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Modelling and Simulation of Hollow Profile Aluminum Extruded Product

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Abstract. The main objectives of this paper is to find the way for solving the problems of aluminum extrusion process, and improve the mechanical properties of the products through a smart design, modelling and simulation of this process by using finite element method (FEM). For the purpose to model a (2D) two dimensions warm aluminum extrusion process, ABAQUS software was used to set up the finite element simulation. The main parameters which have major effects on this process like extrusion stresses, temperature, and die geometry, i.e. extrusion radius, were taken into consideration. Aluminum alloy (Al-2014) was used as the billet material, with 40 mm diameter and 75 mm length. It is important to preheat the billet from the beginning to a specific temperature, and then pressurizes it into the die. This process is an isothermal process with an extrusion ratio of 3.3. Subsequently, the optimized algorithm for these extrusion parameters was suggested based on the simulation results. The results suggest that the large die angle needs a less extrusion load than the small die angle. In all die geometry used, the deformation of aluminum billet, which caused by shearing and compression stresses, happened in a small sectional area, i.e., bearing area. The results also showed that the values of these stresses can increase or decrease depends on the die entrance angle and the die bearing length. To avoid the effects of these stresses on die dimensions; the hardness, material selection, and geometry should be well calculated.

Introduction

Cold extrusion process means that the material is forced to flow in its cold condition under high pressure. It is used for manufacturing special hollow and solid sections. There are many factors that affect the surface finish, properties and structure of the section, which are the conditions of the billet and the container, extrusion speed and extrusion ratio. In fact, all aluminum alloys can be extruded, but the quality of surface finish, required pressure and extrusion speed depending on the alloy properties [1]. Predicting the component dimensional deviations during the extrusion stages is a very important advantage of using finite element analysis procedure. Furthermore, investigation of the work piece, tools temperature variations and the effects of elastic–plastic deformation is also possible [2]. Finite element analysis shows a large plastic deformation occurs in billets during extrusion, and can often lead to heavy remising requirements for such methods and excessive numerical diffusion [3]. Using FEM technique will enable us to show the extruded billet quality (equivalent stress and strain), by studying the effect of the main parameters (extrusion speed and temperature) and die geometry on the extruded billet [4]. Improvement of die and tool design, reducing the trial and error iterations, reducing the wasted time in these iterations and enhancing the output results of the extrusion process is possible by numerical analysis [5].

Modeling Process

The modeling process was designed to simulate an extrusion process for a hollow aluminum tube. In the modeling process, mold design is the main step, which includes drawing all the parts with all required dimensions and tolerances, and then assembling these parts as shown in Fig. 1. The material properties for both aluminum and steel used in this model are given in Table 1.

