

Implementation of a Flexure Based Feed Unit for the Square Foot Manufacturing Concept

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Abstract

Scientists of the Helmut-Schmidt-University / University of Federal Armed Forces Hamburg are currently working on the implementation of the Square Foot Manufacturing concept. This concept, an enhancement of existing desktop manufacturing concepts, is characterised by its modularity and mutability. The theoretic background and important assumptions are presented in [1]. This paper reveals the first prototypes of Square Foot Manufacturing components and furthermore results of their practical application will be shown.

1 Introduction

The Square Foot Manufacturing concept is based on the idea to create small machine tools, in this context called Square Foot Factories, ad hoc out of a kit of modules in a demand and process orientated manner. The small machine tools used in this context, the Micro Machining Units, are specialised for a specific manufacturing operation and will be arranged around a work piece, to enable them to perform their machining operations sequentially or simultaneously [1]. Fundamentally the Micro Machining Units are composed of a tool module (e.g. laser optics, machining spindle) and the feed unit, which can be combined by standardised interfaces. As feed unit a monolithic compliant mechanism, actuated by two piezo actors, is used. This alignment allows a planar workspace and feed motions in millimetre range, which are sufficient for a large number of applications. The general concept, first calculations concerning the workspace and a possible layout have been presented in [2]. A summing-up of its characteristics is shown in table 1.

2 Implementation of the feed unit

The initial design, which has been presented in [2], had to be altered due to parasitic motions of the tool platform, which have been noticed in various FEM analyses. Compared to the original layout the middle frame consists of parallel linkages to prevent rotations of the moveable part, and the external frames are mounted directly on the moveable part of the middle frame. Furthermore the external frames are aligned in the middle of the tool platform to compensate movement in z-direction and to increase the corresponding stiffness. The technique

Table 1: Characteristics of the feed unit

length	162 mm
width	216 mm
height	46 mm
max. traverse path in X	1,9 mm
theoretic resolution in X	46 nm
max. traverse path in Y	+/- 0,42 mm
theoretic resolution in Y	10 nm

of parameter optimisation has been applied to improve the mechanism concerning feed motion, attainable stiffness and resultant stress. According to FEM Analysis the maximal stress occurs in the flexures of the external frames. It has been calculated to 157 N/mm² which is significantly beneath the elastic limit of the specified material, heat treated aluminium alloy 2024, approximately 290 N/mm². The final layout and the feed unit are shown in figure 1.

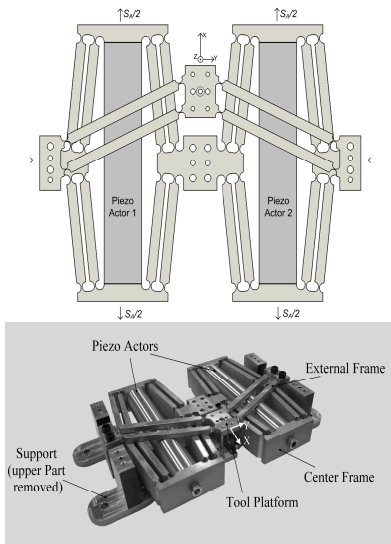


Figure 1: Final Layout (left) and implemented feed unit with support (right)

The stated traverse paths (table 1) have been calculated based on a displacement of 83% of the maximal displacement S_A of the two piezo actors to guarantee a sufficient force to deform the compliant mechanism. The stiffness of the feed unit has been calculated to 1351 N/mm in x- direction, 261 N/mm in y- direction and 36 N/mm in z- direction.

3 Machining Results

Components of the Square Foot Manufacturing concept are designed to machine small geometric elements. Multitudes of innovative approaches [1] are used to enhance the achievable accuracy. To prove these important assumptions it is ascribed great importance to the premature implementation of fully operational Micro Machining Units.

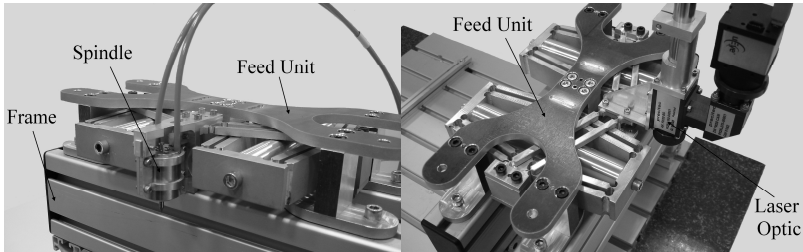


Figure 2: Exemplary Micro Machining Units

Thus two prototypes, based on the presented feed unit, have been assembled. On the one hand the optic of a fibre laser is used as the tool module (figure 2 right), on the other hand a high speed air bearing spindle for milling and drilling operations is used, which has been developed by the Institute for Manufacturing Technology and Production Systems (FBK) of the University of Kaiserslautern [3] (figure 2 left). The tool modules are mounted on the tool platform (figure 1) and aligned in a way to allow planar manufacturing operations.

A result of machining attempts is shown in figure 3. For this purpose the emblem of the Institute of production engineering (*LaFT*) has been machined on stainless steel via laser marking operations. These results prove the point of principle whether the developed Square Foot Manufacturing components are adequate for the range of micro manufacturing.

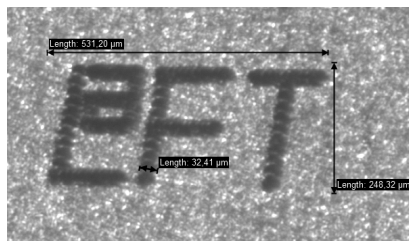


Figure 3: Result of a laser marking operation with a Micro Machining Unit

However it must be ascertained that during operation variations between the desired value and the actual value occur. Possible reasons for this deviation arise from the manufacturing of the compliant mechanism [4]. To estimate the actual behaviour for further machining operations the existing feed units will be measured and calibrated precisely.

4 Outlook and summary

This paper presents the first prototypes of Micro Machining Units for the Square Foot Manufacturing concept. In addition to various design characteristics first experimental results of laser machining operations are shown. The next steps in the development process of the feed unit will be attempts of chipping manufacturing operations and a calibration of the feed unit.

When the results of these evolutionary milestones clarify that the Micro Machining Units meet the expectations subsequent steps for the implementation of the overall concept, like the assembly of a complete Square Foot Factory will be taken into account.

References:

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