研 究 速 報

Finite Element Analysis of Velocity Distribution in Bearing Section during Extrusion of "T" and "L" Sections

—Combination of Numerical Analysis and Die Design−3—

"T" 材，"L" 材，押出し加工時のダイスベアリング部での塑性流動

—数値解析技術とダイス設計との結合法- 3 —

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1. Introduction

In the present investigation results on the velocity distribution in the bearing section as well as average extrusion pressure for "L" and "T" sections extrusion process simulation are presented and, as for angles and channels[1], the optimal position of the die opening is calculated and the axial velocity distribution along the bearing length is obtained.

2. Extrusion Process Simulation

The geometry of the simulated shapes is given in **Fig. 1** for "L" and "T" sections, respectively. The aspect ratio *AR* of the sections is given by the relation $(DXE1 + DXE2)/DYE$ and $DXE/uDXE$ for "L" and "T" sections, respectively. Also, it is noted here that the extrusion ratio *ER* is kept constant for all of the simulated cases, that is $ER = 39$.

Because of the geometric characteristics of "L" sections, it is important to determine the optimal position of the die opening, then, *ECX* is varied from $-0.6R_0$ to $0.4R_0$. Also, in this study *ECY* is determined in such a way that the quantity of material above the plane $X = 0$ be equal to that of under the same plane. However, *ECY* value is also very important and its effect should be studied in order to predict the bending direction or the ocurrence of another kind of defects. Therefore, for a section with $AR = 8$ two additional *ECY* values were simulated, $-0.07R_0$ and $0.07R_0$.

In "T" extrusion die design, the position of the "neutral plane" is first determined. The neutral plane is defined as a plane across which total amount of metal flow is zero during extrusion. As seen in the sketch in **Table 2**, the neutral plane intersects the plane of symmetry at $X = X_C$. The position of X_C of the neutral plane is determined such that the ratio of the area *0ab* to the area 012 is equal to the overall area reduction *ER*. This position is supposed to be the optimal in terms of extrusion force. Then, in order to prove out this statement, the position of the die opening *ECX* is varied from $-0.6R_0$ to $0R_0$.

3. Results and Discussion

Fig 2 shows the variation of P_{Av} (Average Extrusion Pressure) and *SDV* (Standard Deviation of the axial Velocity, V_Z) with *ECX* (Eccentricity of the die opening) and Z_B for a "L" section with $AR = 12$. The values of *SDV* are those corresponding to the cross sectional plane at the die entrance. The effect of *ECX* and Z_B on P_{Av} and *SDV* is shown in this figure . Due to the geometric characteristics of "L" sections, the plots of P_{Av} and *SDV* have a minimum indicating that there is an optimal *ECX* where the P_{Av} required for the process is the lowest and the nonuniformity of the velocity distribution as well. From the results, it was observed that the optimal *ECX* in terms of P_{Av} fairly coincides with the position of the gravity center (indicated by dropped lines) for all of the analyzed *AR* values. However, the optimal *ECX* in terms of *SDV* only coincides with the gravity center position for higher *AR* values. As *AR* decreases the minimum of the *SDV* curves moves towards more positive values, as shown by **Figs. 3** and **4**.

For "L" sections the position of *ECY* is also important. **Fig. 5** shows the effect of this parameter on P_{Av} and *SDV*. For $ECY = 3.33$ mm case, both P_{Av} and *SDV* have the highest values. When *ECY* is -3.33 mm P_{Av} is the lowest

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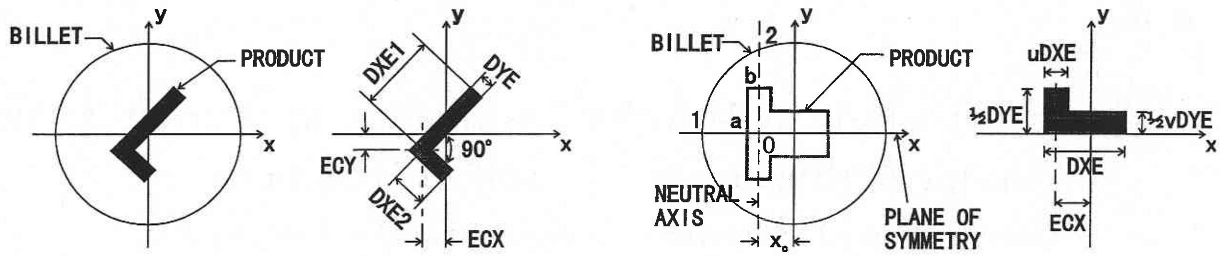

Fig. 1 Computational models of "L" sections and "T" sections.

