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3-D FINITE ELEMENT ANALYSIS OF HOT ALUMINIUM EXTRUSION PROCESS HAVING T- SHAPE PROFILE BY OPTIMIZE IT'S THICKNESS

Devendra Kumar Lohia[1] & Navneet Singh[2]

Abstract – Aluminium extrusion is most widely and preferable forming process but there is very different defects generated in extrusion process. Aluminium extrusion involves the generation of free surface, large deformations and complex geometries, thermal effects. The aim of this paper is to optimize the thickness of cylindrical cover with respect to temperature distribution in hot aluminium extrusion process of a T-shaped profile, considering the thermal effect using the FEM software. And find the relation between the thickness of cylindrical cover with hooper and constant temperature, temperature distribution, total heat flux, directional heat flux and thermal error on steady state and transient state thermal.
To rectify the thermal defects, it is necessary to optimize the cylindrical cover thickness. The temperature depends on the length of extrusion machine and thickness of cylindrical cover. And in this paper, it shows the optimizing of the cylindrical cover thickness and increase productivity with minimum amount of thermal error.
Keywords: – Extrusion; Finite element model; Aluminium; Die-plate design; Die-Pocket design.

1. INTRODUCTION

Extrusion is an often used forming process among the different metal forming operations and its industrial history takes back to the 18th century. A billet (work piece) is placed in the container and pressed by the punch, after pressing the metal to flow through a die with an opening. In process of extrusion, a billet is placed in an enclosed chamber. The chamber has an opening through which the excess material escapes as the volume of chamber is reduced when pushed by ram (punch). The escaped material has a uniform cross section identical with that of the opening. In general extrusion process is used to produce cylindrical bars or hollow tubes. A large variety of irregular cross sections are also created by this process using dies of complex shapes.

Aluminium extrusion is used to define cross-sectional profile by transforming raw grains materials in to certain definite objects, by applying certain force with ram at temperature. For the manufacturing of long, straight semi-objects (such as heat sinks, structural frames and furniture accessories) in the form of solid and hollow with complex designs, the metal forming process is used that is named as extrusion.

For thermo-mechanical process of extrusion, there are relation between thickness of cylindrical cover to the total heat flux, directional heat flux and thermal error. Most theoretical analyses of the process determine that it is composed of two distinctly different states, namely the transient state at the beginning and the steady-state in the rest of the process cycle. It is the sequential presence of these two stages in one extrusion cycle that place very high demand on the capacities of software based on the finite element method (FEM) to simulate the process.

FEA is a good choice for analyzing problems over complicated domains (like cars and oil pipelines), when the domain changes (as during a solid state reaction with a moving boundary), when the desired precision varies over the entire domain, or when the solution lacks smoothness. For instance, in a frontal crash simulation it is possible to increase prediction accuracy in "important" areas like the front of the car and reduce it in its rear (thus reducing cost of the simulation). Another example would be in numerical weather prediction, where it is more important to have accurate predictions over developing highly nonlinear phenomena (such as tropical cyclones in the atmosphere, or eddies in the ocean) rather than relatively calm areas.

The product quality and error-less production rate are the very important factor for manufacturing of the objects which depends on the design of the extrusion machine, consists of cylindrical cover, die-plate, backer-plate.

In this paper, billet material (extruded) was AA6063, which is extruded at temperature of 450ºC and 550ºC to optimize the thickness and minimizing the thermal error.

[1] Head of Mechanical Engineering, Institute of Technology And Management, GIDA Gorakhpur, INDIA
[2] Research Scholar, LPU, Mechanical Engineering, Jalandhar, INDIA

