研　究　速　報

Finite Element Analysis of Velocity Distribution in Bearing Zone During Extrusion of "C", "T" and "H" Sections

—Combination of Numerical Analysis and Die Design-4—

"C", "T", "H" 材の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-4—

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1. Introduction

This paper is continuation of the published papers[1~3]. In these works the complex problem of balancing the metal flow was analyzed by carrying extrusion process simulations of rectangular, angle, channel, "L" and "T" sections. In those works, it was shown how the metal flow is balanced by selecting the optimum length of the bearing land, i.e., the length resulting in uniform velocity across the cross-section of the product. Furthermore, the metal flow as influenced by the position of the die openings along the die face was investigated.

In the present work, the simulation cases are extended to "C" and "H" sections, moreover, the metal flow in extrusion of "T" sections is further detailed relating to the paper[3]. All of these three sections, due to their metal flow characteristics developed during extrusion process, are considered as difficult-to-extrude. Then, in the presentation of the results, emphasis is made on the study of the axial velocity distribution in the bearing land zone and some comments on the application of them to extrusion die design are outlined.

2. Extrusion Process Simulation

Summary of process conditions used in simulations are listed in the previous paper[1]. The computational models for "T" sections are described in the referred paper[2], and for "C" and "H" sections, they are listed in **Tables 1** and **2**, respectively. Also, it is noted here, for comparison purpose, that the extrusion ratio *ER* is kept constant for all of the simulated cases, that is $ER=39$.

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Table 1　Computational models of "C" sections.

DYE1 (mm)	DXE2 (mm)	DXE3 (mm)	AR
4.08	16.33	8.16	6
3.16	15.81	15.81	10
2.88	11.50	23.00	12

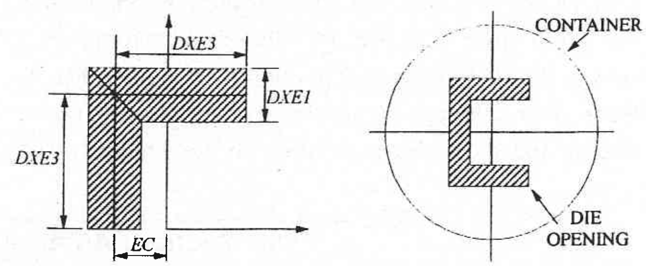
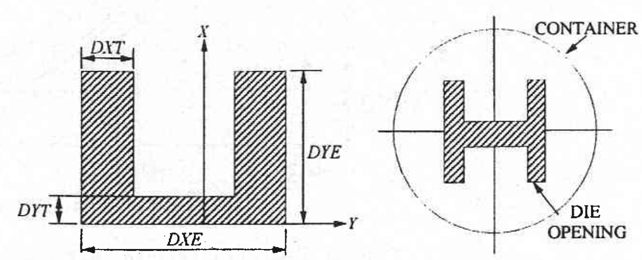


Table 2　Computational models of "H" sections.

Case	DXE (mm)	DYE (mm)	DXT (mm)	DYT (mm)
1	20.65	10.33	7.75	7.75
2	30.97	15.49	3.66	3.66
3	41.30	20.65	2.58	2.58



3. Results and Discussion

Typical examples of the FEM models for workpieces used in simulations are shown in **Fig. 1.** Because of the symmetry, only one half of the model is considered in the calculations. The computation time required for one case lies within 2 hours for a DEC alpha workstation 5/266, which can be considered economically feasible.

Fig. 2 shows the variation of P_{Av} (Average Extrusion Pressure) and *SDV* (Standard Deviation of Axial Velocity V_Z) at the die exit with *EC* (Eccentricity of the die opening) and the bearing length Z_B for a "C" section with $AR=8$. Due to the geometric characteristics of "C" sections, the plots of P_{Av} have a minimum indicating that there is an optimal *EC* where the P_{Av} required for the process is the lowest. It is observed, that the minimum of the plots are slightly displaced towards negative values with respect to the position of the gravity center indicated by the dropped line.

