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Deliberation of CAE Model for Extruded Rectangular Hollow Products

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In recent years, the simulation can be used for a practical stage by the advancement of the computer technology. The application of the simulation technology to aim at the die design efficiency improvement is researched and reported in the aluminum extrusion. In the automotive industry, the products of lightweight aluminum alloys are noticed. Especially, a car's bumper-reinforcement is used high strength aluminum alloys. In this case, the targeted extrusion section has two or more hollow parts. In this extrusion, a billet is separated into some metal streams at the bridges of the die mandrel. After passing the port-hole, the metal streams contact again in a welding chamber of the die cap to form a metallic joint and the extrusion products are shaped through the die. Therefore, the thickness securing of the rib on the inside is a difficult shape of the cross section. In this study, the flow velocity control of the extrusion products and strength of the die are forecast by the analysis. As a result, it is confirmed that the flow velocity of the rib and the stress of the die mandrel change when the shape of the die is changed. This result becomes the index of an actual die design.

Keywords: *Extrusion, Aluminum, FE simulation*

1. Introduction

In recent years, the application of various simulations in hot extrusion of aluminum alloys has proven useful. If it is applied to the matter of the reality, design frequency for trial purposes is reduced, the lead time is shortened, and the cost is decreased. Additionally, the inside of the processing material can be observed. Therefore, a lot of application of this technology that aims at the design efficiency improvement is researched, and reported.

On the other hand, in the automotive industry, the products of lightweight aluminum alloys are paid to attention, and the design and the productive technique that can be supplied at a low price are requested. Therefore, the extrusion processing is a useful processing method. In addition, the development of a more efficient product is expected by applying CAE.

In this study, the Finite Element Method (FEM) code DEFORM-3D is applied to the extrusion process of the car's bumper-reinforcement, and the best die shape is considered.

2. Mode of Analysis

2.1 Analysis Procedure

The analytical object is an aluminum midair section of triple hollow shown in **Fig.1**. It is cross section of car's bumper-reinforcement.

In this report, how the size accuracy of the extrusion products and strength of the die influence the die shape in the midair extrusion is investigated.

As an analytical procedure, the flow analysis is done first, and strength analysis is done after the obtained pressure distribution from it is transcribed in the die. The accuracy of the extrusion products is forecast from the flow velocity distribution of the flow analysis, and die strength is forecast from the stress distribution of the strength analysis.

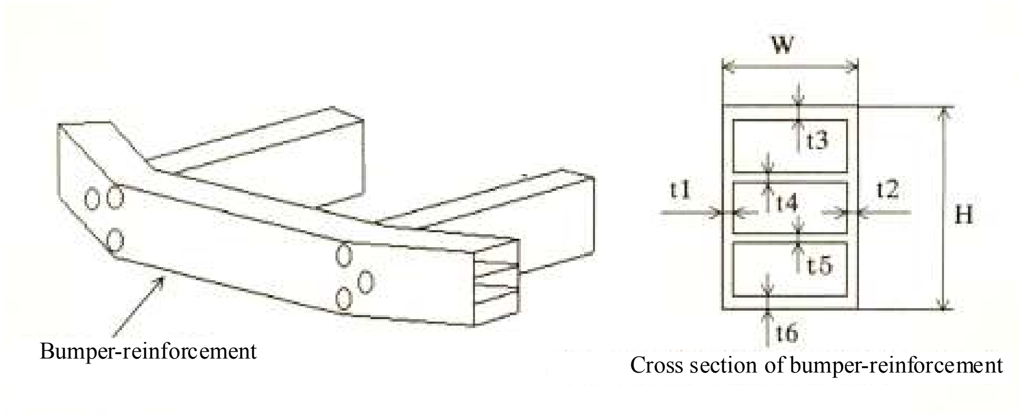
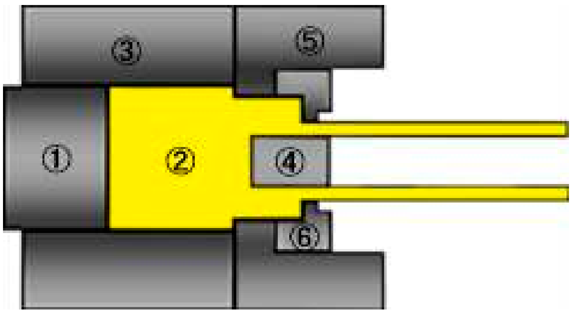


Fig.1 Analytical object

2.2 Model and condition of flow analysis

Fig.2 shows the simplified extrusion model composed of extrusion tools such as container, die mandrel, die cap, etc. and billet of the material to be processed.