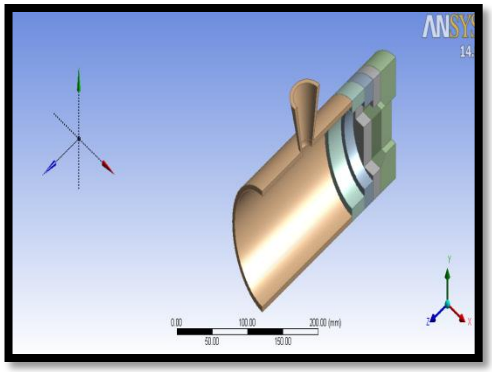

Fig1: Isometric section view of Extrusion Machine

Aluminium AA6063 is common alloy used for extrusion process. It has capacity for creating complex shapes and geometries with super-fine surfaces. It's main application is in architecture, and to manufacturing the window glass frames, door frames, roofs and sign frames, pipes or tubing.
The processes which are carrying out for getting the T-shaped profile are good but cannot give the desired form and quality of products or job. If we manufacture the long bars of any metal, the casting limits the size of the bars or rods or big window pane and the construction of such long moulds are time consuming and costlier too. If we want to do it by forging, again the problem of size and lot of force is needed for which heavy machinery is required. Design of die-plate, die-pocket and cylindrical cover thickness plays very important role in extrusion process without defects such as blow-holes, hot cracks, porosity. For increasing the production rate, the thickness of cylindrical cover of extrusion plays important role. For the viscous behaviour of aluminium, the temperature is given to cylindrical cover outer surface, less then aluminium's melting temperature.

2. DESIGN CONSIDERATIONS

For validation of the results of optimizing the thickness of cylindrical cover with respect to temperature, the finite element simulation method is the best option. It is consider that the extruded bar is T-shaped rectangular of AA6063. And for extrusion machine parts, the materials are choosing with respect to aluminium's physical, thermal behaviour.
It is consider that, cylindrical cover is made of molybdenum. Molybdenum is silvery gray metal with hardness of 5.5. Molybdenum is selected because it has melting point of 2623 °C .it has one of the Lowest co-efficient of thermal expansion at 25°C among commercially used metal.
Density of molybdenum = 10.28 g⁄cmˆ3. It can work at temperature above 1100°C, which is higher than steel and nickel based super alloys.
In extrusion machine, there are two backer plates –
a. Backer plate 1
b. Backer plate 2
It is use to divide the extrusion force. It is made of brass. Brass is metal alloy made of copper and zinc. It has higher malleability than bronze. The relatively low melting point of brass (900 to 950 °C) and its flow characteristics make it relatively ea...sy materials to cast . Density of brass material is 8.4 to 8.73 g ⁄cc . Beta-brasses (copper 50-55% to Zinc 45-50%) are suitable for hot working and suitable for casting.
The die-plate and die-pocket are made-up from nickel. Die-plate is used to extrude the desired shape of the material which is pressed by the ram. It is the main part of the extrusion machine as due to which the desired shape is fabricated. And die-pocket is placed after die-plate, having 45degree chamfer angle, which is used for the straightening of the extruded bar-profile. It is also made-up of nickel.
Table: 1 Materials Properties used in extrusion machine parts
Brass
Brass > Constants

Thermal Conductivity	111 W m^-1 C^-1
Density	8600 kg m^-3
Specific Heat	162 J kg^-1 C^-1

Nickel

Nickel > Constants

Thermal Conductivity	90 W m^-1 C^-1
Density	8900 kg m^-3
Specific Heat	444 J kg^-1 C^-1

Molybdenum
Molybdenum > Constants

Thermal Conductivity	130 W m^-1 C^-1
Density	10220 kg m^-3
Specific Heat	251 kg^-1 C^-1

3. FINDINGS

In this paper, it is consider that the thickness of cylindrical cover is 10 to 20mm, and the given temperature to the outer surface to the cylindrical cover is between 450 - 550°C, for viscous behaviour of aluminium AA6063.

It is consider that the two analysis are carried out – transient thermal analysis and steady state thermal analysis for different temperature.

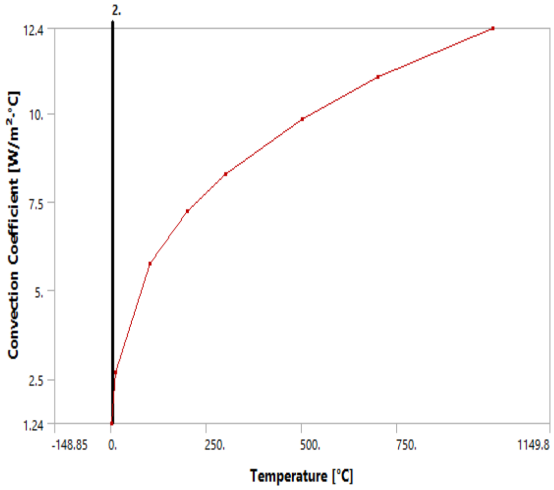

Fig 2 – Graph between Convection Coefficient and Temperature at 450 °C

For comparison of convection coefficient it is shown that it doesn't affected by the high order temperature.

In case of total heat flux and directional heat flux the maximum value of total heat flux is 1.65e^{8} W/m^{2} and it is continuously decreasing to 4.699e^{-5} W/m^{2} (for transient thermal 20mm and 450°C) with respect to time. In case of directional heat flux, the maximum value of it is 4.9075e^{7} w/m^{2}.