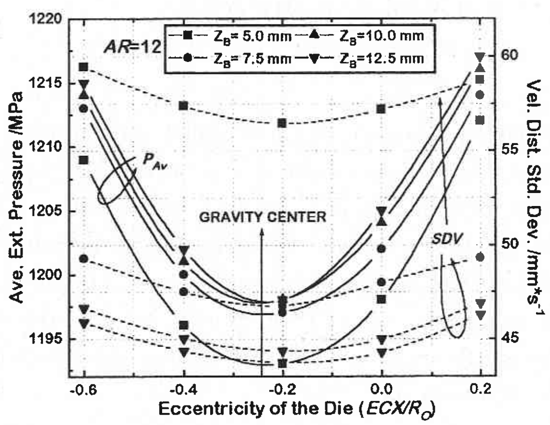

Fig. 2 Variation of P_{Av} and SDV at the die entrance with EC and Z_B for a "L" section, AR = 12.

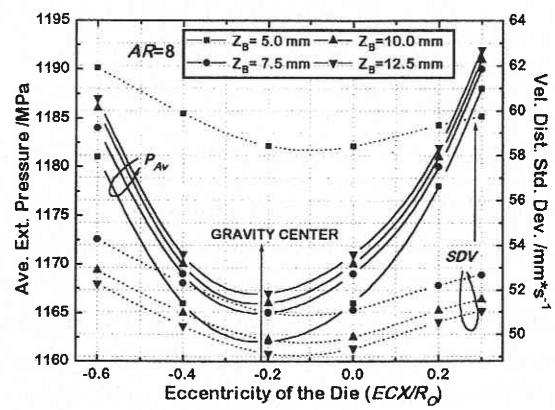

Fig. 3 Variation of P_{Av} and SDV at the die entrance with EC and Z_B for a "L" section, AR = 8.

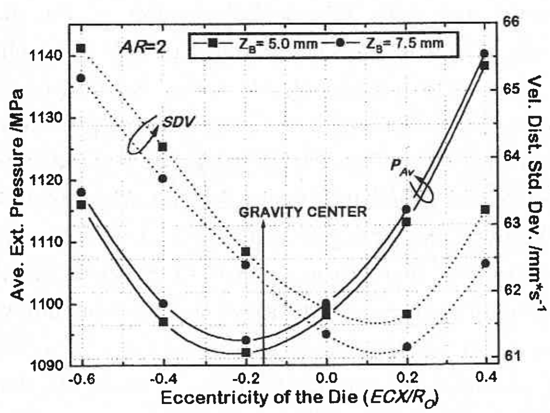

Fig. 4 Variation of P_{Av} and SDV at the die entrance with ECX and Z_B for a "L" section, AR = 2.

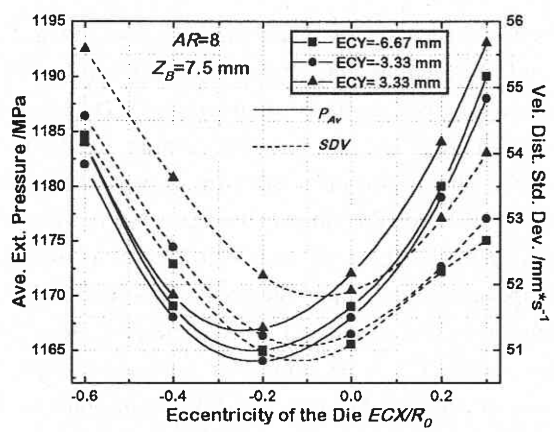

Fig. 5 Variation of P_{Av} and SDV at the die entrance with ECX and ECY for a "L" section, AR = 8, Z_B = 7.5 mm.

and SDV is intermediate and on the contrary for $ECY = -6.67$ mm, which corresponds to the position of the gravity center. From these results optimal ECY lies between $ECY = -3.33$ mm and $ECY = -6.67$ mm. The right decision could be taken by observing the distribution of V_Z at the die exit. **Fig. 6 (a** and **b)** shows this information for both cases. When $ECY = -6.67$ mm, the distribution of V_Z predicts that the product will exit in bending fashion, on the other hand, for $ECY = -3.33$ mm case, it is predicted that the bending direction changes. Then, in according with the post-extrusion operation facilities and the easiness of the defect-removal operation the ECY value could be decided.

