Modular Workpiece Carrier and Clamping System for Micro Machining

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Abstract

Machining micro parts constitutes a special challenge for machine tools and peripheral equipment with high accuracy and precision to obtain. An advanced desktop manufacturing concept, Square Foot Manufacturing (SFM), pursues new ways with methods, materials and techniques uncommon to macro machine tools to meet those challenges. Holding micro parts securely in place for machining operations is an advanced task that, only if done properly, allows one to fully exploit the benefits of the new micro machine tool system. Being designed as a kit, the workpiece carrier extends the capabilities of the current SFM machine tool on demand by not only gripping the workpiece in various ways, but also adding a feed and rotating motion. Besides quickly introducing SFM, this contribution presents the theoretical concept of the workpiece carrier and clamping system and unveils the first practical implementation of a clamping device.

1 Introduction

Approaches to miniaturize machine tool systems have been the focus of research for some time. Desktop manufacturing is one possible attempt. Nevertheless, it is limited to common maxims of machine design, meaning desktop manufacturing concepts are simply scaled-down versions of existing macro-machine tools. An advanced approach to miniaturize machine tool systems is SFM. It differs from desktop manufacturing by using its small size as a general enabler, thus avoiding the drawbacks that occur by simply downscaling existing machining concepts [1]. For example, this allows for the use of new materials and new technical approaches generally not found in machine tool systems. Another distinctive feature of SFM is the modular objective. Machine tool setups can quickly be reconfigured from a kit of modules. Each module offers minimal complexity, thus generating a robust and economical design. The current setup consists of a feed unit [2], mechanical interfaces [3], a milling [4] and laser tool and the workpiece carrier described below.

2 Workpiece carrier and clamping kit

According to the principles of SFM described in [5], the machine tool modules can either be set up as a micro bench or as a flow production. For both approaches one single workpiece carrier is developed. It can be treated like a kit, as depicted in Figure 1, which can be adapted to various production techniques and clamping approaches, allowing a workpiece handling system for the vast majority of possible shapes and materials to be clamped. Depending on the manufacturing task, unnecessary modules can be left out for simplicity and financial reasons. On the other hand, additional modules can be developed and integrated in the future. The objective of development is to continue the modular design of SFM and to convey its design principles to the workpiece carrier and clamping system.

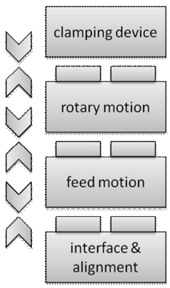

Figure 1: Modular approach for a workpiece carrier kit

The bottom of the workpiece carrier consists of a mechanical interface based on the principle of a kinematic coupling [3], which quickly connects the carrier to a base plate of the corresponding manufacturing station. If movement of the carrier is not required, the interface can be left out and the carrier can simply be bolted to a base structure. To correct manufacturing inaccuracies of the complete carrier, means for alignment could be integrated. Another possibility to cope with systematic errors of a carrier would be to save the data to RFID or other tags so that the feed unit for the tools can automatically correct them.

An additional module will allow for a feed motion along the main axis of the carrier. Combined with a two-dimensional movement of a machine tool feed unit, three-dimensional machining is enabled. Based on the current feed unit, feed motions up to a few millimeters with a repeatability way below 1 µm are aspired.
An indexed turning module will make rotary milling possible. A variety of clamping devices will form the top part of the carrier. Examples might be freeze- or wax-clamp, magnetic or elastic deformation chucks, gluing or vacuum platforms or gripping devices based on memory-shaped alloys. The selection has to be done based on the batch size and workpiece properties.

3 Practical implementation

To date, the current setup consists of one possible clamping device and the interface to a base plate. Due to the required precision, classic machine vise approaches or grippers cannot be applied. Therefore, the clamping device uses an elastic deflection of its chuck to securely fasten miniature workpieces in the three and four digit micrometer size range [6].

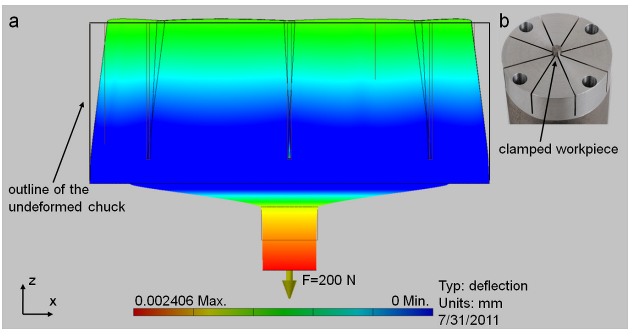

Figure 2: FEM simulation of chuck to secure an outside contour of a workpiece (a) and the actual chuck clamping a 5 mm cylinder (b)

Inner and outer contours can be fastened by either pushing or pulling (Figure 2) on the bottom center of the chuck. The holding force is generated by a manually deformed monolithic compliant lever and measured with a load cell. For an automated solution a high-force piezo linear actuator can be utilized. This way, there is no need for a power supply after clamping the workpiece and the whole carrier can be passed on to different manufacturing stations without a wired connection.

Together with the tool feed unit and mechanical interfaces, the workpiece carrier forms a functional combination in micro manufacturing. Current work focuses on integrating the feed motion in z-direction.

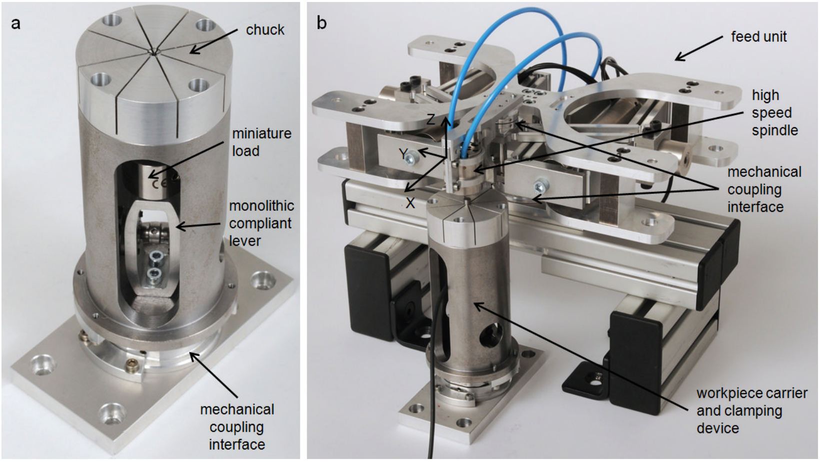

Figure 3: Current workpiece clamping system (a) and a possible setup for micro milling (b)

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