The main important in design of extrusion machine is to decrease the thermal error. And in this previous case the thermal error is maximum. For valid design of extrusion the thermal error should be minimum with continuous flow of aluminium. So there is necessity of new simulation. Now consider the transient thermal analysis for 20mm and 550 °C, the maximum total heat flux is 2.0635e^{8} w/m^{2} and it is continuously decreasing.

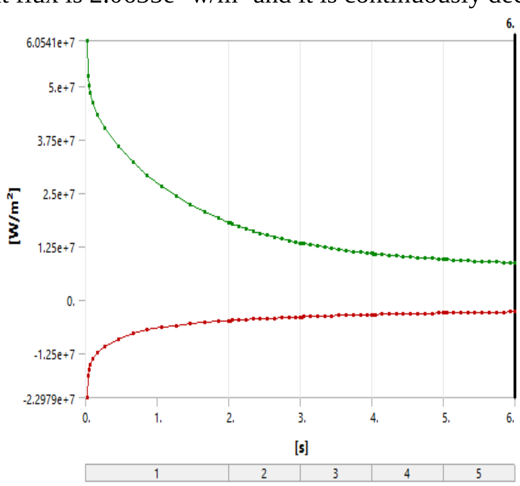

Fig 3 – Directional Heat Flux for transient thermal analysis for 20mm and 550 °C

In this case the thermal error is reducing time to time. It's minimum value is 7.7045e^{-19}. But it is not required for easily flow of aluminium AA6063.

For steady state thermal analysis of different thickness and different temperature the thermal error, heat flux is different with respect to time. For steady state 20mm thickness and 550 °C, the thermal error is $6.0842e^{-14}$, which is easier to flow of aluminium AA6063, with all considerations of heat flux, total heat flux, directional heat flux.

4. RESULTS AND CONCLUSIONS -

With increasing the thickness of cylindrical cover with hooper and maintaining constant temperature of 550 ºC (maximum temperature), it also changing in temperature distribution, total heat flux, directional heat flux and thermal error.

We obtained result for 20mm thickness of cylindrical cover at 550°C (steady state thermal analysis), the thermal error is minimum ($=6.0842*10^{-14}$). It is suitable for easily flow of aluminium alloy.

5. FUTURE SCOPE

- The combination of the basic properties of aluminium and its alloys is possible.
- The infinite variety of shapes possible in the extrusion process gives aluminum extrusion in many advantages over other materials and methods of forming.
- It is lighter weight which can enhance fuel efficiency and performance capabilities, aluminum also offer high rate of recyclability. Almost 90 percentage of automotive aluminum scrap materials are recycled annually and can improve safety by absorbing more crash energy than steel.
- Aluminum does have specific advantage including its capability for safer, higher performance and environmentally friendly automotive technology. but in coming few year aluminum may become the new steel within the automotive industry and other industry also.
- According to the Wall street journal, GM plans to use a mix of different material including carbon fibre, aluminium and steel to meet weight requirements in the future, rather than refitting all the manufacturing plants for just aluminium. Toyota plans to incorporate an aluminium hood into the 2018 Camry.
- It is environmentally friendly automotive aluminium.
- Aluminium is having high strength.
- Aluminium alloy is cost effective.
- Aluminium alloy can be extruded into various shapes.

6. REFERENCES -

[1] 3D finite element analysis of metal flow in hot aluminium extrusion of T-shaped Profile with various offset pockets, S.J.J. Carmai, S. Pitakthapanaphong, S. Sechjarern, Department of Production Engineering, Faculty of Engineering, King Mongkut's and University of Technology North Bangkok, Bangkok, Thailand

[2] G.A. Lee, Y.T. Im, Analysis and die design of flat-die hot extrusion process, International Journal of Mechanical Sciences 44 (2002) 935-946.

[3] Z. Peng, T. Sheppard, Effect of die pockets on die extrusion, Materials Science and Engineering A 407 (2005) 89-97

[4] Finite Element Analysis of gear like form by using lateral and forward extrusion, Tahir ALTINBALIK, Önder AYER, Assoc. Prof. Dr., Trakya University, Faculty of Engineering, Edirne TURKEY, Dr., Trakya University, Faculty of Engineering, Edirne TURKEY

[5] Effect of pocket design on metal flow through single-bearing extrusion dies to produce a thin-walled aluminium profile, Gang Fang, Jie Zhou, Jurek Duszczyk