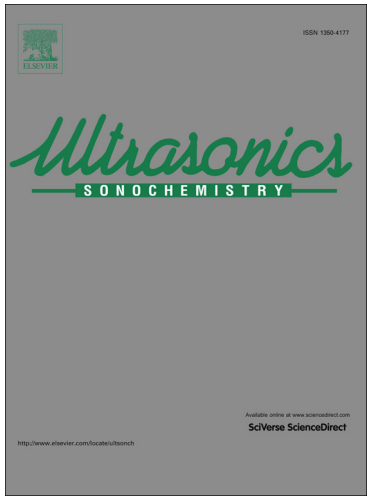

Investigation on ultrasonic volume effects: stress superposition, acoustic softening and dynamic impact

Jun Hu, Tetsuhide Shimizu, Ming Yang

PII: S1350-4177(18)30652-7
DOI: https://doi.org/10.1016/j.ultsonch.2018.05.039
Reference: ULTSON 4197

To appear in: *Ultrasonics Sonochemistry*

Received Date: 27 April 2018
Revised Date: 22 May 2018
Accepted Date: 31 May 2018

Please cite this article as: J. Hu, T. Shimizu, M. Yang, Investigation on ultrasonic volume effects: stress superposition, acoustic softening and dynamic impact, *Ultrasonics Sonochemistry* (2018), doi: https://doi.org/10.1016/j.ultsonch.2018.05.039

Investigation on ultrasonic volume effects: stress superposition, acoustic softening and dynamic impact

Jun Hu *, Tetsuhide Shimizu, Ming Yang
Graduate School of System Design, Tokyo Metropolitan University, 6-6, Asahigaoka, Hino-shi 191-0065, Tokyo, Japan

*Corresponding author. Tel./fax: +81 42 585 8440.
E-mail address: johnnyhu1992@gmail.com

Abstract

Conventional high power ultrasonic vibration has been widely used to improve manufacturing processes like surface treatment and metal forming. Ultrasonic vibration affects material properties, leading to a flow stress reduction, which is called ultrasonic volume effect. The volume effect contains multi-mechanisms such as stress superposition due to oscillatory stress, acoustic softening by easier dislocation motion and dynamic impact leading to extra surface plastic deformation. However, most researches ignored the stress superposition for the convenience of measurement, and few studies considered ultrasonic dynamic impact since the relatively low ultrasonic energy in macro scale. The purpose of this study is to investigate the characteristics and mechanisms of different ultrasonic volume effects in micro-forming. A 60 kHz longitudinal ultrasonic-assisted compression test system was developed and a series of ultrasonic-assisted compression tests at different amplitudes on commercially pure aluminum A1100 in micro-scale were carried out combining the surface analysis by SEM, EDX and micro-hardness test. Three different ultrasonic volume effects, stress superposition, acoustic softening and dynamic impact, were confirmed in the ultrasonic-assisted compression tests. In order to quantitatively predict stress superposition, a hybrid model for stress superposition is developed considering the elastic deformation of experimental apparatus in practice, the evolution of the modeling results fitted well with the experimental results. With low ultrasonic amplitude, stress superposition and acoustic softening occurred because vibrated punch contacted with the specimen all the time during compression. However, with higher amplitude, due to the extra surface plastic deformation by larger ultrasonic energy, forming stress was further reduced by the ultrasonic dynamic impact. A possible method to distinguish the effects of dynamic impact and acoustic softening is to analyze the waveform of the oscillatory stress in the process. In the case of ultrasonic dynamic impact effect, a higher amount of oxidation was observed on the specimen surface, which could be the result of local heating by surface plastic deformation and surface friction when the vibrated punch detached from the specimen. The findings of this study provide an instructive understanding of the underlying mechanisms of volume effects in ultrasonic-assisted micro-forming.

Keywords: Ultrasonic vibration; Volume effect; Stress superposition; Acoustic softening; Dynamic impact; Aluminum

1. Introduction