Accepted Manuscript

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PII: S0924-0136(15)30017-0
DOI: http://dx.doi.org/doi:10.1016/j.jmatprotec.2015.06.006
Reference: PROTEC 14441

To appear in: *Journal of Materials Processing Technology*

Received date: 16-6-2014
Revised date: 4-6-2015
Accepted date: 6-6-2015

Please cite this article as: Bai, Yang, Yang, Ming, The influence of superimposed ultrasonic vibration on surface asperities deformation.Journal of Materials Processing Technology http://dx.doi.org/10.1016/j.jmatprotec.2015.06.006

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ACCEPTED MANUSCRIPT

The influence of superimposed ultrasonic vibration on surface asperities deformation

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Abstract

The process of micro forming with ultrasonic vibration is used to get better surface finishing. This technique was evaluated under different conditions in the current paper. Surface asperities deformation was found to be linear to ultrasonic vibration amplitude and static stress. To quantitatively investigate the influence of ultrasonic vibrations on micro forming, different size samples were compressed and the surface grain model was used to explain the mechanisms of action. The results show that the ultrasonic softening effect at the micro scale was closely related to the surface / total grain ratio, which is a function of the sample's dimensions.
Keywords: Micro forming, ultrasonic vibration, surface asperities, surface grain model

1. Introduction

The rapid growth of mobile business and communication devices greatly accelerates the need for new developments in micro-electro-mechanical systems (MEMS) technology. Smaller size products usually possess more powerful functions compared with their predecessors and present a number of challenges to the manufacturing industry. For instance, there is a demand for micro-scale metal parts with more sophisticated geometry and enhanced mechanical properties. Although current technologies in micro manufacturing techniques such as LIGA (Lithographie，Galanoformung and Abformung or in English: Lithography, Electroplating, and Molding) (Malek et al., 2004), electrochemical machining (Sun et al., 2001) or electric discharge machining (Abbas et al., 2007) could produce microscale metal parts with outstanding accuracy, the production efficiency is an obvious disadvantage. Metal forming technologies have great advantages for their high production efficiency, decreased material removal treatments, enhanced material utilization, and appropriate mechanical properties. However, as the size decreases to the micro scale, material deformation properties are different from the macro scale properties and difficulties in uniform and precise plastic deformation become more evident.

Ultrasonic vibrations have high directivity and energy and are thus applicable to many research areas. In particular, ultrasonic vibrations influence the material deformation behavior of metals by improving their formability significantly. Izumi et al. (1966) conducted compression tests in conjunction with ultrasonic vibrations and found that the forming load suddenly decreased at the moment of the applied vibration. Additionally, the flow stress curves increased when the vibration stopped. These results indicate that ultrasonic vibrations have a softening effect, otherwise known as theblaha effect on the materials. This effect was not induced by the temperature rise since theapplication time was too short. In addition, Huang et al. (2009) found that the ultrasonic vibration amplitude was linearly related to the reduction in the material flow stress. To further investigate influences of ultrasonic vibration on different materials, Abdul and Lucas (2010) demonstrated that the ultrasonic-induced flow stress reduction was closely related to differences in materials. To clarify the mechanisms of altered metal deformation after ultrasonic vibrations, Hirao et al. (2000) conducted observations on the dislocation structure with a transmission electron microscope (TEM). They found that the mobility and rearrangement of dislocations was drastically improved by ultrasonic vibration. Yao et al. (2013) proposed a modeling framework based on crystal plasticity theory to describe the acoustic softening effect. The results predicted by the model were validated by experimental results. Bunget and Ngaile (2011) applied ultrasonic vibration during micro-extrusion. They concluded that the vibration could reduce the friction and the forming load in the metal forming process. Hung and Tsai (2013) carried out ultrasonic vibration-assisted micro-upsetting of brass. The results demonstrated that the size effect, and the flow stress decreased as the specimen was miniaturized. Different size specimens were compressed and the influences of ultrasonic vibration were analyzed qualitatively. However to date there is no comparison between micro and macro scale effects of ultrasonic vibrations.

The objectives of this study were to 1) investigate the influence of superimposed ultrasonic vibrations on micro scale metal surface asperities and 2) investigate the mechanisms of ultrasonic vibration induced

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