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A Literature Survey Die Angle on Stress Distribution During Aluminum Rod Extrusion Process: A Review

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Abstract—The mechanical behavior of materials is profoundly influenced by the processing techniques they undergo. This study investigates the impact of various processing methods on stress distribution within aluminum rods. The focus is placed on understanding how different angles of processing, in relation to the grain structure, affect stress distribution In this review paper discuss the extrusion Process in which the cross-sectional area of a block of metal is reduced by forcing it to flow through a die with a certain shape under high pressure and also discuss the Finite Element Method a thermo-mechanical analysis of axisymmetric extrusion process is carried out through FEM based software ABAQUS(Standard). Finite Element model of ax symmetric extrusion process having die and billet. In last session discuss the modeling of process Modeling the parts can be done by different ways. The modelled parts can be imported from CATIA software. In this study, die, billet container modeled as 3D, and in all cases the billet is modeled as deformable part.

Keywords— Finite Element Analysis (FEA), finite element (FE), Die Angle, Stress Distribution, Aluminum Rod etc.

I. INTRODUCTION

The extrusion process in which the cross-sectional area of a block of metal is reduced by forcing it to flow through a die with a certain shape under high pressure [1]. There are many factors that affect the extrusion process such as die profile, frictional condition at the tool–work piece interface, mechanical properties of the material and extrusion ratio. The ratio applies for both direct and indirect extrusion. The extrusion in comparison with other manufacturing methods use in industrial application has many advantages such as: minimum material waste, high dimensional accuracy, reduction or complete elimination of machining, good surface finish, better mechanical properties of products than those of the original material due to favourable grain flow[14].

The importance of analysis for the extrusion process lies in the determination of forming load, flow characteristics, temperature and state of stress and strain. Typical flow patterns observed in extrusion are shown in Fig.1.1 Flow pattern S is found in the absence of friction at the container and die interfaces, during extrusion of homogeneous materials[15]. Flow pattern A is obtained in extrusion of homogeneous materials in the presence of friction at the die interface only. In the corner of the leading edge of the billet, a separate metal zone (known as the dead metal zone)is formed between the die face and the container wall. Flow pattern B is obtained in homogeneous materials when there is friction at both die and container interfaces, resulting in an extended dead metal zone. Flow pattern C is observed with billets having in homogeneous material properties or with non-uniform temperature distribution in the billet; a more extended dead metal zone is formed and the material undergoes a more severe shear deformation at the container wall [1].

Cold extrusion experiments on some solid profiles and simulations using the finite element method (FEM) have been used to investigate the effect of profile complexity on dead metal zone and metal flow. Studies show that for die cone semi-angles under 45°, the dead metal zone does not form.

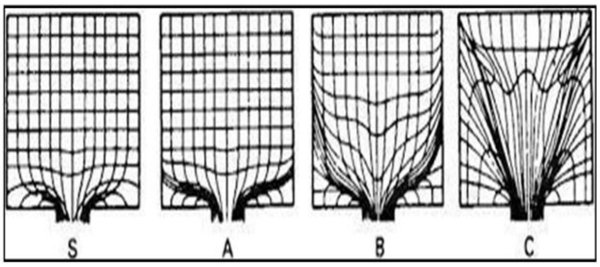

Fig.1. Different types of metal flow in metal extrusion [1]

It has been established by various studies that the size and shape of the dead metal zone, and the pattern and homogeneity of flow lines in extrusion are directly related to the die cone angle, to friction at the billet container interface, and to a lesser extent at the billet-die interface friction. In this study a Finite Element Model has been developed to simulate the extrusion process over a variety of die angle. The effects of die angle had a significant role on extrusion analysis [1].

A. Aluminum Rod

The aluminum rod can be produced using the extrusion process, a technique used to create objects with specific cross-sectional profiles by pushing heated aluminum alloy material through a die [1][3]. This process is commonly used in the production of long components with complex cross-sections [2][4][6]. Aluminum extrusions offer various advantages such as lightweight, strength, corrosion resistance, sustainability, and excellent conductivity [5]. The extrusion process involves forcing aluminum through a shaped opening in a die, allowing for the creation of rods with specific dimensions and profiles [6].

