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Flexible and Space-Saving Machine Concept for Micro Production

K. Dröder[a], H.-W. Hoffmeister[a], T. Tounsi[a]*

[a] *Insitute of Machine Tools and Production Technology, Technische Universität Braunschweig, Germany*

* Corresponding author. Tel.: +49-531-391-7620; fax: +49-531-391-5842. *E-mail address:* t.tounsi@tu-braunschweig.de

Abstract

It is appropriate to adjust and reduce the machine tools to the size of the small parts that have to be machined for saving production space and energy. A concept, which allows individual combination of multiple machine modules to a flexible production unit with the help of a modular system is presented. It is a matter of size-adjusted machine tools that feature a clearly better proportion of working space and overall size than conventional machine tools for micro production. This results in saving storage space on the shop floor and this also results in cost reduction regarding purchasing and running the machines. A modular and reconfigurable machine concept additionally provides a user oriented machine design, that can quickly and easily be adapted to individual production tasks. The low dead weight additionally allows high mobility and quickly adaptable assembly of the machines within the required process chain. Some implementation examples are presented in the paper.

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Keywords: modular machine design; size-adjusted machine; work piece clamping; micro production; flexible manufacturing system

1. Introduction

Development and usage of microsystems have continuously increased within the past years. These systems with small dimensions consist of sensor, actuator, and signal processing elements. These microsystems often consist of electronic and non-electronic components. The non-electronic components, for instance, include case, lenses, but also whole micro gear boxes and turbines. These parts are often produced from synthetic materials in micro injection molding processes, e.g. for the medicine industry. The molds for these parts allow efficient production of medium to large quantities and are produced in machining processes. These processes are suitable for machining any kind of materials and are able to produce structural measurements in the range of 5 to 25 µm with aspect ratios of up to 1:100 in micro machining.

Producing these microsystems or microstructures takes place on precision machine tools. But, these machines are unreasonable large regarding their installation and working space compared to the work pieces that have to be machined. This leads to the approach to set up machine tools, that are adjusted to the size of work pieces, which are manufactured. The less usage of resources and the less requirement of energy as well as less required floor space are the main benefits of size adjusted machine tools. To set up size-adjusted machines, a fundamental new construction of frame, drives, and kinematics is necessary. Installation spaces of 0.125 m^3 up to 0.003 m^3 are targeted. There are no solutions on the market for the required small machine components, so in-house developments have to take place.

The priority program 1476 of the German Research Foundation (DFG) “small machine tools for small work pieces” deals with this issue of size adjusted and modular structured machine tools. The machine concept that is presented in this paper is developed in a cooperate research project of the Institute for Control Engineering of Machine Tools and Manufacturing Units of the Universität Stuttgart and the Institute of Machine Tools and Production Technology of the Technische Universität Braunschweig [1].

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2. Production Cube Module

The decrease of product life cycles and product development cycles results in a continuous change of requirements and conditions for the production of microsystems. This requires adaptable manufacturing equipment that can quickly be adjusted to the work pieces that have to be machined. The new approach of production cube modules (PCM) leads to a more compact construction of machine tools with high flexibility at the same time.

A cube shaped CFRP-frame function as the basic structure, which offers connection ports for adapter plates on each of the six sides. These adapter plates can be equipped with components like feed axis, tools or work piece holders. Due to this modularity, exchanging adapter plates lead to combinations of various machine assemblies.

For instance, figure 1 shows an adapter plate, which is equipped with two drives, that are arranged orthogonally to each other. These drives are connected with a parallel kinematic for movement in x-y-direction. An additional actuator ensures movement in z-direction.

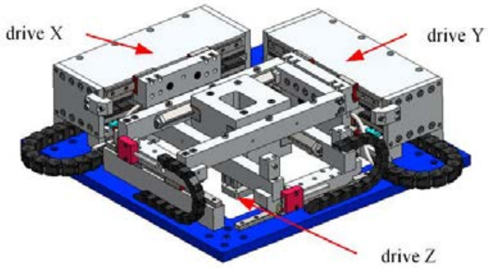

Fig. 1. Adapter plate with actuator components [1].

The presented PCM is equipped with two of these adapter plates at the opposite sides of the CFRP-frame. This leads to a combination of two drives (tool and work piece) for one direction. Only half of the traverse speed per drive is needed for reaching the desired velocity. Besides this, travel path of each drive can be divided in half as well, which leads to an overall more compact machine assembly and also to a better relation of assembly space and working space (fig. 2).

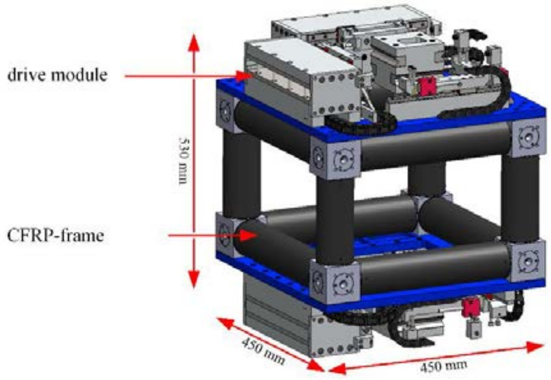

Fig. 2. Production cube module with cooperative axis drive [1].

3. Size Adjusted Machine Components

Reducing the machine size also requires size adjustment of the needed machine components. A lot of components available on the market just fit the PCM in their smallest design. But with them, a further reduction of the cube dimensions is not possible. Other components such as work piece clamping devices do not even exist with required dimensions.

Within the DFG priority program various machine components are developed for size adjusted machine tools. In [2] a work spindle was developed, which is pneumatically driven and aerostatic beared.

For grinding tasks, a spherical micro grinding head was developed in [3], which consists of magnetic bearings and a fluid dynamic drive.

An intelligent machine interface for flexible assembly and disassembly of size adjusted components was developed in [4,5]. The interface consists of two halves, which can be reproducibly coupled with each other.

This paper presents size adjusted components, that deal with clamping and transportation of work pieces. Two work piece clamping systems are developed, that base on the operating principle of force-fit. These clamping systems are exchangeable and allow fast and simple work piece fixation and therefore processing of any kinds of geometries and materials. During machining the work piece clamping systems do not need extra energy to maintain clamping forces.

A new concept for work piece transportation is also introduced. Multiple PCMs can be used to create an individual process chain. In combination with the intelligent machine interface, the work piece clamping systems can automatically be transported between these PCMs.

3.1. Magnetic clamping device

A magnetic clamping device, which allows clamping and unclamping of ferromagnetic work pieces by mechanical moving of permanent magnets, was developed. A laminated top plate, which features steel and brass segments is used as a clamping surface for the work pieces. Permanent magnets below the clamping surface are used to provide the magnetic forces between work piece and laminated top plate. The permanent magnets are located in a cage, which holds them in position. By simply rotating the cage, the clamping forces on the work piece can be switched on or off. In switched on condition, the magnetic flow runs through the work piece and provides clamping forces. In switched off condition, the magnetic flow is already short circuited in the steel segments of the laminated top plate and the work piece can be removed from the clamping surface.

The developed magnetic clamping device with manual switching of the clamping forces features a total height of 30 mm. The clamping surface for work pieces has a diameter of 40 mm. A magnetic clamping device that operates after the same principle, but is suitable for automated processes was also designed. The rotatory movement for switching is performed by a gear motor. This clamping unit has a total size of 70 mm and a clamping surface of a 45 mm diameter. Fig. 3 shows both