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Effect of Hardening Rule for Spring Back Behavior of Forging

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Abstract

Geometrical discrepancy between formed part and designed one is one of the major problems for metal forming processes. Spring back behavior is one of the most important factors on the discrepancy, in not only sheet metal forming but also cold forging process. For cold forging process, it is difficult to observe the change in geometry of forgings before and after release of tools/dies, since the workpiece during forging is covered by tools/dies in most cases. Uncertainty remains for the precision on geometrical prediction after spring back of the cold forged part. In the present research, the diameters of extruded shaft at the bottom dead center and after the release of tools/dies were measured to investigate the spring back behavior in the cold forging process. As a result of experiment, the diameter of extruded shaft was increased at the bottom dead center by spring back and decreased after the release by re-extrusion. For these series of change in diameter, FE analyses using isotropic and kinematic hardening models were performed in order to evaluate influence of spring back on the material hardening models in forging process. For kinematic hardening model, Yoshida-Uemori model modified for large strain region was employed. As a result of calculation, both the isotropic and kinematic hardening models showed the similar tendency on the change in diameter with the experimental one.

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Keywords: cold forging; stainless steel; Bauschinger effect; kinematic hardening model; FEM.

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1. Introduction

Recently, in metal forming processes typified by forging or sheet metal forming, Finite Element (FE) simulation has been actively used for the design of die/tool and process in production engineering and shop floor. FE software for metal forming process has also been developed as dedicated codes. In particular, the simulation has been recognized to be effective for the prediction of spring back behavior; the difference of formed shape to the designed one. The employment of non-linear kinematic hardening (NLKH) model has been approved to be effective for predicting spring back behavior [1]. By applying them, more accurate prediction of geometry has been performed in sheet metal forming process [2-5].

On the other hand, in case of bulk metal forming such as cold forging, the FE simulation isotropic hardening (IH) model is commonly used, because the accumulated plastic strain $\overline{\varepsilon^p}$ often exceeds around 1.0 during the process. In cold forging, however, the required geometric accuracy in simulation has been toward the order of 0.01 mm, which is as the same level as deformation by spring back of forgings. Moreover, in case of multi-stage forging, the control of geometry at each process is quite important. In most cases, however, it is difficult to measure the geometry of forgings before release of tools/dies, since the workpiece during forging is covered by tools/dies except for open die forging process. Therefore, the level in prediction of spring back for forging process by FE simulation has not been as high as for sheet metal forming process.

In the present research, cold forward extrusion as a typical cold forging process is adopted. Figure 1 shows the schematic illustration of typical cold forward extrusion process. If the shaft does not contact to the die surface, the diameter of shaft will be freely increased due to the spring back. Then, the shaft is extruded again when the workpiece is knocked out. As a result, the diameter of shaft decreases closed to the designed value. Therefore, the spring back behavior in cold forging can be evaluated by measuring the change in extruded shaft diameter. In detail, experiment of cold forward extrusion and the FE simulation are carried out. Then the shaft diameter at the bottom dead center (BDC) and after the knockout (KO) is measured and evaluated. In the FE simulation, IH and NLKH model are used as material hardening rules. For NLKH model, YU model modified for taking the work hardening for the large strain [6] is used.

2. Experiment of cold forward extrusion for evaluation of spring back

In order to investigate the spring back in cold forging process, cold forward extrusion and shaft diameter measurement were carried out. The experiments were performed using a Direct Servo Former NS1-1500(D) by Aida Engineering, Ltd. Figure 2 shows the sectional view of the die and the detail dimension. The die can be separated at the position of 10mm below the forming section. The shaft diameter at the BDC can be measured after removing the upper die while the workpiece being in place after forming. Figure 3 shows the state of the shaft diameter measurement at the BDC and evaluation method. The measurement was carried out using Laser probe contour measuring instrument (MLP-2) by Mitaka Kohki, Co., Ltd. The diameter of cross sections were measured from the tip to 20 mm at every 2.0 mm along the axial direction. The diameters in x and y directions of cross sections were measured. The averaged value was used as the shaft diameter of each cross section. SUS304 wire rod subjected to drawing after solution

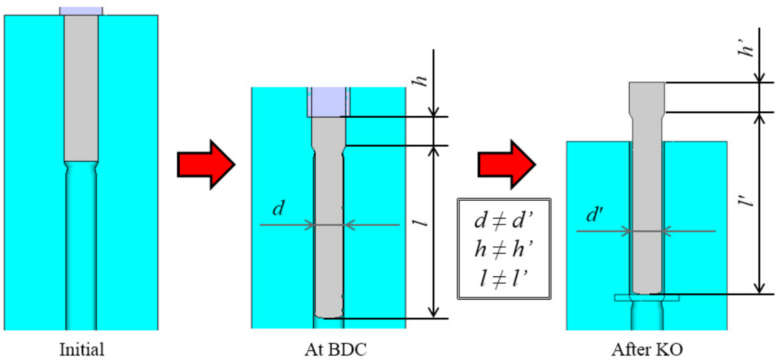

Fig. 1. Schematic illustration of forward extrusion process