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Evaluation of interfacial friction condition by boss and rib test based on backward extrusion

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ABSTRACT

Proper consideration of tribological problems at the contact interface between the tool and workpiece is crucial in metal forming, since interfacial friction condition plays an important role in metal forming by influencing the metal flow, forming load, die wear, etc. In order to quantitatively estimate such friction condition, a new friction testing method "Boss and Rib Test" based on the backward extrusion process is proposed in this work. In boss and rib test, a key design is to use a tube-shaped punch so that the boss and rib at the deforming workpiece along the inner and outer surfaces of the punch are formed during backward extrusion. It was experimentally and numerically revealed that the heights of the boss and rib vary according to the friction condition applied. It was also found that the height of the boss is higher than that of the rib when the friction condition at the contact interface is severe. From this finding, the shear friction factor can be evaluated according to lubricant characteristics assigned. In addition, simulation results revealed that calibration curve demonstrating deformation pattern of the workpiece is affected by strain-hardening exponent of the workpiece.

1. Introduction

Friction condition at the contact interface between the tool and workpiece in bulk metal forming governs metal forming behaviors such as metal flow, forming load, tool wear, quality of the part, etc. It is well recognized in these points of view that the accurate description of friction condition has a significant effect on the reliability of numerical simulations. In order to quantitatively estimate such friction condition, the constant shear friction model of Eq. (1), which is based on the assumption that friction force is proportional to the shear yield strength of material, is generally adopted in bulk metal forming processes.

$$t_i = -m_f k_s \tag{1}$$

In the above, the interface friction condition, in which m_f and k_s represent the shear friction factor and shear yield strength of the material respectively, is applied as part of the traction boundary condition. Here, t_i is the frictional force.

So far, various friction testing methods have been proposed for years to quantitatively estimate the lubricant characteristic in terms of shear friction factor. One famous friction testing method is ring compression test [1–5]. In this method, the characterization of friction condition is simply obtained from the variation of the inner radius of the ring according to the reduction ratio without any requirement to measure the forming load. However, the shear friction factor estimated by this method may not always be suitable for actual metal forming processes since the amount of surface expansion is relatively small. Also, measurement of ring geometry might be difficult in case of non-uniform deformation behavior of the ring. In result, the predicted shear friction factor may be inaccurate during the deforming process.

Thus, combined forward and backward extrusion or backward extrusion [6–13] has been implemented as an alternative measurement technique better suited for practical cold forging processes, due to large surface expansion and high pressure distribution along the punch and high friction level at the interface between the workpiece and dies. In combined forward and backward extrusion test, the extruded heights of the workpiece in the forward and backward directions are used to estimate the friction condition. However, the sensitivity of extruded heights in two directions is reduced when the level of friction becomes higher. In recent, Im et al. [11–13] proposed the 'tip test' based on the backward extrusion process, in which a radial tip is formed on the extruded end of the workpiece. It was experimentally and numerically revealed that both the radial tip distance from the external side surface of the workpiece and the maximum forming load at a certain punch stroke linearly increase with higher level of friction. It was also proved that the level friction of the punch is higher than that of the die by comparing the experimental and simulation results. However, centering of the workpiece within the die is difficult due to the smaller diameter of the workpiece compared to that of the die.

In the present study, the new friction testing method based on the backward extrusion process, "Boss and Rib Test", is proposed.

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