The study of the velocity distribution along bearing length shows an interesting behavior, while other relatively simple sections like rectangles and angles require bearing lengths no longer than 7.5 mm for obtaining uniform axial velocity[2], "C" sections requires more than 12 mm, **Fig. 3.** Furthermore, through the simulations, it is found that even varying the die opening position, to get uniform axial velocity at the die exit is very difficult. For example, **Fig. 4** shows the axial velocity distribution at the die exit in extrusion of a "C" section, the bearing length is 10 mm. The pattern distribution clearly shows that the axial velocity is still non uniform, also, the run-out direction of the extrudate is predicted. Therefore, in order to obtain a straight product, it is necessary to implement another method for metal flow control, i.e., variable bearing land length or flow guides, similar results were experimentally found by Xie[4].

Fig. 5 shows the pattern distribution of the axial velocity in extrusion of "T" sections at the die-exit. The aspect ratio

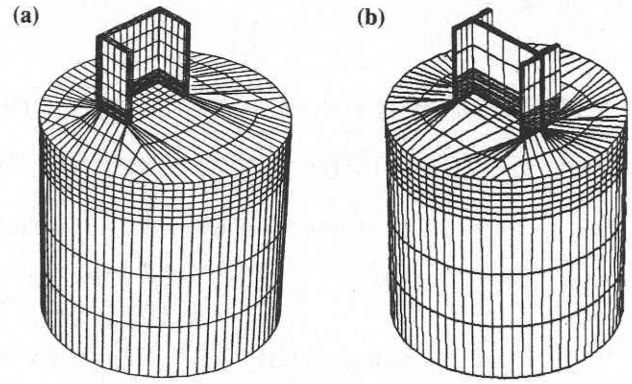


Fig. 1 Finite element model of workpiece: **(a)** "C" section, **(b)** "H" section.

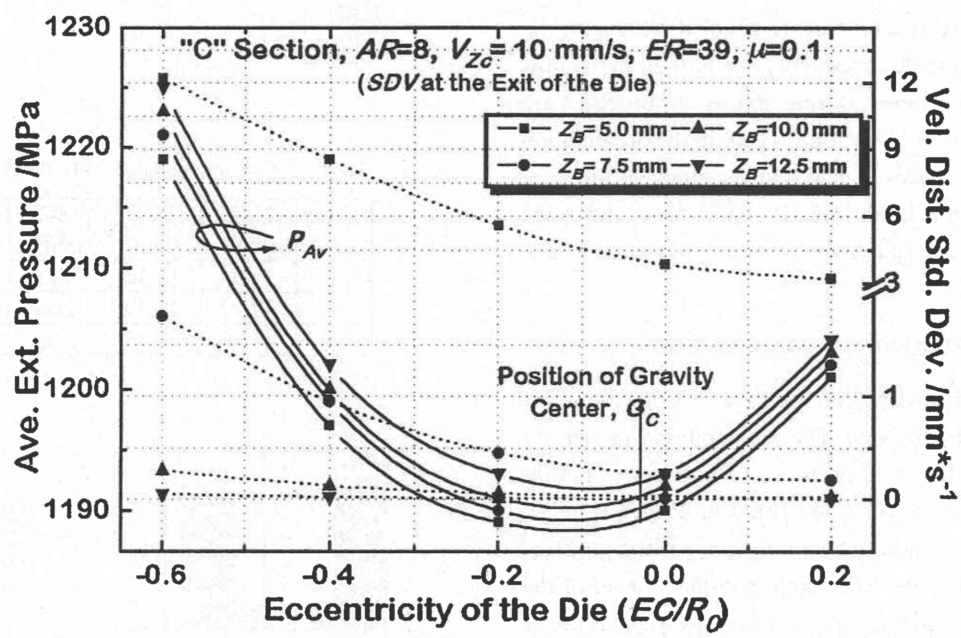


Fig. 2 Effect of Z_B and *EC* on P_{Av} and *SDV* at die exit for a "C" section, $AR=8$.

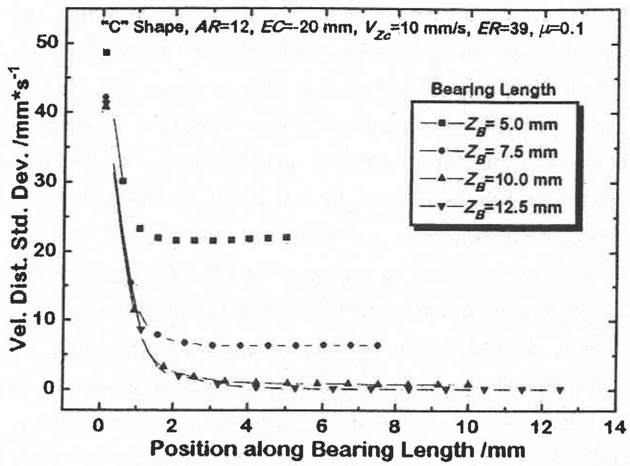


Fig. 3 Variation of *SDV* along bearing length in extrusion of a "C" section, $AR=12$, $EC=-20$ mm.

