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COMBINED FORWARD-BACKWARD EXTRUSION WITH CONTROLLED REVERSAL RAM MOTION

-Effect of Reversal Ram Motion-

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Abstract

In combined forward-backward extrusion with controlled forward speed by a counter punch, accurate parts with forward rod can be formed. As an extension of this method, reverse extrusion is proposed, in which the extruded forward rod is pushed back while the main punch is kept at the final position after the forward-backward extrusion process. The experiment is carried out using lead as a model material. With the reverse extrusion method, longer forward rods can be formed without under-filling defect than that by combined extrusion with controlling extrusion speed.

Keywords: ram motion, combined extrusion, extrusion, counter punch, speed control

1. Introduction

In forward rod – backward can extrusion, the extruded lengths of both sides are sensitively affected by the frictional condition. In this process, the length of the extruded part is not controlled and, further, the end surface is rounded because it is not constrained by tool. To obtain a specified extruded length of forward rod, the die is usually so designed as to stop one of the flows. After stopping the flow to one direction, however, the material flows only to the other direction and the extrusion pressure increases sharply.

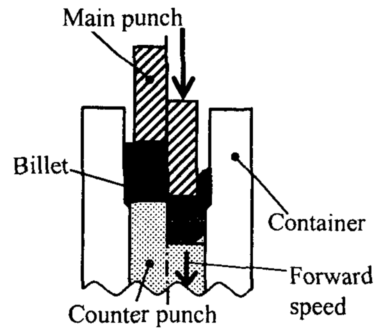


Fig.1 Concept of combined extrusion with controlled forward speed.

To keep a low extrusion pressure throughout the process, it is desirable to maintain the flow to both directions until the end of the process [1]. To attain a good dimensional accuracy and flatness of the end surface with a low extrusion pressure, forward-backward extrusion with controlled exit speed shown in ***Fig.1***, was

Table 1 Experimental conditions.

Billet material	Pure lead
Lubricant	Machine oil
Forming temperature /°C	Room temperature
Punch velocity V_p /mm·s^{-1}	0.30
Reduction in height by punch $\Delta h/h_0$ /%	90
Counter punch velocity /mm·s^{-1}	Forward-backward: V_c = 0.20 – 0.35; Reverse: V_r = 0.10

To attain a good dimensional accuracy and flatness of the end surface with a low extrusion pressure, forward-backward extrusion with controlled exit speed shown in ***Fig.1***, was proposed by the authors [2]. In this process, however, the length of the extruded part is shortened because the forward extrusion speed is lowered by the movement of the counter punch.

In this study, the forward-backward extrusion method with controlled exit speed is modified to increase the maximum extruded length and to improve the flatness of the end surface.

2. Experimental Method and Condition for Computer Simulation

2.1 Experimental Method

Table 1 shows the experimental conditions. Lead is used as the billet material and billets are extruded into a shape with forward-rod and backward-can.

In ***Fig.2***, the concept of the new process is given. At first, (a) the billet is inserted into the die cavity and then, (b) forward rod and backward can extrusion is carried out with controlled forward speed by the counter punch. After finishing the process, (c) the movement of the counter punch is reversed while the main punch is kept at the final position.

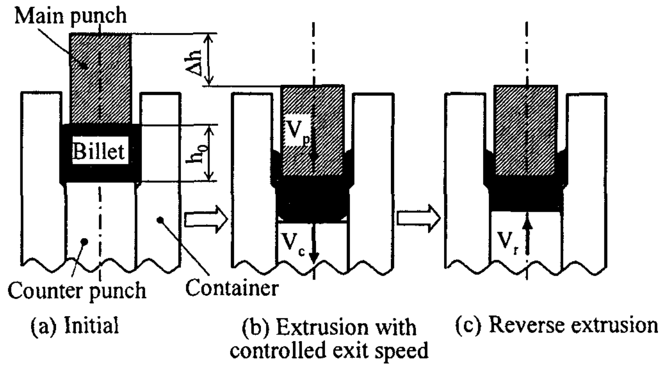


Fig. 2 *Press motion of new process.*

Two types of movement of the counter punch and the main punch shown in ***Fig.4*** are examined. The main punch moves with a constant speed up to the final reduction in height of 90% (18mm).

(A) Forward-backward extrusion with controlled exit speed until forward length becomes 17mm. (***Fig. 2***(a)-(b))

(B) Reverse extrusion (the counter punch movement L_r=4mm) after the process (A) attaining a forward length of 21mm. ***Fig.2***(a)-(b)-(c))

To make the extrusion pressure P_f and the counter pressure P_b dimensionless, relative extrusion pressure ratio P_f* and relative counter pressure ratio P_b* are defined as,

