Thermal Effects on Subsurface Damage During the Surface Grinding of Titanium Aluminide

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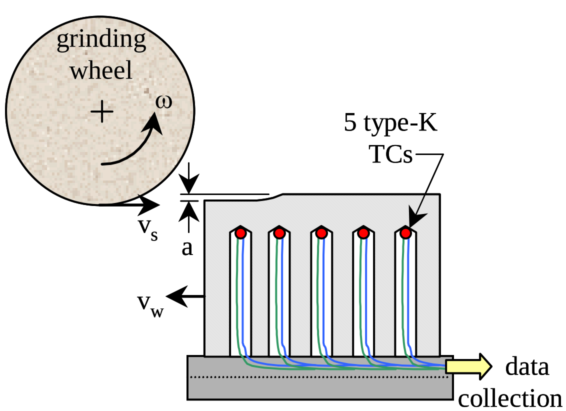
Intermetallic compounds (IMCs) are metals that have component elements that are bonded through covalent, ionic, and/or metallic bonds, typically stronger than those of most metals. Titanium Aluminide (TiAl) is an IMC that has attracted much attention in the aerospace, automotive, and chemical industries, particularly for its high strength to weight ratio at elevated temperatures. Unfortunately it is brittle at lower temperatures, making it difficult to machine. Grinding is a process that is typically used to achieve tight tolerances and to machine complex geometries. As grinding can be a very aggressive, high-energy process, it creates a challenge in maintaining surface integrity, particularly subsurface damage. One form of subsurface damage, the depth of plastic deformation, has been quantified by PMRC graduates Nelson and Razavi as being proportional to the square root of the normal grinding force. This model explains much of the damage, but does not account for thermal effects, which can vary based on input parameters, such as coolant conditions (concentration, flow rate, ambient temperature), wheel type, wheel speed, workpiece velocity, etc. This research will use a multi-step approach to quantify these thermal effects.

The first step is to establish the temperature profile during the grinding process, using thermocouples (TCs) inserted through the bottom of the workpiece. This experimental profile will be compared to the theoretical model by J. C. Jaeger. This profile, a function of process inputs, will be used later to estimate the temperature in the grinding zone when instrumentation with TCs will not be possible.



Experimental setup to establish temperature profile during the surface grinding operation.

Due to potentially large temperature gradients, the TiAl material properties may vary throughout the workpiece and during various stages of the grinding process. A proposal has been approved to evaluate these properties at Oak Ridge National Laboratory's High Temperature Materials Lab (ORNL-HTML).

The next step is to use the knowledge of these changing properties to analytically model the subsurface damage during grinding, based on mechanics of materials and fracture mechanics fundamentals. This theoretical model will be compared to experimental data that evaluate the depth of plastic deformation given varying process inputs, such as wheel type, workpiece speed, wheel speed, depth of cut, coolant conditions, etc.

The experimental validation is based on a bonded interface method previously used by Nelson and Razavi. One of the problems in evaluating the depth of deformation after grinding is that sectioning the sample causes its own damage. Thus, in the bonded interface method the sample is sectioned prior to grinding, polished, and bonded together. After grinding, the workpiece is removed from the clamp, separated, then evaluated under an optical microscope, as well as a scanning electron microscope.

Wes Stone is a Ph.D. Candidate working on the grinding of super alloys. He received his BSME from The University of Texas at Austin, and his MSME from Penn State. He worked for General Electric (Aerospace, Aircraft Engines, and Power Systems) for 8½ years before returning to school. He plans to graduate in May 2002, and is looking for academic or industrial opportunities related to his research interests: materials and manufacturing.

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