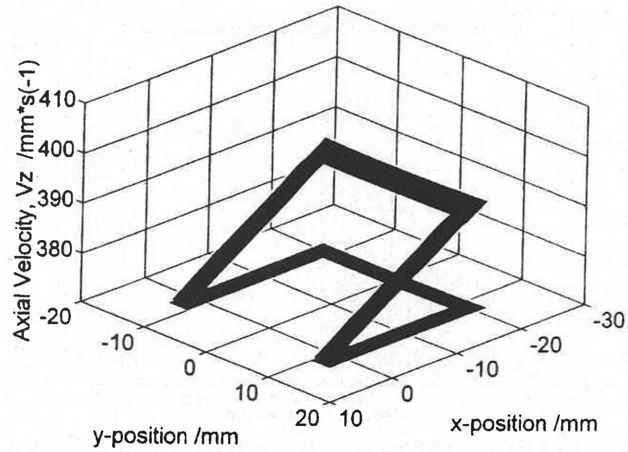


Fig. 4 Axial velocity distribution at the exit in extrusion of a "C" section.

(a)

(b)

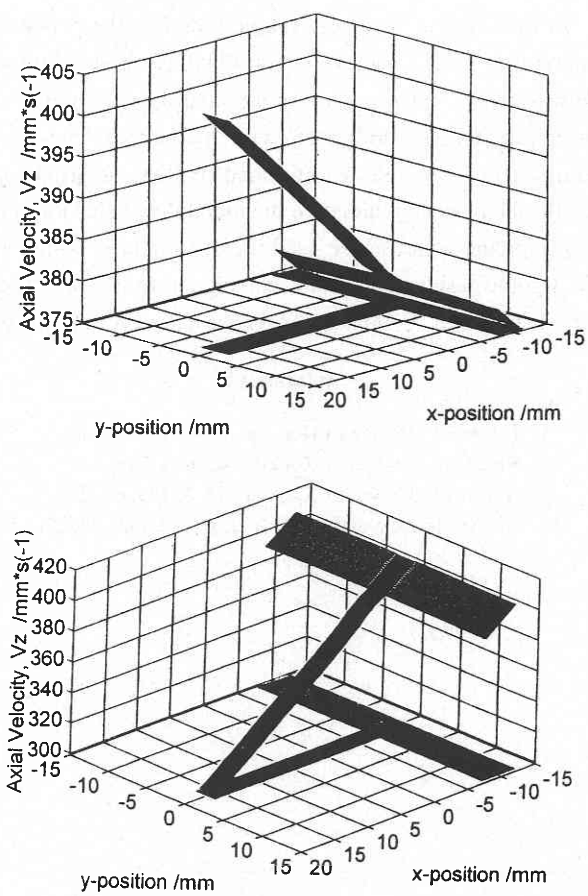


Fig. 5 V_Z profiles for a "T" section, $AR=8$, $EC=-10$ mm, $Z_B=7.5$ mm: **(a)** $u=v$; **(b)** $u=2v$.

