A new workpiece clamping method for micro-machining applications based on van der Vaal forces

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Abstract

Nowadays, most of the workpieces in micro-machining are force-fitted to the working table by chucks or vacuum grippers. The downsides of these methods are deformation and induced stress because of the uneven force distribution. A new approach for workpiece clamping based on Van der Waals forces deliver an even force distribution to minimize these unwanted deformations. Thus, it is possible to clamp and reclamp workpieces with flat and smooth surfaces such as glass, metal, ceramic, plastic, and thin foils precisely and without residuals. In the research presented in this article, the effect of the clamping material and the resulting workpiece damping were analysed. Furthermore, surfaces and micromachined structures made by conventional workpiece clamping and clamping with Van der Waals forces are compared and discussed.

1. Introduction

The potential of microproducts and microstructured surfaces has grown over the last years [1]. The use of small desktop machines for micro-milling or micro-grinding applications represents a suitable process for generating precision components as well as functional component surfaces [2]. Micro structured components vary in size and thickness. Currently, most of the workpieces in micro machining are force-fitted to the working table by chucks or vacuum grippers. The downsides of these methods are deformation and induced stress because of the uneven force distribution [3]. Therefore, a new approach for workpiece clamping based on Van der Waals forces to minimize these unwanted deformations is developed and investigated.

2. Van der Waals clamp

The new clamping device is based on a tape, which consists of a 0.34 mm thick silicone film with microscopic elements (approximately 290 per mm²) on one side.

These create an intermolecular attraction with the workpiece surface and deliver an even force distribution. To characterize the clamping properties of this tape, clamping tests were conducted.

2.1 Clamping properties

The influence of the silicone tape´s elasticity and the resulting characteristics regarding the machining process was tested with the configuration shown in figure 1 left. The silicone tape is bonded on an aluminium plate and then mounted on a piezoelectric dynamometer. To measure the displacement of a workpiece on this silicone tape, a cubic stainless steel workpiece with a surface area of 20 x 20 mm is impinged with force and capacitive displacement sensors to measure the resulting path. Thus, it is possible to analyse the influence of the force on the clamping properties. In a first test, the force was applied to the workpiece from different directions and then taken away again. As shown in figure 1 right (upper graph), the workpiece is exactly moving back to the initial position after displacement.

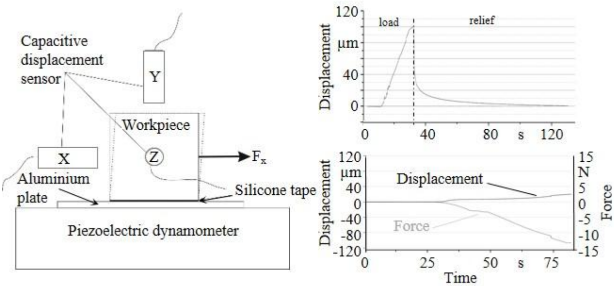

Figure 1: Test configuration (left) and measurement plots (right)

In a second test, the workpiece is distributed with a continuously increasing force up to 12.5 N in each different direction. Figure 1 right (lower graph) shows the displacement and the force depending on time. The change of the workpiece displacement is dependent on the force. At loads greater than 15 N the displacement increases dramatically and the workpiece breaks away. Furthermore, the displacement-force measurements are analyzed concerning the system's stiffness. The stiffness is calculated to 1.25 N/µm. This stiffness value and the maximum fixation force of more than 12.5 N characterize the tape as applicable in the field of micro machining. Experience shows, in micro milling with micro end mills with diameters smaller than 50 µm, the process force is smaller than 0.1 N. To provide stable micro machining processes, the behavior of the silicon tape at this low force has to be analyzed, too.

2.2 Machining test

The machining tests were performed on a precision 3-axis CNC milling machine with a 60,000 RPM air bearing spindle. For the machining tests, 50 µm diameter micro end mills were used to cut tranches of 10 mm length in commercially pure titanium (cp-titanium). The depth of the cut was 5 µm and the feed rates were varied between 5 and 60 mm/min. The results, shown in figure 2, were measured with a piezoelectric dynamometer.

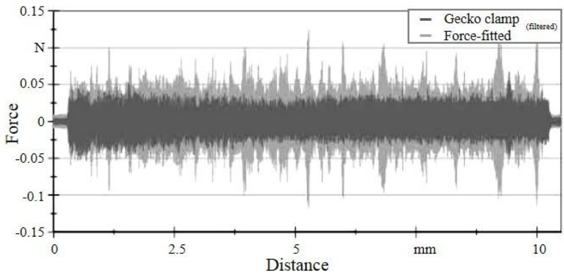

Figure 2: Comparison of process force between conventional and gecko clamped workpieces in macro milling process. (Tool diameter 50 µm, cp- titanium, feed rate 60 mm/min)

Figure 2 shows the machining characteristic of two different clamping strategies. The darker graph in figure 2 shows the same parameters but with a bolted sample. The lighter graph is the same machined part, but fixed with the silicone tape. The result is a more evenly distributed force due to the silicone's damping. This leads to a higher tool life without any difference in roughness of the machined part. After machining, the workpieces can be separated from the silicone tape by applying a few drops of water or alcohol to the clamping device. The higher molecular attraction of liquids leads to a direct (after a few seconds) displacement of the workpiece from the silicone tape. After drying, the tape is able to clamp another workpiece, thus it is a highly flexible and re-usable clamping material. Furthermore, the tape can be cleaned with alcohol, water or cloth after a contamination with dirt, chips, etc. Therefore, it is possible to clamp and reclamp workpieces with flat surfaces fast and easy without residuals. Based on these results, the prototype of the "Gecko Clamp" (shown in Figure 3) is developed. The Gecko clamp's base is made of stainless steel and has a dimension of 100x100mm². The silicone tape is on top of the Gecko clamp. Stop pins provide a repeatable workpiece alignment. Small holes in the tape allow the supply of liquid through the liquid supply. To adjust the liquid supply to the part dimension, liquid supply holes can be switched on or off starting with the middle hole by rotating the hole plate. Thus, it is possible to clamp workpieces with flat, even surfaces, different materials and even thin foils without damage.

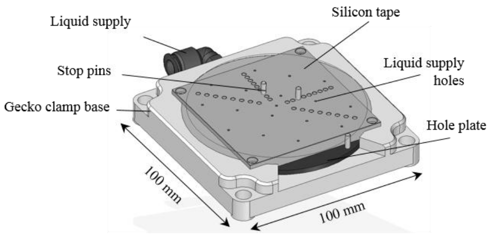

Figure 3: Modell of the “Gecko Clamp” for micromachining applications

3. Conclusion and Outlook

In this paper, a new approach for workpiece clamping in micro manufacturing is described. The analysis of the displacement measurement shows a stiffness of 1.25 N/µm, sufficient for the use in micro milling and grinding applications with typical process forces of less than 0.1 N. Also, thin foils could be fixed and then taken off again from the working table without any damage. Compared to conventional clamping strategies such as bolting or vacuum grippers, a process and time advantage could be achieved. This process advantage can also be transferred to force-free handling applications.

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