EFFECTS OF AXIAL FEED DIRECTION ON FORGED SHAPE IN MANDREL-LESS INCREMENTAL FORGING OF CIRCULAR VARIABLE-CROSS-SECTION TUBE ENDS

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This research investigates the effects of axial feed direction on forged shapes in a proposed mandrel-less incremental forging of circular variable-cross-section tube ends by conducting finite element analysis and forging experiments. The results show that the feed direction from the fixed side to the free side is more effective in reducing ovalization than the reverse direction. These findings can be applied to determine efficient pass schedules for incremental forging of circular variable-cross-section tube ends.

KEYWORDS: INCREMENTAL FORGING – TUBE FORMING – FLEXIBLE FORMING – VARIABLE CROSS-SECTION – TUBE ENDS

INTRODUCTION

To reduce CO_2 emissions in the transportation industry, weight reduction and resource efficiency are crucial issues. Tubes with variable cross-sections offer significant advantages in meeting these needs (1,2). Therefore, the author proposed a new incremental forging process (3). Compared to conventional forming processes such as radial forging, rotary swaging, and drawing, this process provides a more flexible approach. A tube is compressed by a pair of simple flat dies without a mandrel, and its rotational and axial positions are controlled by a manipulator. Initial research primarily focused on forging the center of the tube in the axial direction, and revealed that the rotational feed defined by $2\pi/k$ rad·blow^{-1}, where k is an odd number, is effective in reducing both the outer diameter and ovalization (3). As a subsequent step, it is necessary to study the forging of circular tube ends to enable a wide range of forged shapes. The preceding research focused on height reduction in multi-pass forging without axial feed (4). In this research the effects of different axial feed directions on the forged shape in the proposed mandrel-less incremental forging are clarified.

FINITE ELEMENT ANALYSIS AND EXPERIMENTS

Finite element analysis using Elfen developed by Rockfield Software and forging experiments with a prototype computer numerical control incremental forging machine were conducted. In the finite element analysis, two types of axial feed direction, from the fixed side to the free side and from the free side to the fixed side, were examined with variations in the number of 2π rad divisions k and the average axial overlap number N_{o_ax}. The parameter k defines the rotational feed f_r as $2\pi/k$ and the parameter N_{o_ax} defines the axial feed f_a as $(B_{flat}/k)/(1+N_{o\_ax})$ where B_{flat} is the die width of flat area. In the experiments, selected conditions from the finite element analysis were performed. Pure aluminum AA1070-O was selected as the model material due to its low flow stress and high formability at room temperature for both finite element analysis and experiments.

RESULTS AND DISCUSSION

Figure 1 plots the relationship between the total number of blows and the nondimensionalized cylindricity under various conditions in the finite element analysis. The nondimensionalized cylindricity defined as $\{(D_{Omax}-D_{Omin})/2\}/D_{Oini}$ is a representative value of the forged shape to evaluate oval deformation. A comparison

of axial feed direction under identical forming conditions shows that the value was smaller when the feed direction was from the fixed side to the free side compared to the reverse direction. For each axial feed direction, the value depended on the total number of blows, regardless of the amounts of axial feed and rotational feed. The value decreased with increasing total number of blows. These results indicate that to determine the efficient pass schedules for incremental forging of circular variable-cross-section tube ends, the axial feed direction from the fixed side to the free side should be selected. Additionally, the conditions of axial feed and rotational feed should be selected by considering the trade-off relationship between the nondimensionalized cylindricity and the total number of blows. The finite element analysis results were in good qualitative agreement with the experimental results, verifying the validity of the finite element model.

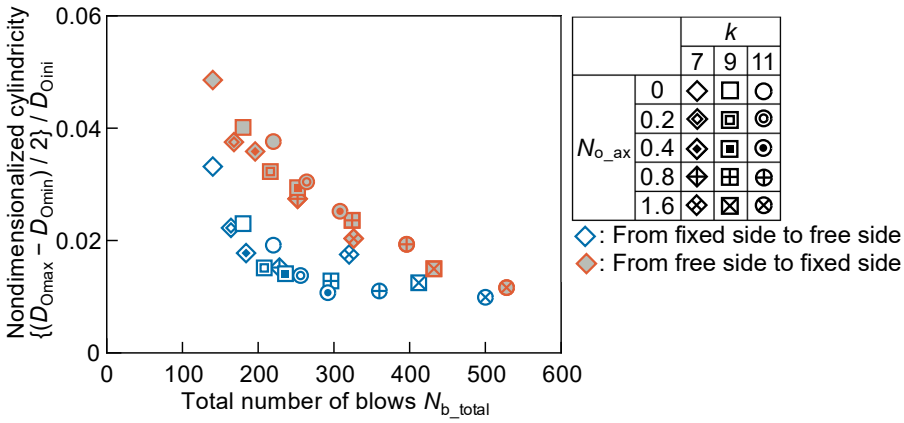

Fig.1 - Relationship between total number of blows and nondimensionalized cylindricity under various conditions in finite element analysis

CONCLUSIONS

This research clarifies the effects of different axial feed directions. The feed direction from the fixed side to the free side is more effective in reducing ovalization than the reverse direction. The nondimensionalized cylindricity, a value for evaluating oval deformation, shows a trade-off relationship with the total number of blows. These results can be applied to determine efficient pass schedules for incremental forging of circular variable-cross-section tube ends.

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