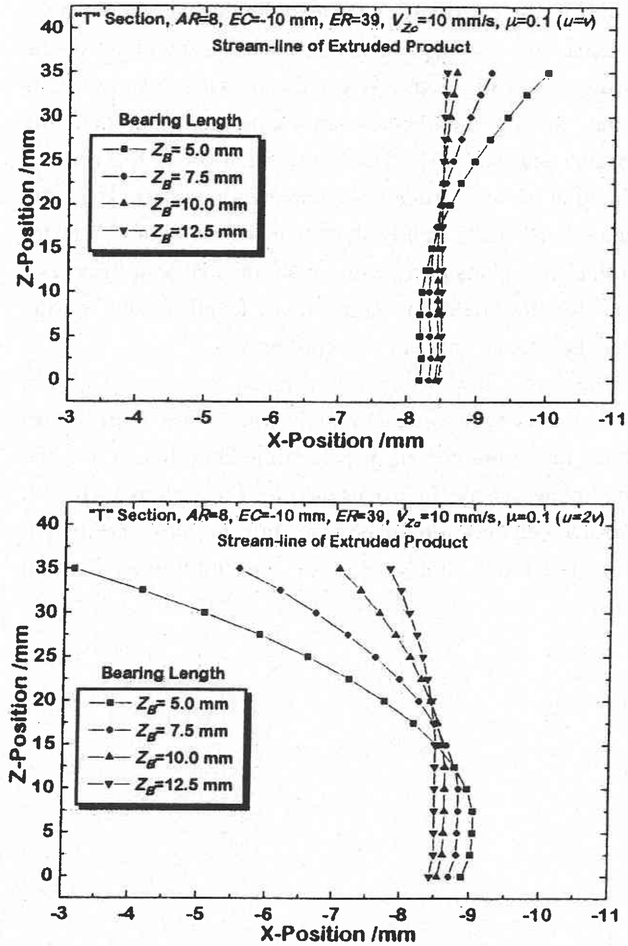


Fig. 6 Effect of die bearing length on streamline shape in extrusion of a "T" section, $AR=8$: **(a)** $u=v$; **(b)** $u=2v$.

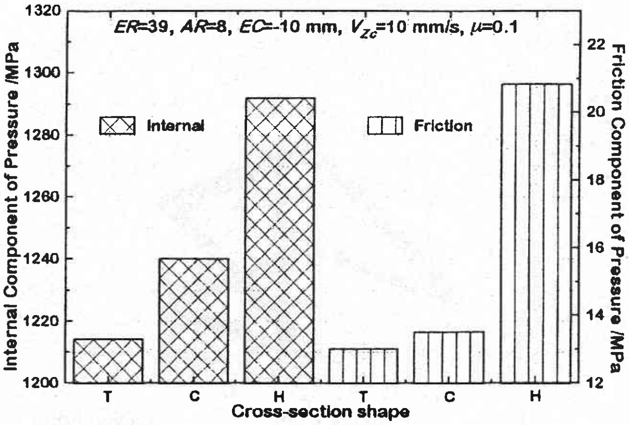


Fig. 7 Average extrusion pressure in extrusion of "C", "T", and "H" sections, ER=39.

AR is 8 and other extrusion process conditions are also the same but the relationship between the thickness of the legs. Comparison between them clearly shows the effect of the difference in geometry. When the thickness of the legs is same, the leg parallel to x-axis emerges faster than the parallel one to y-axis. However, when u=2v the run-out direction of the extrudate is completely reverted. Thus, the simulation results clearly show that the metal flow is faster in thicker regions of a section with unequal wall thickness, and, for the metal flow control, the length of the bearing land has to be increased accordingly.

The metal flow is specially complex in extrusion of thin walled sections of unequal wall thickness. **Figs. 6 (a)** and **(b)** show the influence of the bearing land length on the streamlines shape in extrusion of "T" sections, AR=12. Comparison between them shows how the run-out direction is completely changed due to the differences in wall thickness. Furthermore, it is observed that although the curvature of the streamline diminishes with bearing land length, it is well known that this practice has serious disadvantages, for example, higher extrusion pressure is demanded and, more critical, surface defects are likely to occur, resulting in poor quality products. Moreover, in sections with unequal wall thickness, the desired straightness is not obtained as indicated in **Fig. 6 (b)**, where the streamline obtained in extrusion with very long bearing land length, Z_B=12.5 mm, still shows excessive curvature.

Fig. 7 shows the extrusion pressure components in extrusion of "C", "T" and "H" sections, the results clearly show how the pressure increases with respect to cross-section shape, indicating the complexity of the developed metal flow.

4. Conclusions

In extrusion of relatively simple sections, the balance of metal flow can be achieved by modifying the bearing land. However, in extrusion of more complex sections, it is necessary to use another effective method for metal flow control, i.e., variable bearing land or flow guides. In this work, the results obtained on the metal flow behavior in the bearing land zone can be used for bearing land design and flow guide design meant for achieving uniform axial velocity at the die exit.

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References

1) Kiuchi et.al.: Seisan-Kenkyu, 48–1, (1996), 21.
2) Kiuchi et.al.: Seisan-Kenkyu, 48–6, (1996), 17.
3) Kiuchi et.al.: Seisan-Kenkyu, 48–6, (1996), 21.
4) Xie et.al.: Sci. and Eng. of Light Metals. (1995), 531.