A REVIEW ON PROCESS PARAMETERS AFFECTING ALUMINIUM EXTRUSION PROCESS

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ABSTRACT

Extrusion is an extremely flexible manufacturing process, as a single press can be used to extrude various materials and a large number of profiles by simply changing the die and the associated tooling with it. Extrusion Process is highly influenced by the process parameters required for determining the quality of process and extrude. The process parameters such as billet pre-heating temperature, container temperature, die temperature, extrusion ratio, ram speed, die pre-heating temperature, number of cavities in the die, etc. control the process, which ultimately affects the productivity and quality of the extrude. This paper deals with an extensive literature review of effect of process parameters on the extrusion of various aluminum alloys. The Paper precisely focuses on direct hot extrusion process.

Keywords: Aluminium Alloys, Direct Extrusion, Extrude, Process Parameters.

1. INTRODUCTION

Extrusion is one of the major metal forming processes used in transforming the size and shape of the materials from a cast structure of an ingot to a useful product. Extrusion is a plastic deformation process in which atomic planes slip over each other breaking the atomic bonds and forming new bonds to get the shape of the profile in the die. Extrusion in mainly divided into direct and indirect extrusion processes. Indirect extrusion provides greater dimensional control throughout the length of extrude, since the friction between the billet and the container wall is absent leading to an almost steady state process (i.e. constant exit temperature, constant material flow, etc.). The quality of extrude produced is very high, but the productivity of the process is to be compromised. However, high productivity rates can be achieved by using direct extrusion process as the long dead cycle time for removing billet shell from the container is eliminated. The quality of extrude is not as high as indirect extrusion, but it can be improved by controlling the process parameters. The major problem encountered in the aluminium extrusion industries is control of process parameters governing the extrusion process to maintain the quality and productivity.

Aluminium is the third most abundant element in the earth's crust, which can be used for numerous applications like automobile, aerospace and other industries. Direct extrusion of aluminium alloys is conducted at relatively higher temperatures to achieve lower flow stress of the material permitting larger cross-section reduction, low power consumption and processing times. Direct extrusion also called as forward extrusion is a process in which a ram compresses a metal billet loaded into the container against the die profile to get the required cross-section of the product. A dummy block is used to isolate the ram from the billet to avoid damage of the ram. The schematic of direct extrusion process is shown in the fig 1. Hot extrusion process of aluminium alloys has differences in temperatures of the billet and the tooling used to reduce the heat transfer causing localized temperature difference resulting in reduction of extrude quality. Process parameters has to controlled to reduce the effect of heat transfer on the quality of extrude. The paper mainly focuses on the literature review of process parameters affecting direct hot extrusion of aluminium alloys.

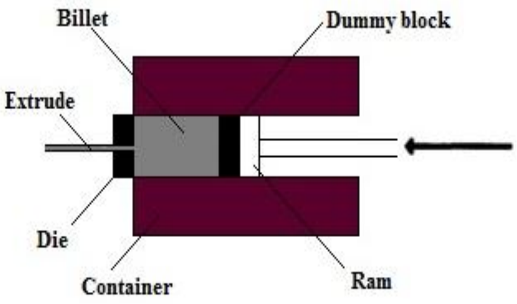

Figure 1: Schematic of Direct Extrusion Process

II LITERATURE REVIEW

2.1 Experimental Results

Zhang et al. opted for Taguchi’s design of experiments and s/n ratio analysis to obtain uniform flow velocity distribution and to minimize the extrusion force in direct extrusion of Al 6063 aluminium alloy by using billet diameter, container temperature, billet preheated temperature, ram speed and die temperature as process parameters. Four levels of each parameter were used for the investigation of process. The minimum velocity distribution was obtained at higher ram speed and tooling temperatures, whereas minimum extrusion force was obtained with lower ram speed and higher tooling temperature. Billet diameter had the maximum effect on velocity distribution followed by ram speed and die temperature, whereas ram speed was the most influencing parameter for extrusion force followed by billet diameter and die temperature. Billet temperature and container temperature had the least effect on the response parameters. The extrusion force was decreased by 24.7% and the velocity distribution was increased by 50% with the optimum parameters achieved [1].

Jawwad and Bashir investigated effect of initial billet temperature, ram speed, extrusion ratio, profile average thickness and number of die cavities on the profile exit temperature using statistical design of experiments for Al 6063 aluminium alloy. A five actor and two levels design for each factor is considered for the experimentation purpose. Extrusion ratio has the strongest effect on the profile exit temperature followed by ram speed, initial billet temperature, profile average thickness and then the number of cavities. Extruding a thinner profile will lead to less homogeneous metal flow and increase in frictional forces between the forming sections and die land, and also between the billet and the container. Increase in die cavity leads to increase in the profile exit temperature. Increase in billet temperature leads to increase in profile exit temperature only at high ram speeds, whereas lower billet temperatures with low ram speeds will result in slightly high exit temperatures as compared to high ram speeds [2].

Saniee et al. used Taguchi method to investigate the effects of three die profiles and three extrusion ratios on the extrusion force. L9 orthogonal array was selected for analyzing the experimental results. Taking the maximum extrusion force as the main response on the experiments, ‘‘the smaller is better’’ was chosen as the criterion for calculation of signal to noise ratio for various test conditions. Performing this procedure in MiniTAB software, the contributions of the extrusion ratio and die profile in maximum extrusion load were found to be 68.6% and 26.3% respectively. The remaining percentage was related to the interaction of these process variables. It was expected to find a great influence of extrusion ratio on the required load. However, Taguchi analysis showed that the effect of the die profile was greater than one third of the contribution of the extrusion ratio in maximum extrusion force [3].

