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Study on ultrasonic vibration assisted upsetting of 6063 aluminum alloy

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Abstract

Ultrasonic vibration assisted metal forming is a novel kind of combined forming processes. 6063 aluminum alloy upsetting tests with and without ultrasonic vibration under different conditions were conducted. The effects of ultrasonic vibration on upsetting load, material flow stress, relative reduction in height, die/workpiece interface friction and microstructure, as well as the influence of height-diameter ratios on the ultrasonic vibration effect, were studied. After applying ultrasonic vibration, upsetting load, material flow stress and compressive strength decrease apparently, the relative reduction becomes larger than no ultrasonic vibration, and the frictional coefficient of the die/workpiece interface decreased significantly. Moreover, the surface hardness of the specimen improves slightly and increases with the increase of the amplitude and the ultrasonic vibration is helpful to the grain refinement and grain refinement efficiency of the upsetting.

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Keywords: Ultrasonic vibration; Upsetting; Deformation behaviour; Aluminum alloy

1. Introduction

Ultrasonic vibration has a remarkable influence on plastic behaviours of metals. Compared to the conventional metal forming, ultrasonic vibration assisted metal forming can reduce the forming load and the friction in the metal forming process and improve the surface quality of the workpiece effectively.

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Recently, many researchers focused on ultrasonic vibration assisted metal forming. Hung et al [1] studied the effects of applying ultrasonic vibration to micro-forming, along with two other factors: specimen size and grain size. Liu et al [2] analyzed differences in metal flow and forming force between ultrasonic vibration assisted upsetting and conventional upsetting. Djavanroodi et al [3] and Ahmadi et al [4] introduced the ultrasonic vibration into the equal channel angular pressing to improve the effect and efficiency of the grain refinement. Dutta et al [5] studied the effect of an in situ ultrasonic treatment on the microstructure of low-carbon steel under tensile deformation. Liu et al [6] pointed out the input of the vibration energy caused the increase of dislocation density and movement velocity, and the initial grains of material were refined into small grains or subgrains.

Indeed, many researches showed ultrasonic vibration assisted metal plastic forming is a novel and effective kind of combined forming processes. Thus, in this work, focusing on ultrasonic vibration assisted upsetting (UV-upsetting) of 6063 aluminum alloy and comparing to the conventional upsetting (C-upsetting), effects of ultrasonic vibration on upsetting load, material flow stress, deformation, die/workpiece interface friction and microstructure were studied.

2. Experimental system and preparation

The experimental system consists of a universal material testing machine (SANS CMT5205) and a set of ultrasonic vibration unit, as shown in Fig. 1. The ultrasonic vibration unit includes ultrasonic generator, transducer, amplitude transformer and tool head. The frequency of the ultrasonic power is 15 kHz.

The experimental material is 6063 aluminum alloy. The chemical composition is listed in Table 1.

Table 1. Chemical composition of 6063 aluminum alloy (wt %)

Element	Si	Fe	Cu	Mn	Mg	Zn	Ti	Cr	Al
Content	0.32	0.35	0.1	0.1	0.6	0.1	0.1	0.1	Balance

Three kinds of upsetting specimens (Φ5×7.5mm, Φ5×5.0mm andΦ5×3.5mm) were machined. Obviously, the height-diameter ratios of specimens are 1.5, 1.0 and 0.7, respectively. The machining allowance of 0.1 mm was kept in the height direction of specimens for the subsequent grinding of the end face.

In order to eliminate the residual stress caused by machining operations and to ensure the consistency of microstructure and properties of samples, the specimens were fully annealed at 350 °C for 3 h in an SX-9-12-16 resistance-heated furnace utilizing high-pure nitrogen as the protective atmosphere to ensure the annealing process. After annealing, specimen heights were grinded to the design size.

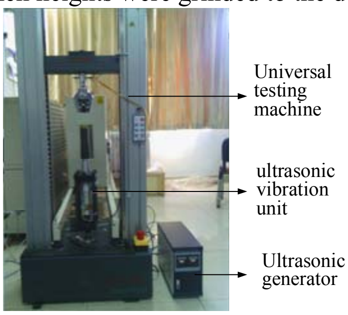

Fig.1. Ultrasonic assisted test system

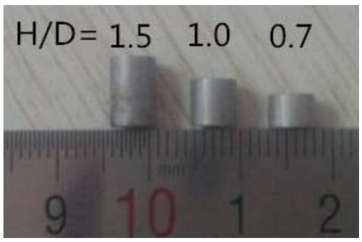

Fig. 2. Upsetting specimens with different height-diameter ratios

The liquid paraffin was used as lubricant. The material testing machine was at a constant press speed of 1 mm/min at room temperature during upsetting. The ultrasonic generator can output 1000 W, 1400 W, 1800 W and 2200 W. The corresponding output amplitudes are 3.34 μm, 3.96 μm, 4.48 μm and 4.96 μm, respectively.

Because it has a slight impact on the material's elastic deformation, the ultrasonic vibration is applied to upsetting after the stable plastic deformation occurs. In our work, when the forming load reaches 3 kN, the system starts applying the ultrasonic vibration. When the forming load reaches 9 kN, the upsetting stops.