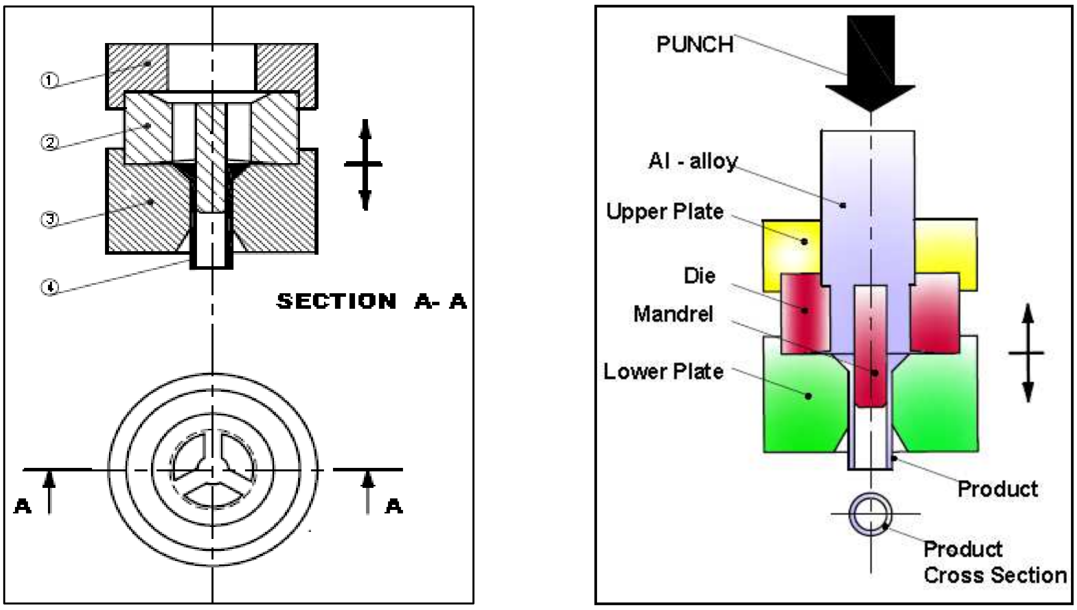

Fig. 1 Model geometry of extrusion process.

Table 1 Material properties of aluminum and steel used.

Material	Density (kg/m^3)	Yield Stress at 150 °C MPa	Plastic Strain at 150 °C	Expansion Coff.	Conductivity(W/m.K)	Young's Modulus (MPa)	Poisson's ratio
AL	2700	111 E6	0.5	8.42 E-005	225	69 E9	0.33
STEEL	7800	375 E6	0.2	0.00012	50	200 E9	0.3

In Finite Element software (ABAQUS), the axi-symmetrical (2D) geometric model was drawn and assembled, including all required definitions and materials selections. The materials were assigned to each part, and the interaction properties, boundary conditions, with a suitable mesh, applied loads were also defined. Fig. 2 below shows the meshed model.

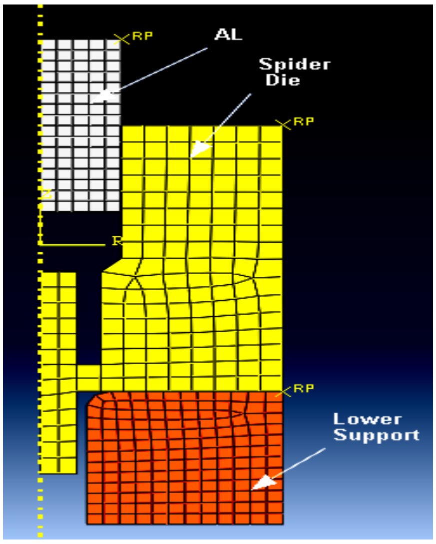

Fig. 2 The meshed model.

Extrusion ratio and the required extrusion force are calculated by Eq.1 anal Eq.2 respectively [6].

$$R = A_o / A_f \tag{1}$$

$$F = P * A_o \tag{2}$$

where R is the extrusion ratio, A_o and A_f are the primary and final cross sectional area of the blank, while F and P are the extrusion force and extrusion pressure respectively. [6].

Finite Element Analysis and Simulation Process

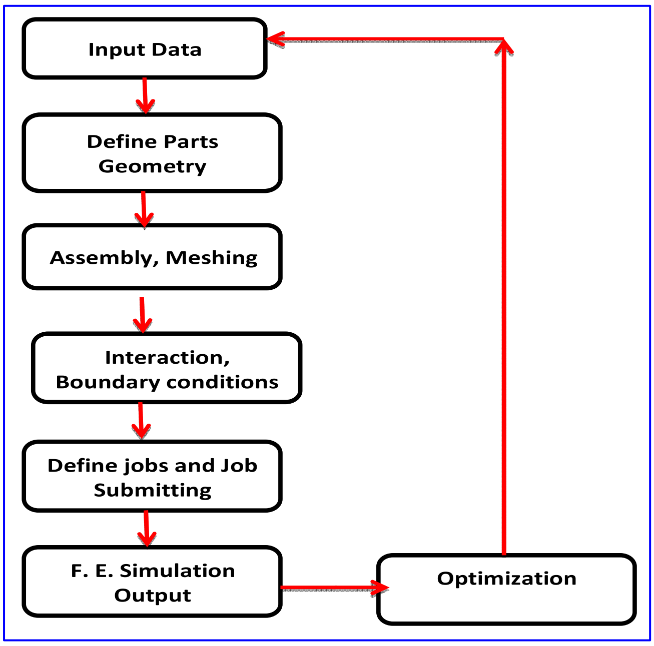

Fig. 3 Modeling and Analysis Flow Chart.

