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The research development of basic theory in micro-forming

Xiyang Sun[a], Dongmei Li[b]

School of Mechanical Engineering, Nanjing University of Science and Technology, Nanjing, China

[a]Sunyang.89@163.com, [b]ldmsky@163.com

Key words: plastic micro-forming; basic theory; size effects; temperature effects

Abstract. With the increasing demand for high efficiency, low cost and the bulk, so the production of micro-forming has a very important significance. Firstly, the introduction of micro-forming is introduced in this paper. Then, its basic theory, including size effects and temperature effects, is presented. At last, a future research direction is highlighted.

Introduction

With the rapid development of electronics industry and precision machinery, product miniaturization has become an irresistible trend of the industrial sector, particularly manifested in communications, electronics, micro-electromechanical systems (MEMS), micro systems technology (MST) and other fields.

Now, the development of micro-machining technology and process mainly depends on the micro-machining technology, lithography and etching technology. These limit the development of micro-electromechanical product because of difficulty in manufacturing, complex process, equipment investment and strong specificity. So, efficient and low-cost micro-forming technology is treated as the key problems of the areas of MEMS and micro-component.

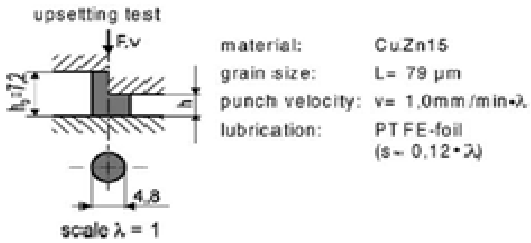
Not only plastic micro-forming has strong potential in processing, can produce a variety of high aspect ratio micro-mechanical components, achieve three-dimensional and quasi-three-dimensional design and processing, but also the process is simple, sophisticated equipment, can be high efficiency, low cost batch production, the production of parts, high strength, good quality. Therefore, the research on the development of plastic micro-forming technology and producing high-strength fine shape complex parts has an importance of the micro mechanical and electrical products and economy and industrialization in micro-systems.

Plastic micro-forming is a technology [1] which processes the component and structure in the two-dimensional direction and sub-millimeter scale.

Size effects

About the size effects of plastic micro-forming, there is no accurate and complete definition. But with the understanding of forming member decreasing, some characteristics in the process of micro-forming vary greatly compared with the traditional shape of the phenomenon. This depends on the size of the effect especially in the rheological properties and friction characteristics. The discussions about two aspects are shown as follows.

Rheological properties. German Geiger professor et al. [2-3] used upsetting experiment which is shown in Fig. 1 that systematic studied the material flow stress of the size effect phenomenon. The results showed that the material flow stress is reduced with the sample size decreased. The scale factor λ was introduced in the experiment .the sample size and deformation process parameters reduced according to scale factor λ. When the scale factor λ was reduced to 0.1, the material flow stress decreased by 20%, shown in Fig. 2.



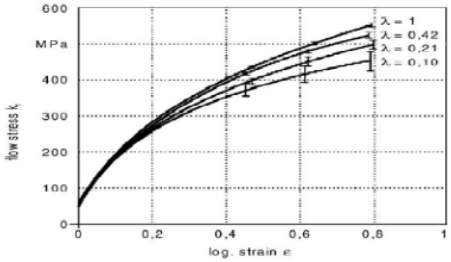


Fig.1 Micro-upsetting experimental program Fig.2 Micro-upsetting results

Engel et al. [4] measured the strain distribution of sheet CuZn15 with bending deformation, which is thickness of 0.5mm, grain size of 10µm and 70µm respectively, shown in Fig. 3. When using fine-grained plate bending deformation, the inner layer is compressed, the outer layer of tensile deformation, the middle layer is not deformed zone and plastic deformation is uniform. While coarse grain plate bending deformation, the strain distribution confuse and plastic deformation is extremely uneven. It indicates that the size of plastic micro-forming equals to grain size, the heterogeneity properties of material microstructure has a significant impact on the plastic deformation of the blank.

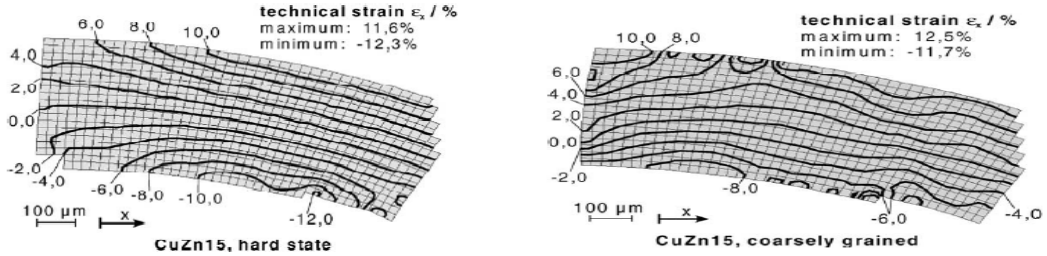


Fig.3. Strain distribution of fine-grained and coarse-grained sheet with bending deformation

WL Chan et al. [5] performed some micro-cylinder compression tests, which indicate the macro-isotropic of the blank no longer exists with the blank down to the micro level (only a few grains). As shown in Fig. 4, the effect of properties of each grain (shape, size, orientation) on the mechanical properties and deformation behavior of the blank become dominant.

