Description for the general public

Miniature devices and components with features that range from tens of micrometers to a few millimeters in size are presently widely applied in the many industries, including aerospace, biomedical, electronic and automotive. These parts are usually manufactured with the application of photolithography, micro-electro discharge machining, ultrasonic and laser beam techniques, as well as ultra-precision machining with diamond tools. However, the majority of these methods has low productivity and is limited to the relatively small group of processed materials. Moreover, the above technologies are basically inhibited to the manufacturing of planar surfaces. The alternative for these methods can be found in micromilling process, which is conducted with carbide end mills, with diameters not exceeding 1 millimeter. (Fig. 1a). This technology enables efficient and precise machining of various materials. In addition, the machining with the micro ball end mills additionally allows the formation of free-form surfaces in the features intended to the biomedical process, which are made of titanium alloys and stainless steels, e.g.: bone and joint implants or neurovascular device components. Apart from biomedical engineering, precision milling with micro ball end mills allows also the manufacturing of micro-injection molds made of hardened alloy steels and devices for the bio-micro-electro-mechanical systems (bio-MEMS). Nevertheless, the fundamental technological limitations occurring during the micromilling are related to the difficulties in obtainment of high machined surface's quality and common tools' fractures (Fig. 1b).

a) b)

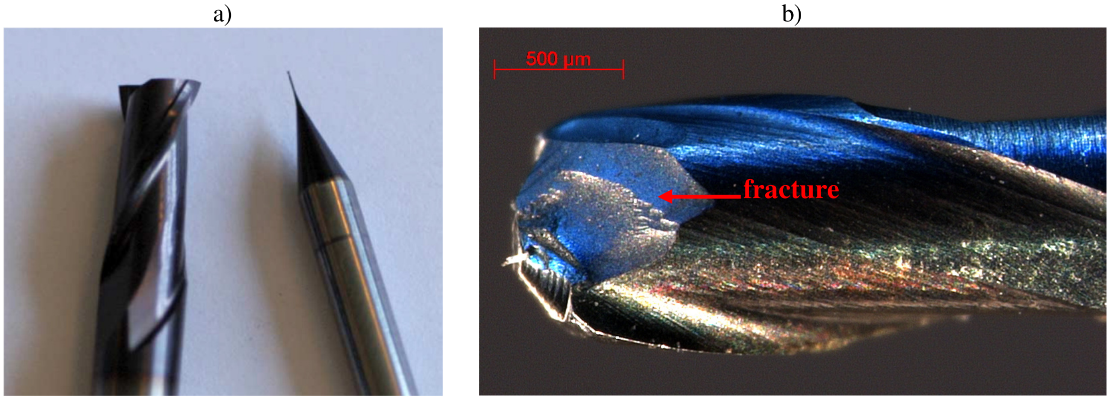

Fig. 1. Carbide micro end mills: a) comparison of micro mill (diameter: 0,2 mm) with conventional end mill (diameter: 6 mm); b) catastrophic tool's failure by the fracture of the working part (diameter: 1 mm). Own elaboration

These problems are mainly caused by excessive cutting forces and micro tools' deflections. The reduction of cutting force and deflection values is possible by the appropriate selection of machining parameters and strategies, as well as the effective cooling/lubricating technique of the cutting zone (e.g. the application of minimum quantity cooling lubrication). In order to achieve it, the formulation of accurate and complex mathematical models of micromilling process' dynamics is essential. Therefore the primary project objective is the development of complex models which describe cutting forces, instantaneous displacements and mechanical strength of the micro ball end mill during precision milling of hardened alloy steel. To this end, the simulation and experimental approaches will be applied. The simulation approach will include solutions of the developed micromilling process' mathematical equations with the application of finite elements (FE) and numerical methods. Thereafter, the formulated models will be empirically validated during micromilling with the variable input parameters. This research will include the measurement of cutting forces, vibrations, surface texture and micro ball end mill's condition. Undertaking this project subject was dictated by the need of scientific knowledge extension related to the micromilling dynamics, as well as the improvement of tool life and machined surface quality. Finally, the results can be an important basis for popularization of micromilling technology, and its extension to the production of micro-parts with free-form surfaces, intended to the biomedical, electronic and aerospace industries.