The general steps of simulation process by (ABAQUS/Explicit) are illustrated in Fig. 3. Penalty and kinematics contact formulations were used in the definition of contact interactions. In the first step of the solution, the aluminum material was moved to a position where contact is established and slipping against the die surfaces. In the second step, the rod was extruded through the die to realize the extrusion process. This was accomplished by prescribing a constant velocity for the nodes along the bottom of the rod.

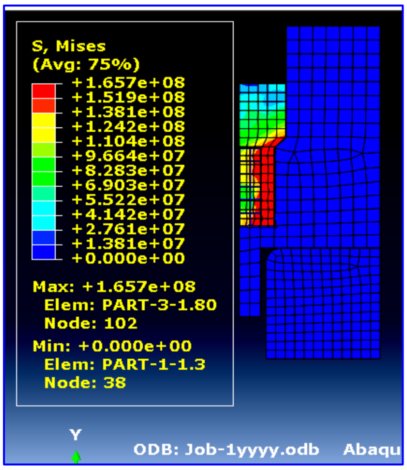

Fig. 4(a) Mises Stresses.

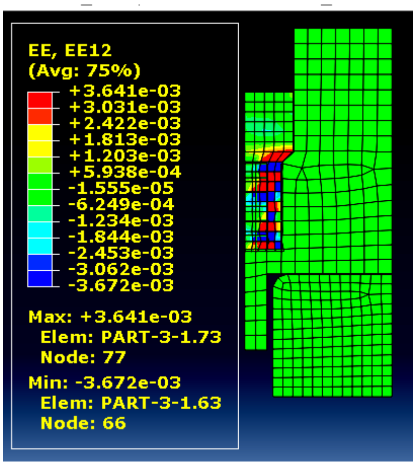

Fig. 4(b) Plastic strain.

The contour plots of plastic strain and the mises stress at the end of extrusion step for the fully coupled analysis using (ABAQUS) are shown in Fig 4a and Fig 4b. The contour shows that the maximum stress values occur in the area where deformation takes place, and when the cross section changes, as well as along the contact surface. The plastic strains exceed 100% near the surface of the billet due to the plastic deformation.

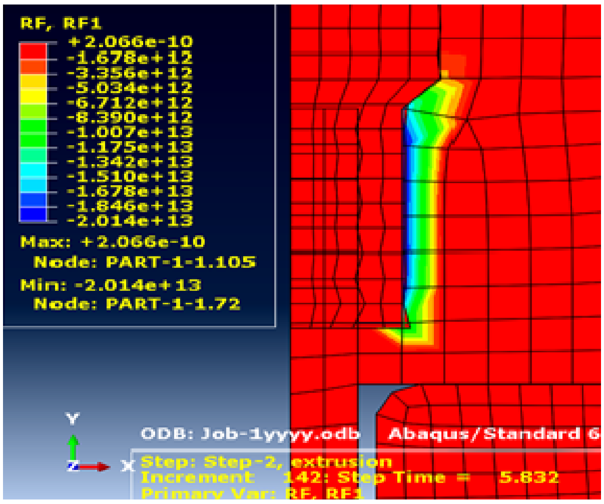

Fig. 5 Reaction force Contour.

The reaction forces component in X direction (RF1), which caused by the interaction between the blank and die is shown in Contour plot in Fig. 5. The value of this force is considered as a measure of deformation rate of the blank.