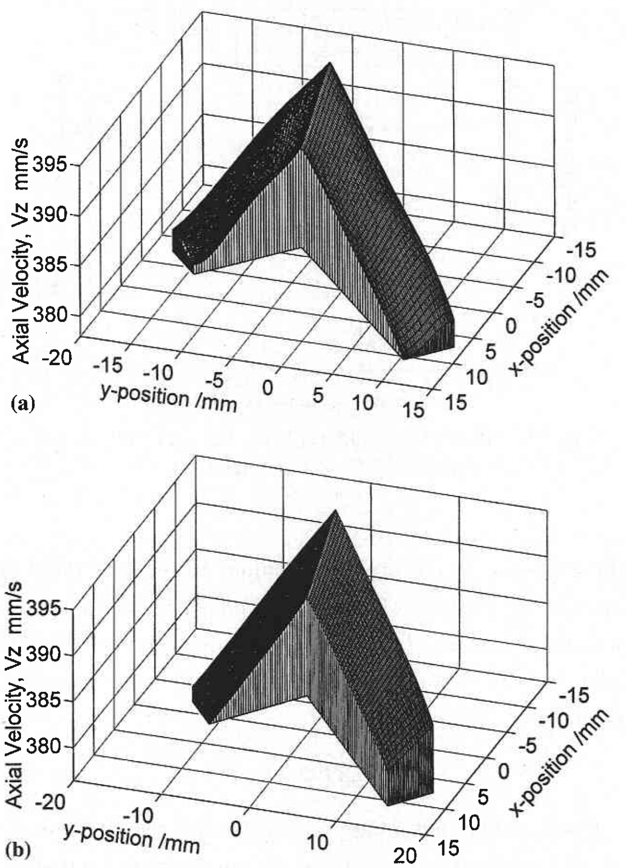

Fig. 6 V_Z profiles for a "L" section, AR = 8, ECX = −10 mm, Z_B = 7.5 mm (a) ECY = 26.67 mm (b) ECY = −3.33 mm.

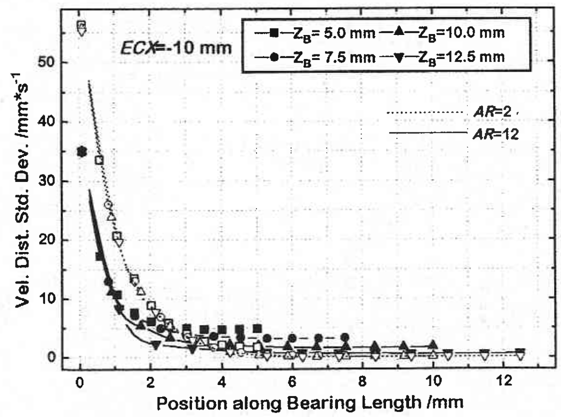

Fig. 7 Variation of SDV along bearing length for "T" sections, ECX = −10 mm.

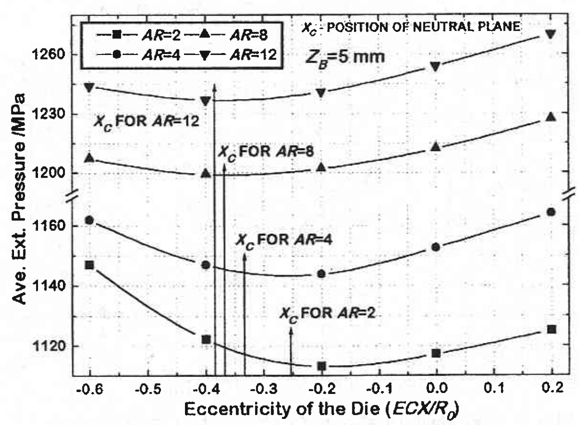

Fig. 8 Effect of ECX and AR on P_{Av} for "T" sections, Z_B = 5 mm.

The influence of Z_B on the variation of SDV along the axial position of the bearing for "T" sections is shown in **Fig. 7**. The results for two AR values are included, 2 and 12. The plots indicate that although the section with AR = 12 has lower SDV at the die entrance, the velocity distribution becomes uniform slower than that of the section with AR = 2. For example, it is observed that Z_B = 5 mm is almost long enough to get uniform distribution for a section with AR = 2, nevertheless the section with AR = 12 apparently needs a longer Z_B.

Results on the effect of AR and ECX on P_{Av} for "T" sections are summarized in **Fig. 8**. It is clear that the variation of P_{Av} shows a similar behavior to that for "L" sections, that is, it has a minimum. In the figure are indicated by the dropped lines the position of the neutral plane for each AR value. The minimum of each curve agreeably coincides with X_C, the position of the neutral plane, mostly for sections with higher AR. It confirms the statement that the position of the die opening at $ECX = X_C$ demands the lowest extrusion force.