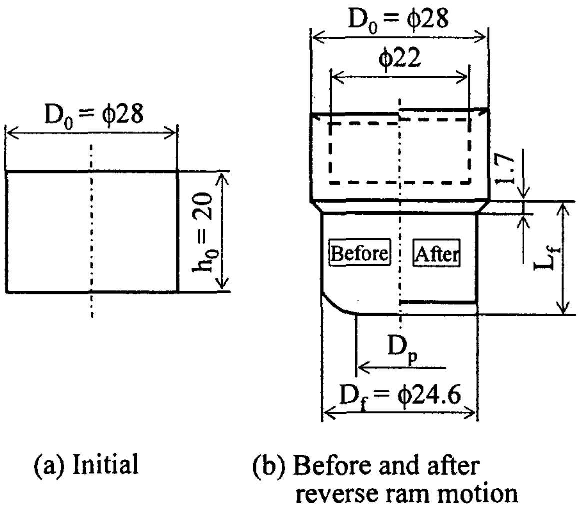


Fig. 3 *Initial and final billet shape.*

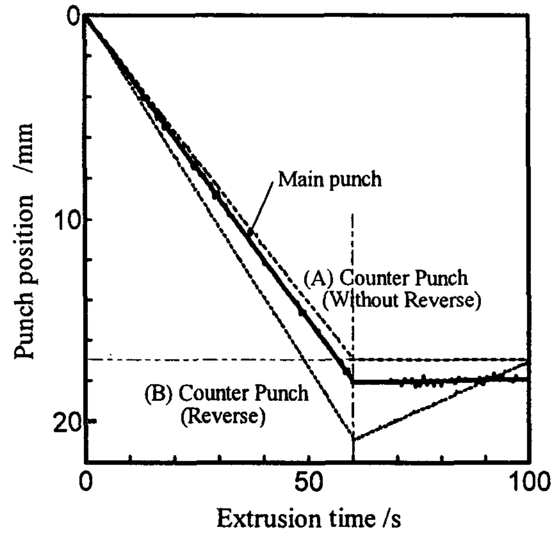


Fig. 4 *Ram motion of main punch and counter punch.*

$$P_f^* = P_f/\bar{\sigma}_1 \qquad (1)$$
$$P_b^* = P_b/\bar{\sigma}_1 \qquad (2)$$

where $\bar{\sigma}_1$ is the equivalent flow stress of billet at an equivalent strain of $\bar{\varepsilon}=1$ and the equivalent strain rate of $\dot{\bar{\varepsilon}} = 1/s$.

The degree of flatness of the end surface is define by F (flatness ratio) as shown in ***Fig.3***

$$F = D_p/D_f \qquad (3)$$

where D_p is diameter of the flattened part of the forward extruded end, D_0 is diameter of container.

2.2 Method of Simulation

For numerical simulation, the rigid-plastic FEM system, RIPLS-FORGE, was used. The right half of the billet cross-section was divided into about 700 elements, and the calculation was carried out under the same conditions as the experiments. The flow stress curve of pure lead was determined by the compression test as follows.

$$\bar{\sigma} = 59.6\bar{\varepsilon}^{0.277}(\dot{\bar{\varepsilon}}/\dot{\bar{\varepsilon}}_0)^{0.107} \ /\mathrm{MPa}\ (\dot{\bar{\varepsilon}}_0 = 1/s) \qquad (4)$$

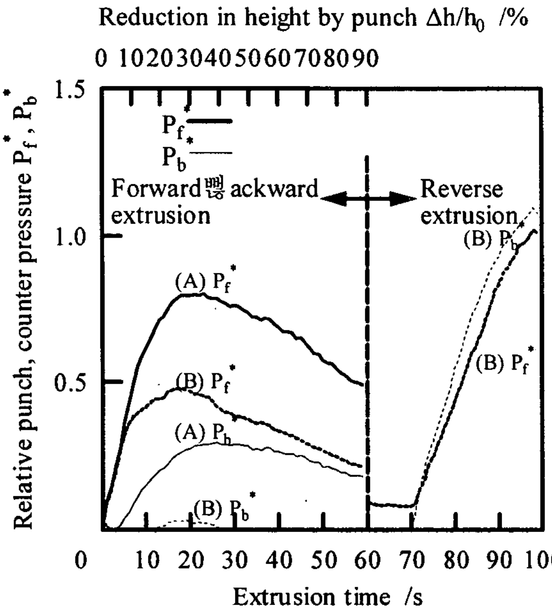
From the ring compression test, the coefficients of friction between the container and the lead billet with the machine oil lubricant is determined to be $\mu=0.086$ and between the punch/counter punch and the lead billet with the machine oil is determined to be $\mu=0.145$. The difference of the friction coefficients may be caused by the difference of the surface roughness of the tools.

3. Experimental and computational results

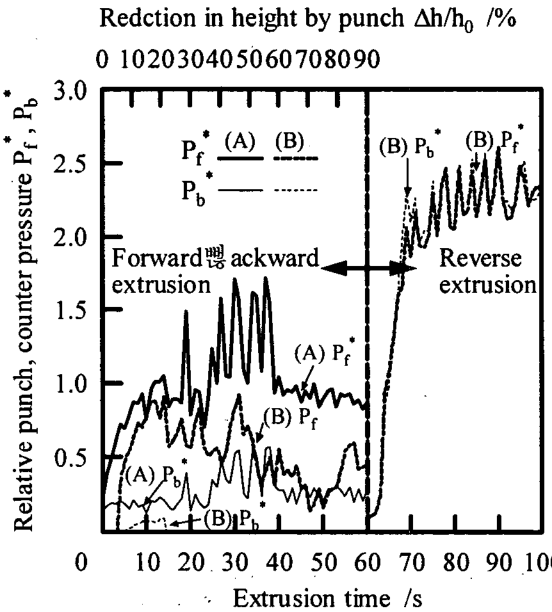
3.1 Punch pressure

The histories of punch pressure and counter punch pressure during the processes are shown given ***Fig.4***. In the process (A), the forward-backward extrusion is carried out to obtain forward length of 17mm and the motion of the counter punch is not reversed.