Fig. 2 Aluminum Rod

II. LITERATURE REVIEW

Rafid Jabbar Mohammed et al [1] have investigated on Type of metal flow and stress distribution in metal extrusion process is a highly complex for the complicated die design. In this work a finite element simulation of Al-1100 rod extrusion was successfully achieved using the commercial finite element code Deform-3D.The results show that the finite element model was successfully simulate the stress distribution in the direct rod extrusion of Al-1100.Besides that the optimum die angle reduces the magnitude of normal, shear, and effective stresses. We can conclude from this study that maximum stresses occour when the rod is with contact with the die at exit stage. From the present paper he can conclude the following notices:

The finite element model was successfully simulated the stress distribution in the direct rod extrusion of Al-1100. Also this study demonstrated that optimum die angle reduce the magnitude of normal, shear, and effective stresses. This paper showed that maximum stresses occur when the rod is with contact with the die at exit stage.

Dr. Hazim Ismael Radhi et al [2] have investigated extrusion, among other types, is one of the most important forming processes due to its high productivity, lower cost and its good ability to improve the physical and mechanical properties of extruded materials. FE simulation was carried out on ABAQUS software ver.6.9 The results of present study are accentuated that, there is a complicated relationship between stress and temperature distribution relative to die angle and friction coefficient. It was found, in the range of tested cases, at friction coefficient of more than (0.08), for (45o) die angle, the maximum value of temperature is twice higher than that of (75o), hence the die angle has more significant effect on state of stress and temperature than that of friction coefficient. Nevertheless, a high die angle (α = 75o) emerged low value of maximum temperature due to easily flow of material toward the die orifice. Furthermore, there are a gradual increasing of von Mises criterion and temperature with increasing the friction coefficient while they are decreasing with increasing the die angle.

The influence of stress and temperature distribution by die angle and friction coefficient has been investigated using finite element analysis. The die angle has a significant effect on temperature distribution of billet (i.e. high die angle will decrease the temperature distribution and vice versa). Furthermore, the finite element simulation of process was illustrated that, the maximum values of von Mises stress and temperature are attain at die angle of (45o) and friction coefficient of (0.1).

M. Noorani-Ajad et al [3] have investigated In this paper, the effect of die profile on the variation of stress and load in the cold forward extrusion of aluminum has been studied. The aim of this research is the reduction in deformation load, improvement in the metallurgical properties of the product and increasing in the die life by means of an optimum die profile. In this respect, the stress and load relations in forward rod extrusion for curved profiles have been obtained by using the slab method. In addition, by using a developed computer program, the optimum die profile has been obtained considering work hardening of the material in cold extrusion, on the basis of minimization of stress and load in die–work piece contact surface. The obtained profile depends on the extrusion ratio, material properties of the work piece and coefficient of friction which are the input parameters to the program. By using the finite- element software, ABAQUS, the optimum die angle for the conical die in the same conditions is determined. Furthermore, the finite-element and experimental load–displacement curves have been determined. The obtained results illustrate that the cold extrusion load for aluminum in the optimum curved die is considerably reduced, compared with that in the optimum conical die. In this research, based on the slab method and developed iterative algorithm, the optimal die profile in rod cold forward extrusion of aluminum is established. Also, by using the finite-element software, ABAQUS, the optimum die angle for conical die is determined. The load–displacement curves are obtained experimentally, and also by the FE software. The results illustrate that the required load in the optimum curved die is significantly less than that in the optimum conical die.

