Abstract

Cutting of nickel-based alloys is one of the most challenging tasks in production. The outstanding properties of these materials are important for the efficiency of turbines, yet they increase production costs. High speed machining with ceramic inserts can significantly reduce machining time.

Due to design restrictions it is not possible to make tools with ceramic inserts smaller than 16 mm. As a result, cemented carbide and high speed steel tools are used below this diameter. The focus of this thesis is to develop a solid ceramic end mill for high-speed machining of nickel-based alloys with a tool diameter of 8 mm.

As a starting point for identifying a design of a solid ceramic end mill, the analysis of tool geometry and machining process is critical. Cutting force calculations have shown that adjusting tool geometry and cutting parameters influence cutting forces to favor the material properties of ceramics.

In this study, the effects of cutting velocity on process temperature and cutting forces is analyzed by milling tests. Build up edges and cutting forces reduce significantly with increasing cutting velocity. Tools made of Sialon-ceramic achieved material removal rates of 35 cm^3/min at cutting velocities of 1,400 m/min in a very stable process. In addition, wear mechanisms showed to have a strong correlation to material selection.

Machining MAR M247 with Sialon ceramic is dominated by flank wear, while chipping of cutting edges is critical for machining Inconel 718 with Whisker ceramics. The effects of mechanical and thermal loads on the stress distribution of the cutting edge are analyzed by FEA. It was shown, that high temperatures on the cutting edge result in compressive stress that compensates the tensile stress resulting from the cutting forces. Overall, a high temperature has a favorable effect and can reduce flank wear and chipping.

It was shown that a 30% machining time reduction can be achieved by employing solid ceramic end mills, using the example of a gas turbine guide vane. The outputs of this study are cutter geometries and the description of a process environment, that allow stable application in high speed machining of nickel based alloys.