2.2 Artificial Intelligence

Lucignano et al. used artificial neural network technique to predict the optimum temperature profile of billet for Al6060 aluminium alloy at the exit of the induction heater and die exit. Billet stay time, temperature recorded by four thermocouples in the induction heater and the observation frequency were used as the process parameters for predicting induction heater exit temperature while extrusion ratio, induction heater exit temperature and observation time were used for predicting die exit temperature. The billet temperature at induction heater exit increased with the increase in billet stay time at constant induction temperature and the die exit temperature increased by increasing the extrusion ratio. The predicted billet temperature profiles at the induction and die exit closely resembles with the experimental results [4].

Bingol proposed a step wise, a linear and a curvilinear decreasing speed models for maximum constant ram speed to reduce the extrusion time of Al 6060 aluminium alloy. The models were developed with reference to critical extrusion temperature as 540^{o}C. For a constant billet pre-heating temperature the extrusion temperature increases as the ram speed is increased. The extrusion time decreased with the application of proposed models for maximum constant ram speed [5].

Hajeeh developed two optimization models based on cutting patterns of billet for minimizing scrap the in an aluminium extrusion industry. All possible patterns were investigated and the weight of the scrap generated is calculated. The first optimization model was developed based on different billets cut from a single log, whereas the second optimization model was an improved model which considered the billets cut from different logs. While comparing the total amount of scrap generated for the different dies, is was found that the total scrap produced using the convention procedure is around 2035 cm whereas it is around 1145 cm using the suggested optimization model [6].

2.3 Simulation of Extrusion Process

Arif et al. conducted experiments to understand the inter-relationship between the ram speed, ram pressure, and tool complexity for direct extrusion of Al 6063 aluminium alloy. It was observed that the set of data only becomes reliable after 4-5 billets have gone through the press to stabilize the control panel settings. Increase in exit temperature is observed to improve the metal flow and decreasing temperature. The complexity of the profile was distinguished as hollow, semi-hollow and solid profiles. Pressure increased with the increase in complexity of the profile at constant ram speed. Higher pressure curves were obtained at higher ram speeds for fixed shape complexity [7].

Reggiani et al. used eight competitive objective functions for the multi-objective optimization of a porthole extrusion die used to manufacture a thick AA7003 round tube. Seven input variables (welding chamber height, port width, bridge height, undercut on ports, die entry angle, mandrel-bridges fillet radius, ram velocity) and output parameters (welding chamber pressure and temperature, weld quality index, relative exit speed difference peak principle stress in the die, peak mandrel deflection, peak process load, production rate) were selected for the optimization procedure. The multi-objective optimization was performed by means of modeFRONTIER using meta-models generated over a selected set of experimental and numerical training [8].

Flitta and Sheppard focused on simulation of the extrusion process and in particular the effect of the initial billet temperature on friction and its consequences on material flow. All the simulations are performed with the implicit finite element codes FORGE2 and FORGE3. A comparison with experiments is made to assess the relative importance of some extrusion parameters in the extrusion process and to ensure that the numerical discretization provided a true simulation of the process. A specific functional relationship to directly measure interfacial friction under conditions approaching those encountered in the quasi-static deformation process was described. The results revealed that the friction factor increases with increase in initial billet temperature and varies from 0.65 at 300°C to a 0.91 at 450°C after reaching the peak pressure. The dead metal zone is observed to vary in form and has a greater volume at high temperatures. The increase in friction results in an increase of initial extrusion load. The finite element program appears to predict all the major characteristics of the flow observed macroscopically [9].

Paulisch et al. focused on the optimization of the strength and ductility of the almost copper free aluminium alloy 7108 and copper containing aluminium alloy 7175. The work was carried out in three steps. First, the extrusion ratio, product speeds and billet temperatures have been varied to examine the influence in the extrudability of the alloys, which was followed by water quenching and then by peak aging to analyze the influence of extrusion parameters on the precipitation behavior and mechanical properties [10].

Arif and Sheikh studied the effect of process parameters on the metal flow and dead metal zone in extrusion of aluminium alloy Al 6063. Extrusion was carried out at four different speeds. Commercial finite element packages ANSYS and ANSYS-LSDYNA had been used for numerical investigation of the effect of variations in important extrusion parameters. It was concluded that, at higher ram speeds a narrow dead metal zone was observed, when the extrusion ratio increases the dead metal zone and extrusion pressure increases [11].

III CONCLUSIONS

The extensive literature review makes it clear that, extrusion is a flexible manufacturing process which depends on the change in process parameters. Therefore, conducting the experiments by altering the level of input parameters, it is possible to get the optimum parameters which has the least effect of external sources on the extrusion products. The literature review states the effect of various process parameters affecting the direct hot extrusion of aluminium alloys.

- Al6063 aluminium alloy is found to be extruded in most of the extrusion industries due to its wide spread applications in numerous fields.
- Ram speed is considered to be the most influencing process parameter for the response parameters like extrusion force, profile exit temperature, flow velocity, etc.
- Change in billet temperature and metal flow due to friction and shearing of metal are found to be the most influencing uncontrollable parameters on the extrusion process.

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