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Numerical Simulation of Tube Extrusion Process of AISI304 and Comparing with Upper Bound Solutions

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1- Introduction

Extrusion is a common bulk-forming process to transform materials into semi-finished products. A product that is produced by this method is seamless tubes. The seamless AISI304 stainless steel tube has been an important profile widely used in oil, transportation and national defense industries mainly due to its excellent corrosion and oxidation resistances and good performance at high and low temperatures.

The seamless stainless steel tube can be produced by extrusion method using glass as lubricant. The process is carried out at high temperatures and it is associated with large deformations and high strain rates.

Analysis of metal forming processes is commonly performed utilizing analytical, numerical, or physical techniques. Due to the complexity of the equations involved in the analytical approach, application of such methods is only practical for the case of simple geometries and boundary conditions.

Finite element (FE) simulation has become an important tool in the design and development of extrusion and other manufacturing processes. Most of the simulation work involves aluminum extrusion, but some work on steel and titanium extrusion has also been reported on titanium extrusion and on steel.

Simulation of extrusion using the finite element method (FEM) has become more common during the last decade. The most common approach in these simulations is to use a uniform billet temperature as initial condition in the extrusion model. The initial stages of heating and transport are often ignored. Although the finite element method can provide a basis for studying and optimizing the deformation occurring in a complex extrusion process, it cannot design the tooling.

2- Experimental

Due to the axial symmetric geometry of the extrusion process, a two-dimensional symmetric finite element model was used as shown in Fig. 1.

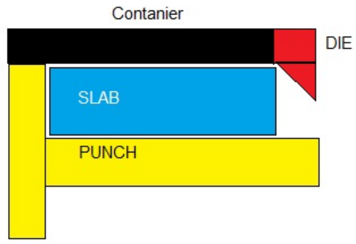

Fig. 1 schematic location of the process components.

The dimensions of components of the model are given in Table 1.

Table 1 Dimensions of components of the model (mm)

Length of slab	500
Outside radius	300
Inside radius	100
Thickness of tube	60
Thickness of container	40
Die angle	30

In the model, the primary ingot was considered as pre-pierced. the properties of AISI 304 stainless steel are used for the primary ingot and the properties of AISI H13 are used to model process equipment.

In this study, a completely coupled thermal-displacement analysis was used. To achieve the degree of freedom required for analysis, the CAX4RT element was used. Patterning the model with this element was done using the Lagrangian-Eulerian mesh-layout method.

Parameters of the extrusion model are given in Table 2. The upper bound analysis method was used to solve the analytical process. The Johnson and Cook formula was used to correlate between the yielding stress and strain, rate, and temperature.

3- Results and Discussion

The maximum Extrusion force was calculated using upper bound and compared with the results obtained from the FEM. The result of this comparison is shown in Fig. 2. This figure shows the extrusion

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force obtained from the model and calculated according to the initial temperature of the ingot.

Table 2 Parameters of the extrusion model

Parameter	Range
Punch Velocity	250-100 (mm/s)
Initial Slab Temp.	1273-1473 (K)
Initial Punch, Die, Container Temp.	573 (K)
Coefficient of Friction Between Slab-Die, Slab- Container	0.03
Coefficient of Friction Between Slab-Punch	0.4
Coefficient of Heat transfer between Slab-Container	1500 (W/m^2K)
Coefficient of Heat transfer between Slab-Punch	2500 (W/m^2K)
Die angle	30-90 deg
Outside Tube Radius	180-240 (mm)

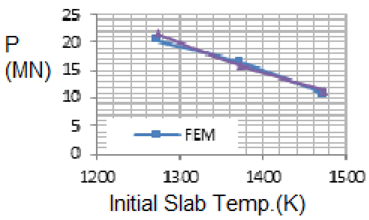

Fig. 2 Maximum extrusion force from the FEM method and calculated according to the initial temperature of the ingot

The comparison of the results of calculated and FEM show good matching. The maximum difference between the results is 5%.

Fig. 3 shows the maximum extrusion force obtained from simulation and analytical relationships at various speeds. According to this result, with increasing extrusion speed, the increasing extrusion force is negligible and can be ignored.

In Fig. 3, the maximum extrusion force obtained from the simulation and analytical relationships have been shown in different extrusion ratios.

According to Fig. 3, the extrusion force has been significantly increased by increasing the extrusion ratio.

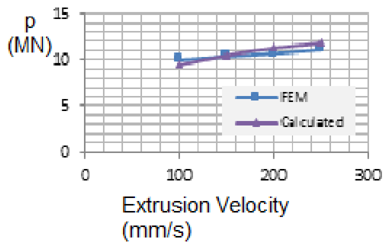

Fig. 2 Maximum extrusion force at various extrusion speeds

According to Fig. 3, it can be said that by doubling the extrusion ratio, the extrusion force has almost doubled its value.

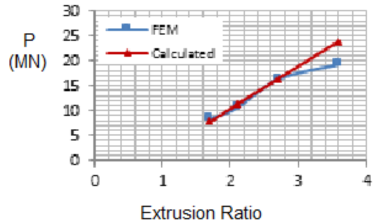

Fig. 3 Maximum extrusion force at various extrusion ratios

4- Conclusions

The calculated maximum extrusion force due to simulation and upper bound method have good matching.