ABSTRACT

BAKKAL, MUSTAFA. Machining of Bulk Metallic Glass. (Under the direction of Dr. Albert J. Shih)

The turning and drilling of $Zr_{52.5}Ti_5Cu_{17.9}Ni_{14.6}Al_{10}$ metallic glass (BMG) are evaluated in this study. The mechanics of machining and chip formation and characterization are investigated. In the lathe turning of BMG, above a threshold cutting speed, the low thermal conductivity of BMG leads to chip temperatures high enough to cause the chip oxidation and associated light emission. The high temperature produced by this exothermic chemical reaction causes crystallization within the chips. Oxide layer, amorphous region, fully crystalline region, and crystalline-amorphous transition region are observed in the cross-section of the chips. The x-ray diffraction peaks match the pattern for monoclinic ZrO_2. Turning chips morphology suggests that increasing amounts of viscous flow control the chip-removal process. Moreover, viscous flow and crystallization can occur during the machining of the bulk metallic glass, even under the high temperature gradient and strain rate. For the BMG chip without light emission, the serrated chip with adiabatic shear band and void formation was observed. High cutting speed significantly reduced the forces for BMG machining due to thermal softening. Roughness of machined BMG surfaces is generally better than that of Al6061-T6 and SS304. Tool wear is a problem for BMG turning. Chipping and thermal softening on the lathe tool cutting edges can be observed. Drilling of BMG shows that holes with precision geometry and good surface roughness can be efficiently produced in BMG using the high speed steel and WC-Co drills at spindle speed that does not exceed the

limit for chip light emission. Morphology of BMG drilling chip are classified and analyzed. The thermal conductivity of tool material and cutting speed are concluded as two critical factors that triggered the chip exothermic oxidation and light emission. The chip light emission has profound impact on the drill wear, as shown by the experimentally measured thrust force and torque. This study concludes the precision machining of BMG is possible with the selection of feasible tools and process parameters.

MACHINING OF BULK METALLIC GLASS

by
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APPROVED BY:

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Chair of Advisory Committee	Co-Chair of Advisory Committee

DEDICATION

To Aybike

BIOGRAPHY

Mustafa Bakkal was born on November 25, 1974 in Bilecik, Turkey. He grew up in Bilecik, Ankara and Istanbul. Mustafa is the only son of Fatma and Ramazan Bakkal and brother of Bilge and Aybike Bakkal. He was admitted to the Istanbul Technical University in 1993. He received his Bachelor's degree and entered the graduate school in 1997. During his master research, he worked on "Effect of iron nitriding on austempered AISI 8660 steel" work with the guidance of Professor Mehmet Demirkol. He awarded with Turkish Higher Education Council scholarship in August 2000 and joined California Institute of Technology. After 3 semester course work in Applied Mechanics under supervision of Professor Guru Ravichandran, he received another Master's degree in Applied Mechanics. He joined the Ph.D. program in North Carolina State University in August 2001. He has spent the last three years pursuing a Doctoral degree in Mechanical Engineering at North Carolina State University.

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