In the process (B), the extruded part is pushed back after extruding the forward part up to 21mm. The upper punch is stopped when the forward length reaches 21mm and then only the counter punch is driven to push back the forward extruded



(a) Experimental



(b) Calculated

Fig. 5 *Variations of punch pressure and counter punch pressure during the process given in Fig.2.*

part by 4mm until the length becomes 17mm.

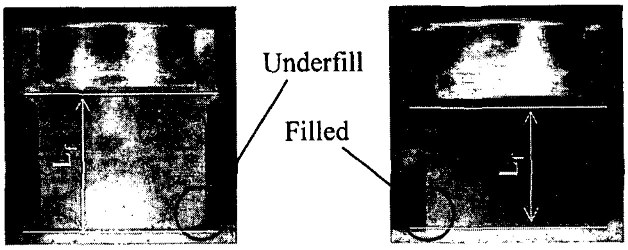
Fig.5 shows the relationships between the extrusion pressure and time after onset of the processes (A) and (B). In the first part of extrusion when the forward extrusion speed is controlled, the counter punch pressure decreases as the forward speed increases. In the case of (B), almost no pressure is applied to the counter punch because the natural speed of forward extrusion without counter pressure is almost the same as the counter punch speed.

In the pushing back process of the process (B), the counter punch pressure P_b^* increases with punch travel and reached a peak value. The computed counter punch pressure in the pushing back process is higher than that of the experimental one possibly because no elastic deformation of the machine and tools is considered.

The flatness ratios F are 89% and 100% in the cases of (A) and (B), respectively. When the product made by the process (A) is pushed back until the forward length becomes 15mm, the end surface is flattened completely.

3.2 Flatness of the Extruded End Surface

In ***Fig.6 (a)*** under-filling defects observed at the end of the forward extruded part in the processes of (A) is shown. Under-filling defects are not found at the end of forward extruded part in type (B).



(a) Controlled exit velocity (b) Controlled exit velocity and reverse extrusion

Fig.6 *Formed shape of specimen.*

Fig. *7* shows the experimental flatness ratio of the end surface plotted against the length of the forward extruded part. When the length of the forward part reaches 20mm, it is pushed back. The open marks indicate the flatness ratio in the process of forward-backward extrusion with controlled exit speed. The flatness is reduced as the length of the forward extruded part increases because the pressure acting on the counter punch decreases.

The solid marks in the figure show the flatness ratio during the pushing back process. It is apparent that the flatness is improved very much with small amount of pushing back. The end surface becomes completely flat after pushing back by about 2mm, when the forward length is 18mm.

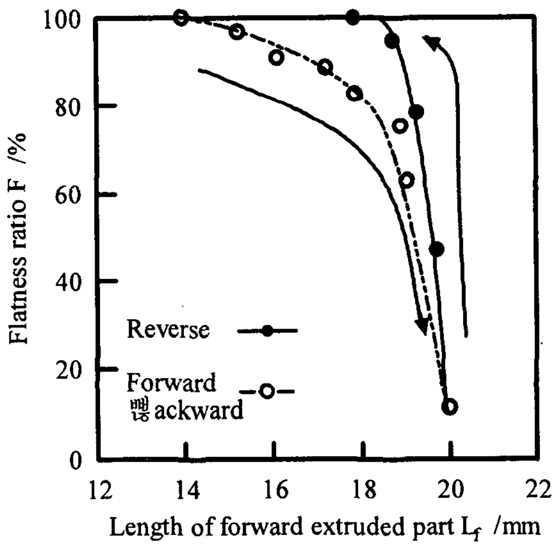


Fig.7 Ram motion and flatness of the extruded top surface

4. Conclusion

By adding a pushing back process in the combined forward-backward extrusion with controlled forward speed, longer accurate rod can be formed without defects. It is confirmed that combining controlled exit speed and reverse extrusion is most efficient to produce accurate products of backward can with long forward rod.

References

[1] K. Osakada, S. Hanami and N. Arai: Deformation Mode in Extrusion against Counter Pressure -Extrusion against Floating Tool Supported by Pressure I-. J. Japan Soc. Tech. Plasticity, 41-477(2000), 1026. (in Japanese)

[2] S. Hanami, K. Osakada, M. Otsu, T. Watanabe and D. Hayashida: Combined forward-backward extrusion with controlled exit velocity. Proc. 7th Asia Sym. Precision Forging, Guilin, China, October 2000, 41.