Yogesh Dewang and Vipin Sharma [4] have investigated on Finite element analysis has been carried out to investigate the effect of various parameters on ax symmetric hot extrusion process using aluminum alloy. The objective of the present work is to investigate the effect of friction coefficient, die angle, die-profile radius and predefined temperature of work piece through FEM simulation of extrusion process. Nodal temperature distribution, heat flux, peak temperature at nodes and peak flux induced are identified as the output variables to assess the thermo-mechanical deformation behavior of aluminum alloy. Mesh sensitivity analysis is performed for the evaluation of mesh convergence as well as depicts the accuracy of present FEM model. The higher the coefficient of friction between interacting surfaces of die- billet assembly, the higher will be the increment in nodal temperature in billet. The higher the coefficient of friction, the higher will be the generation of heat flux within billet, as this is achieved for highest coefficient of friction. Peak nodal temperature diminishes with increase in die profile radius nearly by 17 %..
Finite element analysis of extrusion process has been carried out to study the thermo-mechanical behavior of aluminium alloy. The validation of present numerical model is established on the basis of deformation behavior in terms of evolution of nodal temperature distribution upon comparison with previous studies available in literature. Major findings of the research work can be summarized under the following sections:

- Influence of friction coefficient - The higher the friction coefficient the higher is the increment in nodal temperature in billet. - It is found that the higher is the friction coefficient, the higher will be the generation of heat flux within billet, as this achieved for highest friction coefficient. - Maximum nodal temperature and maximum heat flux rises with increase in friction coefficient nearly by129 % and 131 % respectively.
- Influence of Die-angle - It is found that maximum nodal temperature developed diminishes upon increase in die angle in range of $\alpha = 45^\circ$, 50° and 55° and again increases with increase in die-angle from $\alpha = 55^\circ$
- to $\alpha = 60^\circ$. - It is found that maximum heat flux diminishes first upon increase in die- angle owing to easier material flow along profile radius of die as well as dependent on maximum nodal temperature, which actually decreases too.
- Influence of Die profile radius: - It is found that maximum nodal temperature diminishes with increase in die profile radius nearly by 17 %. - It is found that maximum heat flux diminishes non-linearly by 30% with increase in die profile radius.
- Influence of Predefined temperature of billet: - It is gathered that maximum nodal temperature increases nearly linearly by 14 % with increment in predefined temperature of billet. - It is gathered that maximum heat flux decreases non-linearly by 5 % with increment in the initial temperature of work piece.

Atul Kumar et al [5] have investigated Recently, extrusion processes have been used to make a wide range of metal products, including bars and tubes and strips and solid and hollow profiles, that are usually long, straight, semi- finished metal products. In order to govern the extrusion parameters, it is also critical to understand the history of the process reactions. Prior to the experimentation, a finite element analysis of extrusion was used to predict the performance. Friction between the die and the blank can have a significant impact on numerous process parameters during extrusion. It is preferable to run the lathe at a modest pace to avoid overheating the blank owing to friction and distortion. It causes the blank to heat up too quickly. Inefficient use of memory resources results in higher operating costs and a longer time to complete tasks. A review has been done on optimization of process parameters in extrusion of aluminium alloy.
dependent on the change in process parameters, according to an exhaustive literature assessment. As a result, it is feasible to determine the best parameters for extrusion products by performing trials with different levels of input parameters.FEA of the extruded product and die has been carried out using various software, i.e. Hyper extrude, deform 3d, ploysim, etc., to obtain uniform velocity distribution, optimize exit velocity distribution, optimise process condition, predict temperature distribution, and study the effect of process parameter."
According to the research, several process factors impacting aluminium alloys' direct hot extrusion.

- Many extrusion companies use Al2024 aluminium alloy because of its wide range of uses in many different sectors.
- Extrusion force, profile exit temperature, flow velocity, and other response parameters are all influenced by ram speed.

- The most influential uncontrolled aspects on the extrusion process were discovered to be billet temperature and metal flow owing to friction and shearing of metal.

