Integrated Design and Analysis of Diamond-Coated Cutting Tools

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EXTENDED ABSTRACT

Diamond-coated cutting tools are attractive alternatives to polycrystalline diamond tools for machining lightweight, high-strength components made of advanced materials such as composites. However, residual stresses induced by the diamond deposition process, due to thermal mismatch between diamond and the substrate, significantly impact the coating-substrate adhesion, and thus, the tool performance in machining. Moreover, the tool geometry, particularly at the very tip, complicates the stress fields because of the geometry changes. The objective of this research is to investigate the effects of critical tool geometry parameters on the residual stress augmentations around the tool tip.

In this project, Pro/Engineer software was used to create the solid model of various tool geometries. Pro/Engineer can create an accurate model of the tool, which emulates each aspect of the tool geometry, e.g., as small as 5-micron edge radius on a 12.7-mm tool. The solid model was then exported to ANSYS software for 3D finite element simulations of residual stresses generated in the tool with given deposition conditions. The obtained stress data was transformed, coordinate-wise, to evaluate the interface stress profiles around the tool edges. Current results show that the cutting edge radius is critical to the stress concentrations around the tool tip. For a 5-micron edge radius, the radial normal stress increases from 0 at the bulk surface to about 1 GPa in tension, and the circumferential normal stress increases from around 2.5 GPa in compression to over 3 GPa.

To systematically investigate tool geometry effects, the test matrix, determined using the design of experiments approach, includes 4 factors (edge radius, relief angle, nose radius, and insert shape) and 2 levels with a full factorial design. Statistical analysis will be performed to quantitatively reveal the significant factors and interactions between the factors that dominate the stress concentrations. In addition, a white-light interferometer (3D optical profiler) is employed to assess the tool geometry, before and after coating. The results will offer tool makers guidelines in the design of diamond-coated cutting tools.