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Size-adjusted workpiece clamping systems for micro production

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Abstract
Nowadays workpieces with small dimensions of few millimetres up to some centimetres are processed on relatively large machine tools compared to the size of the workpiece. In adaption of machines and their working space to the size of these small workpieces size-adjusted machine tools are required. These machines benefit from a flexible and space-saving machine concept, that allows high mobility and quickly adaptable assembly to different production tasks. However, required machine components cannot easily be downscaled to integrate them into the machine tool. Instead, a fundamentally redesign is necessary. This also affects workpiece clamping systems, which have a significant influence on a secure and non-damaging clamping of workpieces. Avoiding workpiece damage due to clamping force peaks as well as precise and repeatable positioning are essential demands in micro production. These clamping systems have to be suitable for workpieces with various geometrics. Thus, they have to be adapted to use them in size-adjusted machine tools.
This paper presents two different workpiece clamping systems that are developed for size-adjusted machine tools. These clamping systems can easily be exchanged due to an intelligent machine interface. A fundamentally redesign leads to a drastically reduction of the overall size of the whole system. The clamping systems are switchable so they can be used in automated machining systems. Further, the machine interface allows repeatable positioning of the clamping systems in other size-adjusted machines. As a result, clamping and unclamping as well as measuring tasks can be performed simultaneously to the machine productive time.

Size-adjusted machine tools; workpiece clamping systems; micro production

1. Introduction

Clamping systems have big influences on workpiece quality during machining. Especially in micro machining the prevention of stress concentrations that could lead to workpiece damages is required by workpiece clamping systems. Surface topography and workpiece contours must not be affected by clamping the workpiece. Additionally, the design of clamping systems has to be adjusted to the material and geometry of the workpieces.

In general, workpiece clamping systems are based on the physical operating principles of form-fit and force-fit [1].

Due to the required fitting tolerance, exclusive form fitting clamping systems are rarely used in micro machining. Usually, those systems are combined with elements which allow transmitting additional force during the clamping process. In most cases these systems are individual and special solutions.

Prevalent clamping systems are based on the force-fitting operating principle. Especially in micro machining vacuum, magnetic and freezing technologies are appropriate.

This paper presents two miniaturized prototypes of workpiece clamping systems.

2. Adhesion clamping system

Freezing clamping systems only use a small amount of water between the workpiece and clamping surface. After positioning the workpiece, the clamping surface is cooled down to sub-zero temperatures. Thereby, the water freezes and the workpiece is fixated by adhesive forces.

As an advantage, there are no limitations of workpiece materials which should be clamped by freezing, e.g. metals, plastics and ceramics can be clamped safely in this way. In addition, the geometry of the workpiece is not subjected to any restrictions. Therefore, small and filigree structures like clock gears can be clamped safely by freezing.

However, it is of high importance to ensure, that the temperature of the clamping surface is always below the melting point of water. Otherwise the workpiece may loosen.

Because of the temperature gradient between the clamping surface and the environment, a heat flow into the frozen water arises. To prevent defrosting it is necessary to constantly dissipate heat from the warmed water. Peltier elements are suitable for this purpose. Mounted near to the clamping surface, Peltier elements work as electro-thermic heat pumps. They consist of two thermally separated ceramic sides. By applying electric current, a stream of heat flows from one side (cold side) through the element to the opposite side (hot side). Any heat that is generated on the warm side needs to be dissipated effectively by an appropriate cooling system. One prototype of a size-adjusted clamping system by freezing is shown in fig. 1.

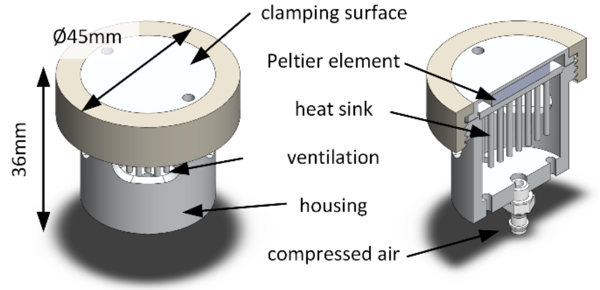

Fig. 1. Construction of the adhesion clamping system.

On the hot side of the Peltier element a heat sink made of aluminium is mounted. Through the bottom of the adhesion clamping system compressed air is blown at the heat sink to absorb part of the generated heat. Workpieces made of copper with the dimensions of 16 mm x 16 mm x 8.5 mm can be fixated by freezing within 250 s. The cooling air flow rate is 5.0 m³/h. After a total of 400 s the temperature on the clamping surface is -2.5 °C. Compared to common clamping systems, the time required to fixate the workpiece could be cause for concern in fully automated production tasks. A further increase of air flow rate does not affect freezing time and temperature of the clamping surface. One crucial point is the used heat sink made out of aluminium. The heat conducting resistance of the heat sink prevents faster freezing of workpieces. At present, there are no purchasable heat sinks with lower heat conducting resistance within the required dimensions.

