Mechanisms of Plastic Deformation of Cemented Carbide and Cermet Cutting Tools

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Abstract
In this thesis, the physical mechanisms acting during plastic deformation of hardmetals used in metal cutting applications have been investigated. Microstructural and microanalytical studies have been performed on cemented carbides as well as cermet materials. The main experimental techniques used were scanning electron microscopy (SEM), transmission electron microscopy (TEM), energy filtered TEM (EFTEM), electron backscattered diffraction (EBSD) and atom probe field ion microscopy (APFIM). Comparisons between some of the experimental results and ab initio calculation have also been made.

All materials were produced as triangular cutting inserts and were plastically deformed with a turning operation at varying cutting speeds. SEM was used to get an overview of the microstructure whereas more detailed features were studied by TEM. The microstructures before and after deformation were compared on different scales. It was found that the hard phase skeleton had partly broken up during deformation and binder phase films had formed in the broken up grain boundaries.

In order to detect any dissolution of the hard phase during cutting the binder phase composition was measured by APFIM. No signs of dissolution were detected with this technique but instead dissolution of the hard phase along grain boundaries and at triple points could be seen with TEM and EFTEM. Some dislocation glide was observed in the cemented carbides but not in the cermet materials.

In one material spinodal decomposition of the binder phase was found and was also confirmed by thermodynamical calculations.

Materials with additions of TaC were also studied to investigate the effect of tantalum on the deformation mechanisms. It was found that Ta has a beneficial effect on the plastic deformation resistance in some cases. In addition, Ta was found to affect the sintering procedure since it lowered the melting point of the binder phase.

A model for the plastic deformation was presented where the materials were said to deform mainly by grain boundary sliding, made possible by stress induced dissolution of hard phase grain boundaries.

Ab initio calculations showed that Σ2 grain boundaries are stronger and more resistant to Co infiltration than general boundaries and EBSD was used to assess the importance of these boundaries for the plastic deformation resistance. They were not believed to constitute any important contribution to the total plastic deformation resistance but if their amount is increased they could improve the deformation resistance.

Methods to prepare TEM and APFIM specimens from deformed cutting inserts with focused ion beam (FIB) milling were also developed. Preparation of thin foil TEM specimens was performed with so called in situ lift-out where a thin foil is cut out with high precision from the deformed region and finally thinned by ion polishing. The needle-shaped APFIM specimens were prepared by cutting out a rod from the cutting edge and thin the deformed region with dimple grinding. Final sharpening was obtained by FIB milling.

Keywords: cemented carbides, cermets, plastic deformation, SEM, TEM, EFTEM, APFIM, FIB, EBSD, ab initio calculations