Popular Science Summary

Performance and Wear Behavior of Ultra-Hard Cutting Tool during Machining of Titanium Alloy

Since the 1950's, a wide range of titanium alloys has been developed. Attractive titanium properties are the high strength-to-weight ratio, resistance towards corrosion, low thermal conductivity and low thermal expansion. Properties that make titanium alloys difficult-to-machine materials are those of low thermal conductivity, chemical reactiveness and the high strength, requiring low cutting data, resulting in low material removal rate and therefore high manufacturing costs. This implicates the importance of solutions for high speed machining and knowledge about wear mechanisms and machining performance.

The purpose of the study is to accumulate knowledge on the basic performance, wear mechanisms and cost efficiency of selected cutting tool materials and workpiece material. This knowledge enables selection support for suitable cutting tools and cutting data to a certain workpiece material.

The results refers to be a part of the ongoing research in the metal cutting area. The results will primarily be used by the contracted company, be a part of the examples in the courses at the department at which the master thesis is performed and be a base for other master theses or doctoral dissertations.

The most commonly used cutting tool for machining in titanium alloys are those of cemented carbide with sharp edges. The study includes a range of cutting tool materials: cemented carbides (coated and uncoated), PCD (Polycrystalline Diamond) and pcBN (polycrystalline cubic Boron Nitride), to compare and analyze with regard to wear mechanisms and chemical reactions in the cutting tool.

This study investigates the machining performance and wear mechanisms during high speed machining in (α + β)-alloy Ti6Al4V, the most commonly used titanium alloy. The cutting data are for finishing operations, where tolerances and surface roughness are essential result parameters. The machining is performed with longitudinal continuous turning under application of high-pressure coolant.

Cutting tools of interest are subjected to in-depth microscopic analysis with FIB-SEM (Focused Ion Beam and Scanning Electron Microscopy) and TEM (Transmission Electron Microscopy) to find possible chemical reactions in the cutting tool during the machining. Selected cutting tools are subjected to cost-efficiency to present the results regarding machining performance and cutting tool cost in relation.

The result shows that the uncoated cemented carbide has a better cost efficiency compared to coated cemented carbide. For the higher values of the cutting speed for the uncoated cemented carbide and the PCD, the PCD is superior regarding cost efficiency compared to the uncoated cemented carbide. The PCD has got a better cost efficiency compared to the pcBN.

The chemical analysis with TEM on PCD and pcBN are somewhat difficult to read. There are small boundary areas between the cutting tool material and the adhered workpiece material. Probably, there are formations of titanium carbides or diffusion of carbon into the workpiece material in the cutting tool PCD. Between the diamond grains, there seems to have been titanium working its way down into the cutting tool material. Regarding the pcBN, there might be formations of titanium nitrides in this boundary area or possibly diffusion of boron or nitride into the workpiece material. Leftover elements from the cutting tool manufacturing process are noted.