No	Tool name
1	Dummy Block
2	Billet
3	Container
4	Die mandrel
5	Die ring
6	Die cap

Fig.2 Extrusion model

The flow analysis condition is shown in **Table.1**. This model is 1/4 models because it is symmetry. As a result, analytical time can be shortened. The mesh division targets only the metal, and analytical method is Eulerian (analysis for steady state). Friction is considered only between billet and tools.

Table.1 Flow analysis condition

Analytical method	Eulerian (steady state)	
Physicality condition	Billet	Rigid-plastic solid
	Tools	Rigid solid
Temperature condition	753K (billet and all tools)	
Loading condition	Ram speed 0.5 [mm/sec]	
Frictional condition	m=0.9	

2.3 Model and condition of strength analysis

The strength analysis model is composed of the die mandrel and the die cap shown in **Fig.3**. The analytical object of the analysis is a load caused in the die mandrel and the die cap.

This time, only the die mandrel set the mesh because it targeted only the die mandrel, and the die cap was made a solid body.

No	Tool name
①	Die mandrel
②	Die cap

Fig.3 The strength analysis model

The condition of the strength analysis is shown in **Table2**. Because the elasticity analysis is assumption in strength analysis Solver of DEFORM, the die mandrel is set by the elastic body.

Table2 condition of strength analysis

Physicality condition	Die mandrel	SKD61, elastic body
	Die cap	SKD61, solid body
Temperature condition	753K	
Loading condition	Transcribe the pressure distribution of the flow analysis on the die surface	
Restraint condition	Die ring and Die cap	
Frictional condition	μ =0.2 (between tools)	

3. Analysis result

3.1 Flow analysis result

When flow velocity is compared, the viewing screen is decided under the die bearing. **Fig.4** shows the flow velocity distribution.

It can be confirmed that the flow velocity of the rib has slowed extremely from **Fig.4**. It is thought that this causes the defect such as shrinkage.

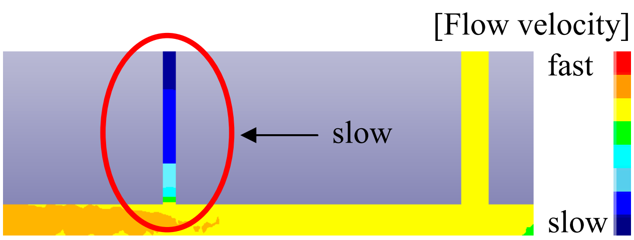


Fig.4 Flow velocity distribution

The shape of the slit of the die mandrel is changed to evaluate the flow velocity of the rib, and the flow velocity of the rib is compared.

Fig.5 shows the flow velocity of the rib when the slit width is changed and **Fig.6** shows the flow velocity of the rib when the slit height is changed. It can be confirmed to obtain faster flow velocity when the slit width is large and the slit height is low.

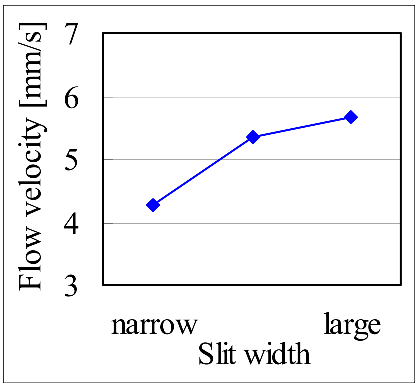


Fig.5 Influence of slit width on flow velocity

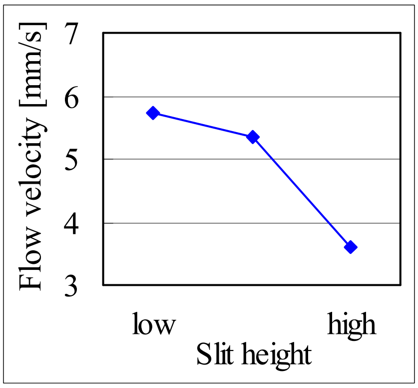


Fig.6 Influence of slit height on flow velocity

3.2 Strength analysis result

When die mandrel strength is compared, the viewing screen is decided upper part of the die bearing. The shape of the slit of the die mandrel is changed to evaluate the strength of the die mandrel, and the stress of die mandrel is compared.

