1. Introduction

The tendency to make progressively smaller and increasingly complex products is no longer an exclusive demand of the electronics industry. Many fields such as medicine, micro mechanics, biomechanical technology, the automotive and the aviation industries are searching for tools and methods to realize micro and nanostuctures in various materials. The micro-structuring of very hard materials, like carbides or brittle-hard materials, pose a particularly major challenge for manufacturing technology. For these reasons the Institute for Production Engineering and Laser Technology (IFT) of the Vienna University of Technology is working in the field of electrochemical micromachining with ultra short pulses.

2. Electrochemical Micromilling with ultra short pulses

With the theoretical resolution of 10 nm, this technology enables high precision manufacturing. The main targets for the work at the IFT are the development of pre-pulse technology and machining strategies to speed up the production rate, as well as the elaboration and testing of new material-electrolyte combinations to expand the field of application for this technology and to build up a knowledgebase for the large number of varying parameters of the process. This needs to be accomplished in order to fulfill the requirements of industrial production because in industries such as the automotive sector, the rate of production is very important.

The machining technology of electrochemical micromilling (ECM) is based on the already well-established fundamentals of common electrochemical manufacturing technologies. The greatest advantage of higher manufacturing precision underlies the fact that extremely small working gaps are achievable through ultra short voltage pulses. This describes the main difference to common electrochemical technologies. Another big advantage of the electrochemical micro milling technology is that the treatment of the work piece takes place without any mechanical forces or thermal influences. Therefore, no abrasive wear of the tool occurs and aspect ratios of >100 are possible, which sets the basis for extremely sharp-edged geometries; so there is no unintentional rounding of edges and no burring on the part.

The ECM process is an electrochemical manufacturing method where an opposing electric voltage for the work piece and the tool is used. At the phase boundaries between the tool and the electrolyte and also between the work piece and the electrolyte, an electrochemical double layer is formed; whose functionality can be understood principally as a kind of double capacitor. In addition to the correct choice of the electrical process parameters, like the amplitude of the pulses, the pulse width, the voltages at the tool, the work piece, and the backing electrode, the right choice of the electrolyte is probably the most important aspect for this process. The whole machining process takes place in a basin filled with an electrolyte solution which has to be adequately adapted to the work piece material. Even during the filling of the basin, the greatest caution must be taken due to the fact that once in contact with the electrolyte, the surface of the material immediately begins to corrode. To shield the work piece surface from the influence of the electrolyte solution, a cathodic protection current is applied. So far, some appropriate electrolyte material combinations have already been found, for example nickel-HCL, tungsten-NaOH, and the non-corroding steel 1.4301-HF-HCL.
Characteristics of the ECM process:
- High precision (theor. resolution of 10 nm)
- No thermal load
- No mechanical process forces
- High aspect-ratio (>100)
- No tool wear
- Small working gaps (< 1 µm)
- Manufacturing of hard materials
- Very small edge-rounding
- No burring
- High quality measuring function

The technology of electrochemical micromachining with ultra short pulses has successful displayed the many applications especially for prototype building or for the manufacturing of special products where there is no other technology which can combine a very high manufacturing precision for special materials without any mechanical forces or thermal influences. Also the use of pre-pulse technology and the applicable effects on process accuracy and material removal rate of difficult to machine materials offers a wide range of possible applications for ECM technologies. The occurring electrochemical problems are tradable and topics at the Institute, as well as the micromachining of many materials like nickel, tungsten, non-corroding steels or hard metals.

3. References