Rahul Ranjan Yadav et al [6] have investigated Extrusion is a manufacturing process used to create objects of a fixed cross-sectional profile. A material is pushed through a die of the desired cross-section. A brief and concise review of the contributions made by the previous researchers in the area of extrusion process has been presented. Steel material and aluminium alloys are mostly used by researchers as die and billet material in extrusion process. FEM modelling of extrusion process is carried out by employing axisymmetric conditions in most cases. Meshing of the work piece is generally done by using axisymmetric quadrilateral elements. Experimental set- up and tools utilized in formation of extrusion process are presented and discussed. FEM results are presented in terms of variation of punch stroke, punch force. In the body of work presented in this paper, extrusion process is studied by considering various aspects of extrusion process. A brief and concise review of the contributions made by the previous researchers in the area of extrusion process is also presented. It is found that researchers have utilized aluminium material for extrusion as workpiece material in majority of cases, however in the recent past, the usage of steel alloy has also been started.

Hani Mizhir Magid et al [8] have investigated in This paper presents the influence of stresses on the nature of the forward extrusion behaviour of aluminium alloy Al-2014, using different die angles, and different die bearing length (4, 6, 10 mm). These stresses became high effect towards the die life. It was observed that the high values were created in the contact area between the die and the extruded material. The results showed that, a small die angles required higher extrusion load with 20% more than that of large die angles. In all used die geometry, the deformation of aluminium billet, which is caused by shearing and compression stresses, occurred in a small sectional area (bearing area). The results also showed that, the values of these stresses can either increase or decrease depending 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. A correlation between the calculated data and FEA was studied in this research by constructing an ax symmetrical 2D geometric (Al) model of the tooling and billet for analysis purpose. The required data, which include: effective stress Strain, material deformation velocity and die-work piece contact pressure were obtained from the finite element (FE) model.

- Extrusion load increase with decreasing of die angle (a), since small die angle causes a dead metal zone.
- Careful design of the extrusion dies profile can therefore control and reduce the stresses, which cause a main defect in product structure, that will support that it can be used to minimize the amount of in-homogeneity imparted in to the product, and therefore control the product quality.
- The temperature of the extruded profile can be controlled as a constant throughout the whole extrusion cycle. The exit temperature is a measure of product quality.
- Die specifications can be improved by controlling the finishing, hardness, tolerances, and material selected.
- The ram speed and temperature should also be controlled, considering their significant impact on plastic properties of the billet material. As a whole, this study demonstrates the main advantage of this type of extrusion. These advantages including the way to improve the mechanical properties of the work piece.

III. METHODOLOGY

In the current research work, a thermo-mechanical analysis of axisymmetric extrusion process is carried out through FEM based software ABAQUS(Standard). Finite Element model of ax symmetric extrusion process having die and billet shown in Fig.1.4. Finite element method (FEM) is one of widely used means for the analysis of many manufacturing process such as aluminium extrusion, as well as other forming processes. Both two and three dimensional aspects of extrusion can be investigated with this valuable tool.

During the extrusion process, the billet gets shorter and the friction surface and container decreases. Therefore, the necessary ram force decreases during the process. The die is also preheated before loading the first billet. A previous study has shown that many factors greatly influence metal flow in forward extrusion, such as the interface behavior between the die and billet, distribution of thermal stresses along the contact area, and finally the die geometry[9]. In addition, the influence of reduction ratio and die half- angle on extrusion was been studies for the hydrostatic extrusion process and can be utilized for the forward conventional extrusion process.

Some mechanical characteristics of the extruded material will be change during the extrusion process, like the strain hardening. Many finite element solution methods were presented by researchers using ABAQUS software.By these solutions, they try to estimate the optimum die design and the relationship between the forward extrusion pressure and the die radius. Other studies try to combined tools of physical modelling technique and Finite Element simulations through studied the material flow behaviour over a conical punch. By using ABAQUS, the optimum die angle for conical die can be determined. In cold extrusion the radii of curvature of this extruded alloys and the average hardness along the product was to be increase with the increasing of the die length[16].

IV. CONCLUSION

In this review paper, a study of the thermal response of The analysis of stress distribution during different processes applied to aluminum rods provides valuable insights into the mechanical behavior and performance of the material. The Die Angle is a crucial factor in shaping and forming processes, influencing the distribution of stress within the aluminum rod.

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