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THE IMPACT OF SIZE REDUCTION ON THE ENERGY EFFICIENCY, DYNAMICS AND MACHINING PERFORMANCES IN MILLING

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Abstract
The Micro[5] 5-axes milling machine was specifically developed for micro, or mini, technical productions and focused on simplicity and efficiency. It provides functional, qualitative and economical performances. Designed for low cutting forces (HSC technology), it has an excellent dynamics. The first vibration modes and compliances being very high, the machine is insensitive to axes accelerations. It therefore produces excellent surface finishes and high efficiency in finishing. This paper presents the results of an evaluation project. A comparison with a usual size machine is made.

Keywords:
size reduction; micro-machine; milling; energy; dynamics; machining performances; air consumption; thermal characteristics; modal analysis;

1 INTRODUCTION

The University of Applied Sciences and Arts Western Switzerland (HES-SO) develops a high efficiency 5-axes milling micro-machine Micro[5]. The main idea of the project is to develop a machine for the production of small parts with a high efficiency in terms of energy consumption.

In the bibliography, the existing measures show the energy used to remove the material is about 15% of the total energy consumed during machining. The idea is to design a machine for the production of small parts with dimensions in relation. The capacity is a cube of 50 mm length (Fig. 1). The market objectives are the watch and medical industries.

During the project, we found that, many other aspects of this machine are comparable with the best achievable, not only the energy consumption. This paper presents, after 14 months of evaluation tests, the performances of this machine. The measured characteristics are:

- Machining production performances
- Static stiffness
- Dynamic modes, compliances
- Thermal behavior
- Energy consumption: air, electricity

The paper discusses the advantages and disadvantages of the size reduction based on these measurements. At the same time, a usual size machine, a Mikron 5-axes HSM400, has been measured and the results compared to the Micro[5].

The Micro[5] has been developed and built completely in the HES-SO academic environment. Today, production rights have been sold to two Swiss machine tool suppliers. Actually, products based on this development are on the market.

A test part has been designed (Fig. 2) and used with several programs in order to evaluate the precision, the surface finish and the achievable production speed. The precision is very good, but the most impressive result in comparison with a standard machine, is the very fine surface finishes we obtained. We discovered that this could be achieved without working on the CNC strategy in regard to the modal frequencies. The analysis of the dynamics of the machine shows that the modal frequencies are very high in comparison with a standard machine. This is a great advantage. Also, the static stiffness is high due to the small length of the axes (therefore small effort loop). These two results lead to the fact a complex CNC strategy is not needed to deal with the generally low modal frequencies of the machine structure.