-6
[4] Wulfsberg J P, Lammering R, Schuster T, Kong N, Rösner M, Bauma E and Friedrich R 2013 A novel methodology for the development of compliant mechanisms with application to feed units *Production Engineering* **7(5)** 503-510