Fig.7 shows the stress of the die mandrel when the slit width is changed and **Fig.8** shows the stress of the die mandrel when the slit height is changed. It can be confirmed to obtain major stress when the slit width is large and the slit height is low.

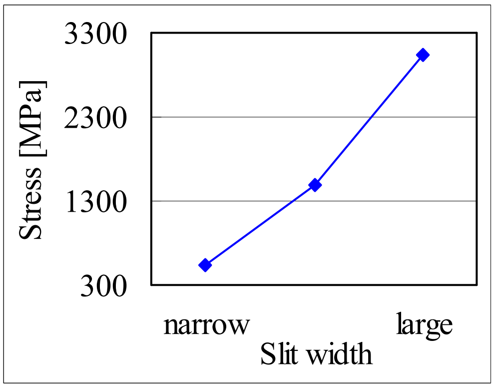


Fig.7 Influence of slit width on stress

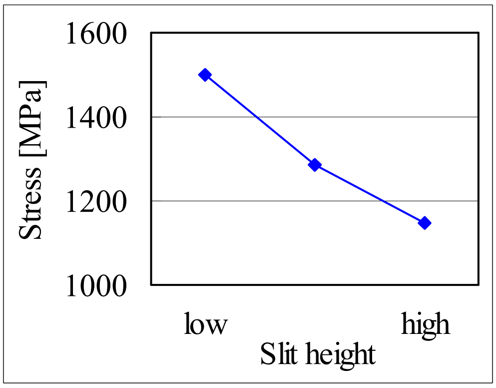


Fig.8 Influence of slit height on stress

3.3 Change in die bearing shape

In the analysis to here, the length of the die bearing is assumed to be constancy for easiness. In an actual extrusion, the length of the die bearing is adjusted in consideration of the flow of the metal. Then, a new die bearing is made referring to the die actually used to obtain an analysis result near a real machine and to confirm reproducibility. The die bearing shape is shape corresponding to the flow velocity distribution shown in **Fig.4**. It means the die bearing in the part with fast flow velocity is long. (It in the part with slow flow velocity is short.) The flow analysis is done with this die, and it compared it with a past die.

Fig.9 shows the flow velocity distribution when the die bearing is changed. The tendency that the flow velocity of the rib is slow when **Fig.4** and **Fig.9** are compared doesn't turn. But, it can be confirmed that the flow velocity of the rib quicken a little, flow velocity of other part is made uniform and flow velocity distribution is steady. Therefore, it can be said that the metal flow can be controlled by devising the shape of the die bearing also in the analysis.

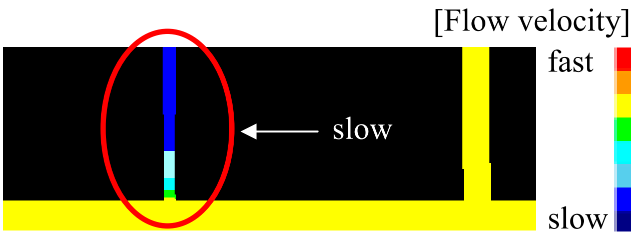


Fig.9 Flow velocity distribution when die bearing is changed

4. Conclusions

The following findings are obtained by this analysis.

1) It causes the defect such as shrinkage because of the flow velocity of the rib slowness.
2) When the slit width is large and the slit height is low, the flow velocity of the rib and the stress of the die mandrel increase.
3) When the height of the die bearing is changed to the real machine corresponding, the flow velocity difference between the outside and the rib of the extrusion products is improved. This is an appropriate flow velocity distribution.

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