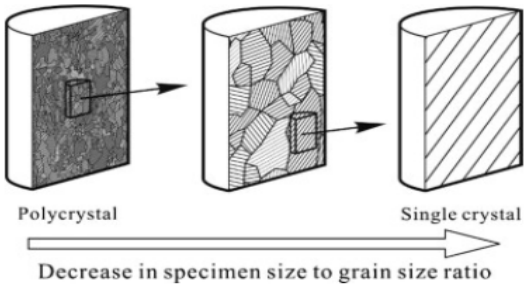


Fig.4 Transition diagram from polycrystalline to single crystal

Friction characteristics. Bin Guo et al. [6] made block compression tests with micro column copper alloy C3602 to measure coefficient of friction in the various lubrication conditions and temperatures. As shown in Fig. 5, the results show that the friction coefficient significantly increases with the decrease of specimen size under vegetable oil lubrication, while the friction coefficient varies erratically in other lubrication conditions. The phenomenon can be explained by "Open and closed lubricant pockets" [7].

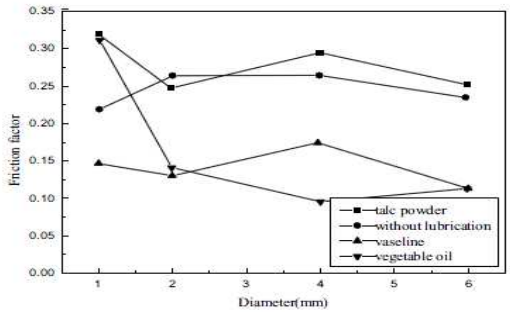


Fig.5 The diagram with specimen diameter versus friction coefficient

Bernd-Arnol et al. [8] conducted compression tests with aluminum ring AW-6082. As shown in Fig. 6, the results show that the friction coefficient increases with temperature increment at a constant strain rate.

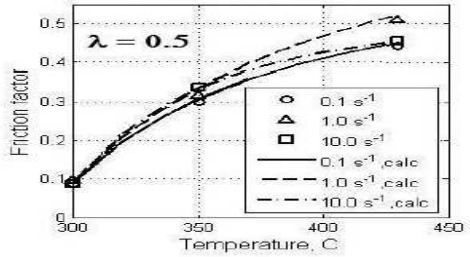


Fig.6 The graph with specimen temperature versus friction coefficient

Temperature effects

In the field of micro-forming, temperature distribution of specimen and mold will directly affect machining accuracy of the test-piece and strength and life of the mold. Due to process characteristics of plastic micro-forming and the speed of high-speed forming, mold temperature will increase, so the accurate prediction of the temperature field is the key to success of plastic micro-forming.

To evaluate the effect of forming speed and friction coefficient on temperature field, Zhao Ying-Hong et al. [9] took numerical simulation methods by a simple upsetting process with a radius of 1mm, height of 1mm cylinder upsetting. As shown in Fig. 7, experimental results show that the friction coefficient increases with the temperature rises, the increase of hammer velocity.

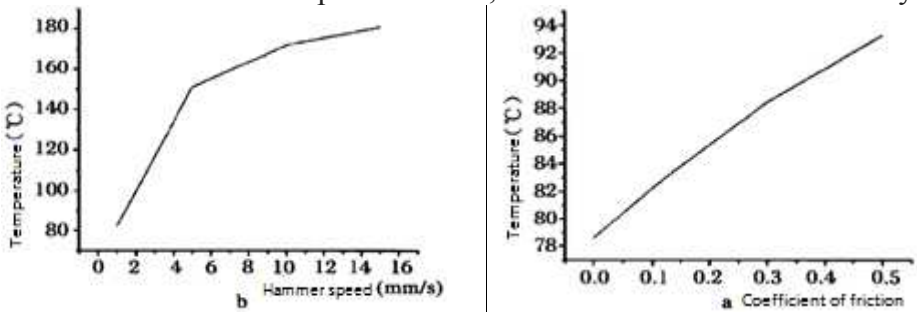


Fig.7 Effect diagram of molding conditions on temperature field under upsetting

Imbaby et al. [10] studied surface roughness of micro-gear under different sintering temperatures. As shown in Fig. 8, the results show that the surface roughness increases with increasing sintering temperature.

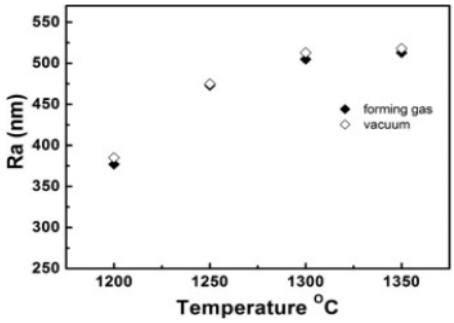


Fig.8 The diagram with surface roughness versus sintering temperature

Development direction

Although micro-forming is not a new research area, but there are many problems to be solved. The effects of size effect, forming speed, other factors on plastic micro-forming based on experiments must be studied profoundly. Furthermore, the nature of deformation mechanism and mechanical behavior must be understood fully.

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