Results and Discussion

To analyze the flow of aluminum through complex dies within reasonable time spans, algorithms generate tetrahedral meshes that are directionally and spatially refined to capture the solution fields accurately while the number of elements is kept to a minimum are used here. The mesh generation is divided in to many regions rather than one enormously complex region.

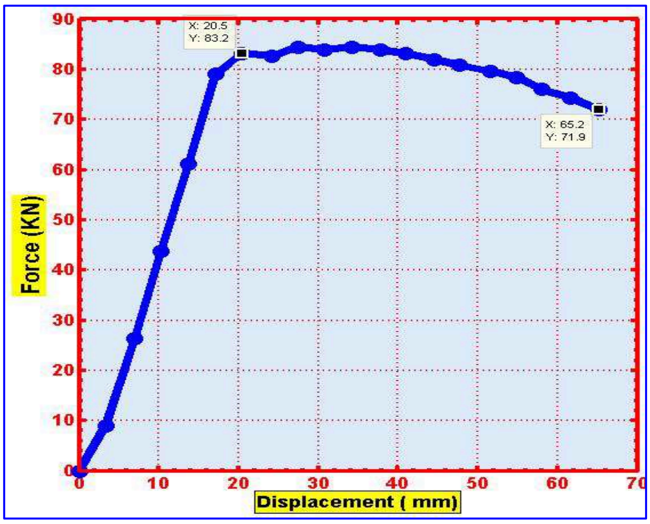

Fig. 6 Extrusion force with blank displacement.

The main result is explained in Fig. 6, for the relation between the force and displacement, in which the extrusion force is proportional with the displacement in the beginning of the process. After the dislocation of blank particles, the required force shows a decrease. Various factors such as geometrical dimensions, variation of mechanical properties over the extruded length and cross section, appearance and regularity of the microstructure, chemical composition and surface finish, are functions that determine the quality of an extruded product. The solution has been repeated for different values of the process parameters such as punch velocity, coefficient of friction and die angle and a number of simulations have been realized.

Conclusion

Low material waste and energy consumption, high productivity, good mechanical properties of extruded components, is the main features of cold extrusion technology. Optimization of cold extrusion procedure in terms of main process parameters and in terms of work piece quality is possible by enhancing the design quality, controlling manufacturing method and improving the analysis and simulation process. Modeling and simulation show the best solution to avoid the stress in the dead zone by selecting a suitable design in this area, by avoiding the sharp edges and enhance the surface quality. Regardless of the extrusion die profile, or its type (flat or hollow), the finite element model is able to accurately predict the performance of extrusion dies. Numerical experiments indicate that the problems associated to the flow, the temperature, the outflow shape, the die deflection and the mesh displacement has a noticeable influence on the outcome of the simulations.

References

[1] R. Woodward. Aluminum Extrusion, Alloys, Shapes and Properties. TALAT lecture. Information on http://www.alueurope.eu/talat/lectures/1302.pdf.

[2] M.K. Abrinia, S. Orangi. Numerical study of backward extrusion process using finite element method, in: D. Moratal (Ed.), Finite Element Analysis, InTech Europe, Rijeka, 2010, pp. 381-407.

[3] M. Prakash, P.W. Cleary, “Modelling of Cold Metal Extrusion”, Fifth International Conference on CFD in the Process Industries, pp. 1-7, Dec 2006.

[4] A.E. Lontos, F.A. Soukatzidis, “Effect of Extrusion Parameters and Die Geometry on the Produced Billet Quality using Finite Element Method”, 3rd International Conference on Manufacturing Engineering (ICMEN), pp. 215-228, Oct 2008.

[5] A.J. Koopman, (2008) Analysis tools for the design of aluminum extrusion dies (PhD Thesis), University of Twente, Enschede, The Netherlands.

[6] G. van Ouwerkerk. (2009) CAD Implementation of Design Rules for Aluminium Extrusion Dies (PhD Thesis), University of Twente, Enschede, The Netherlands.