Therefore, the aim of further investigations is designing and developing a matching heat sink made out of copper. The lower heat conducting resistance allows an increase of efficiency while the housing dimensions remain the same. In addition to that, an improved design of cooling fins leads to a larger surface of the heat sink. In combination with an optimized airflow, the cooling air is able to absorb more thermal energy.

When using the adhesion clamping system the clamp medium water can be replaced by wax. The solidification temperature of wax is in the range of 50 °C and thereby above the temperature of the environment. As a result, while machining no energy is needed to keep up clamping forces. Just the procedure clamping respectively unclamping needs energy for a short period of time. Heisel et al. [2] have shown that clamping forces by using wax are higher compared to freezing. Against it the stiffness when clamping with wax is less compared to clamping by freezing.

3. Magnetic clamping system

Requirement for the operation of magnetic clamping systems is the use of ferromagnetic materials. An essential advantage is the quick handling of these clamping systems. The workpiece is immediately fixated by simply switching on the system. In general, a laminated top plate, which features steel and brass segments is used as clamping surface. To ensure a safe fixation, the thickness of each segment has to be adapted to the height of the workpieces.

The following magnetic clamping system is designed to fixate workpieces with dimensions of 16 mm x 16 mm x 8.5 mm (fig. 2).

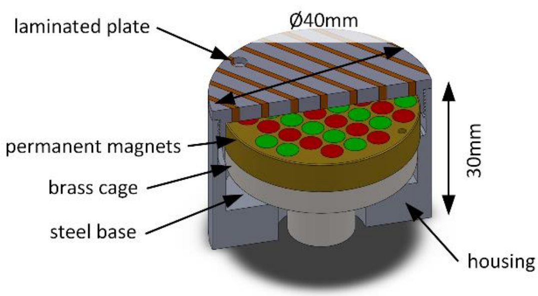

Fig. 2. Construction of the magnetic clamping system.

It could be shown, that varying the height of workpieces leads to a critical height workpieces should have to profit from maximum magnetic forces. The analyses have shown constant clamping forces of workpieces higher than 2 mm. Below 2 mm the forces are significant lower.

Fig. 3 shows the correlation between workpiece height and period of steel and brass segments.

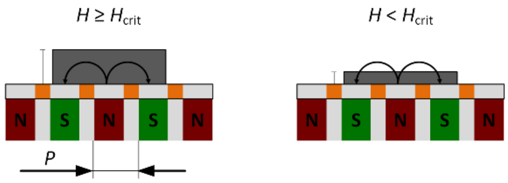

Fig. 3. Critical workpiece height in correlation to the period of steel and brass segments on laminated plates.

The thickness of the steel and brass segments is 3 mm respectively 1 mm. This results in a period P of 4 mm. The formula to calculate the critical height of workpieces is:

$$H_{\text{crit}} = \frac{1}{2} \cdot P$$

On average, clamped workpieces made out of steel 100Cr6 with the dimensions of 16 mm x 16 mm x 8.5 mm can withstand static mechanical forces of 26 N in parallel direction to the clamping surface. Clamping forces get up to 95 N in direction perpendicular to the laminated top plate.

Furthermore, low surface roughness and high accuracy of flatness decrease the amount of trapped air between workpiece and clamping surface. As a result, the overall magnetic conductivity increases in common with clamping forces.

4. Summary

Two workpiece clamping systems for the use in size-adjusted machine tools for micro machining were presented. The maximum overall dimensions of these clamping systems are 45 mm in diameter and 36 mm in height.

An adhesion clamping system was developed that is able to clamp workpieces of any kind of material by freezing. Compressed air is used to transport heat out of the housing. It could be shown that purchasable components for the cooling system are either incapable of offering enough cooling performance or just too big to fit these dimensions. Further investigations of developing small components, e.g. heat sinks, will take place. When using wax instead of water as a clamp medium, the adhesion clamping system keeps up clamping forces without energy while processing the workpiece.

Another possibility to fixate workpieces provides the developed magnetic clamping system. It is able to provide high clamping forces to securely fixate ferromagnetic workpieces. With the use of permanent magnets, also no energy is needed while machining.

The presented clamping systems are designed to fit the intelligent machine interface developed in [3]. The interface consists of two halves, which can be reproducibly coupled with each other. The reachable repeating accuracy is 0.5 µm. One part of the interface is mounted to the clamping system, whereas the machine tools are equipped with the other part.

References

[1] Wulfsberg J, Lehmann J 2003 Spanntechnik für die Mikrofertigung. *Werkstatttechnik* **93**

[2] Heisel U, Pasternak S, Stehle T 2012 Haltekräfte in der Mikrospanntechnik. *Werkstatttechnik* **102**

[3] Grimske S, Kong N, Röhlig B, Wulfsberg J 2012 Repeatable Positioning Accuracy of Mechanical Interfaces for Micro Manufacturing. *Proceedings of the 12th international conference of the European Society for Precision Engineering and Nanotechnology* **2**