Simulation results considering the influence of Z_B on P_{Av} and SDV at the entrance of the die for "T" sections are shown in **Fig. 9** (**a** and **b**). The AR values of the simulated sections are 2 and 12, respectively. From the results it is clear that P_{Av} increases with the bearing length, however, the effect is visibly larger for the sections with AR = 12. Again, as mentioned before, the curves of P_{Av} have a minimum, which in the case of AR = 12, agreeably corresponds to the position of the neutral plane indicated by the dropped line in the figure.

With respect to the effect on SDV, the figures shown an interesting behavior. When the AR value is low, SDV increases with the eccentricity of the die opening, however, in the case of higher AR value, the change of SDV with

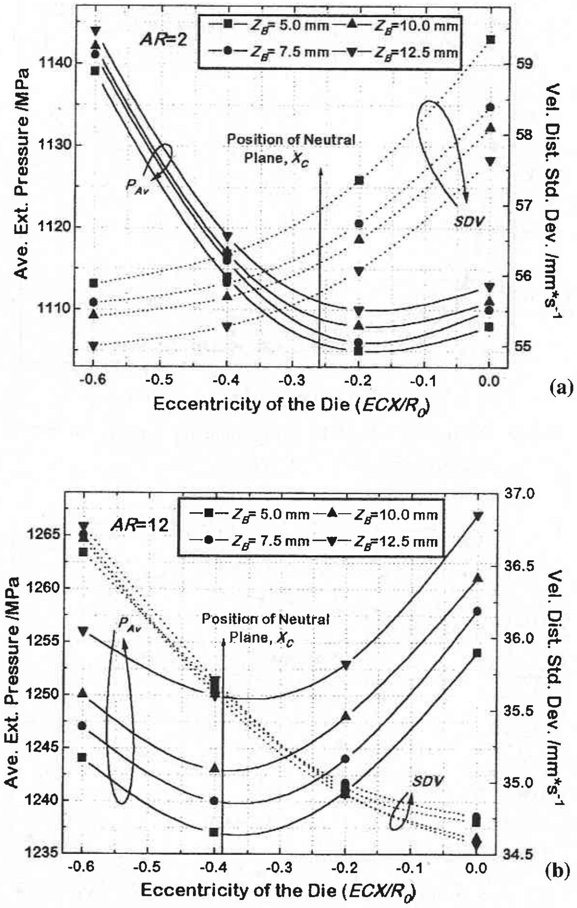

Fig. 9 Variation of P_{Av} and SDV at the die entrance with EC and Z_B for "T" sections **(a)** AR = 12, **(b)** AR = 2.

ECX is inverse, that it to say, it decreases. Moreover, the effect of Z_B on SDV is larger for sections with lower AR. Also, at least in the analyzed interval of ECX values, the curves of SDV in both cases don't have a minimum.

The influence of Z_B and ECX on P_{Av} and SDV at the exit of the die is shown in **Fig. 10** for a section with AR = 12. It is obvious that when Z_B is long, SDV will be low, however P_{av} increases. Again the curves have a minimum indicating

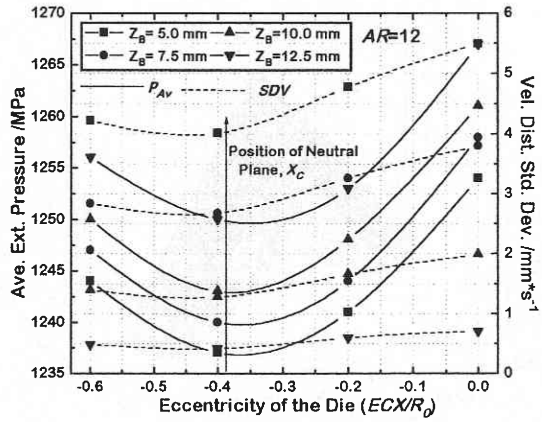

Fig. 10 Effect of Z_B and ECX on P_{Av} and SDV at the die-exit for a "T" section, AR = 12.

the existence of the optimal position. In the plot there is marked the position of the neutral plane that fairly agrees with the minimum of the curves. Moreover, the variation of SDV also shows a minimum, in this case it is also near the position of XC.

4. Conclusions

It was shown that a long bearing assures the straightness of the material at the die exit, however the extrusion pressure increases and mostly for sections with higher aspect ratio.

The results showed that the most influential parameter is the position of the die opening with respect to the billet axis. Both, the distribution of the axial velocity and the extrusion pressure are very sensitive to effect of this parameter.

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References

1) M. Kiuchi et.al.: Proc. JSTP Spring Conf. (1996), to be published.