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Modelling Plastic Deformation of A36 Mild Steel Under Extrusion Process

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***Abstract*—Technology of metal forming is used for shaping any metal into useful products by forming processes such as Rolling, Forging, Extrusion, Drawing, and Sheet-metal forming. But the research is specifically devoted on hydrostatic extrusion finite element modeling. Hydrostatic extrusion is an advanced metal forming technology. In hydrostatic extrusion there is a hydraulic medium that interposes between the billet, that is deformed and the extrusion punch.**

Modelling the plastic deformation of A36 steel under hydrostatic extrusion is concerned with describing a computer based technique for aiding the optimization of metal deformation process, product design, reduce lead time, and improve the facility and reliability of the products.

The ultimate goal of this task is to simulate the plastic deformation of A36 steel that deformed by hydroextrusion processes, in order to reduce 'trial and error' experimental task and to predict incoming difficulties such as defects formed on end products and die angle.

In this study, commercial abaqus software is used for modelling. Computational model has been developed to simulate plastic deformation of metal by means of hydroextrusion and optimize the deformation process with considering the process parameters such as pressure, deformation rate, die angle, stress distribution.

Keywords—Modeling; Deformation rate; Homogenous deformation: Metal forming; Hydrostatic extrusion; Die angle.

I. INTRODUCTION

Metal forming is the area of metallurgy which is concerned with conversion of metal casting ingot into more useful shape such as flat plate, rod, bar and sheet metal with important analysis. Forming technology refers to shaping of metallic materials by means of plastic deformation when the term of plastic deformation describes permanent shape change, in contrast to elastic deformation. In order to plastically deform a metal, a force must be applied that will exceed the yield strength of the material.

There are different metal forming techniques are used today but the most widely used is extrusion. Extrusion is the process by which a block/billet of metal is reduced in cross section by forcing it to flow through a die orifice under high pressure. In general, extrusion is used to produce long parts and uniform cross-section components.

Different metals can be extruded under extrusion process but this research emphasis on A36 mild steel. A36 mild steel is a low carbon steel that exhibits good strength coupled with formability. A36 mild steel extruded can be used for a wide range of industrial applications, including truck and trailer frame supports, equipment and machinery frames and supports, building frames and other components.

II. BACKGROUND OF THE PROBLEM CONVENTIONAL EXTRUSION PROCESS

Extrusion process is reducing a block/billet metal by forcing through a die orifice. During metal deformation take place under conventional extrusion process the flow of the metal is not only flow into the die orifice but also fill in the container. The reaction of the extrusion billet with the container results in high stresses which are effective to increase the cracking of materials during primary breakdown from the ingot.

These problems are lead to:-

- Raising the friction between the wall and billet.
- Buckling the billet in container before deformation.
- Surface cracking when the surface of an extrusion splits due to the billet direct contact with container wall and non-uniform load applied on billet.
- Internal cracking when the centers of the extruded part developing cracks or voids due to lack of homogeneity deformation.
- A thin skin will be left in a container finally new metal surface is obtained.
- Wearing and fracture formed on punch due to direct contacting with billet material (A36 mild steel).
- Inhomogeneous deformation (lose isotropy strength)
- Die wearing due to high operating temperatures.

By convectional extrusion working of metals that are difficult to form like steels, nickel- based alloy, and other high temperature materials. There is technique to solve the problem of billet filling the container, non-homogeneity and other problems in conventional extrusion process through replacing ram force type extrusion by hydrostatic extrusion process.

Hydrostatic extrusion is an advanced metal forming technology that used hydraulic medium between the billet, that is deformed and the extrusion punch, as shown in fig.1.

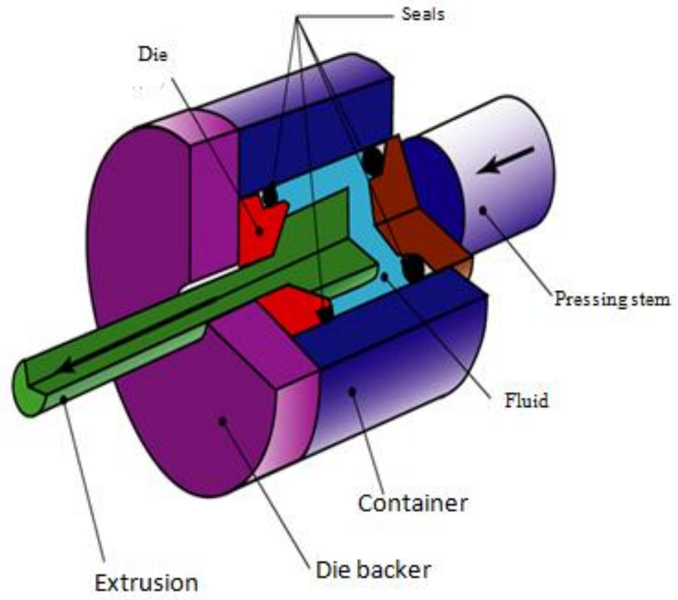

Fig.1. Working principle of hydrostatic extrusion machine.

In hydrostatic extrusion triaxial state compression stress is formed. The triaxial state of the compression stresses that are created during the deformation leads to increasing the homogeneity deformation. Hydrostatic extrusion method is generally severe as a plastic deformation and recognized as a method of grain refinement in metals. Formation of such structures results in a considerable improvement of the mechanical properties of materials. In this way results a hydrostatic pressure (P) of a certain level that is uniformly distributed over the whole surface of the billet that gets into contact with the liquid. In this process there are no container wall friction; no contact between the punch and the billet.

III. OBJECTIVES

The main objective of the research is to model the plasticity deformation of the A36 steel material.

Specific objectives are:-

- Reduction of trial-pressings of extrusion processes in hydrostatic for A36 mild steel
- Modelling the plastic deformation in hydrostatic extrusion with concerning the description of flow nature A36 mild steel.
- Analysis the process parameter that affect the homogeneity deformation under hydrostatic extrusion process.

IV. METHODS EMPLOYED

To meet the objectives of the research, the following methods have been employed.

- For modelling of plastic deformation of A36 mild steel material Abaqus software is used.
- Deformation of A36 mild steel was analyzed based on:-
  - By experimental result of effective stress relation with plastic strain as shown in fig.2.

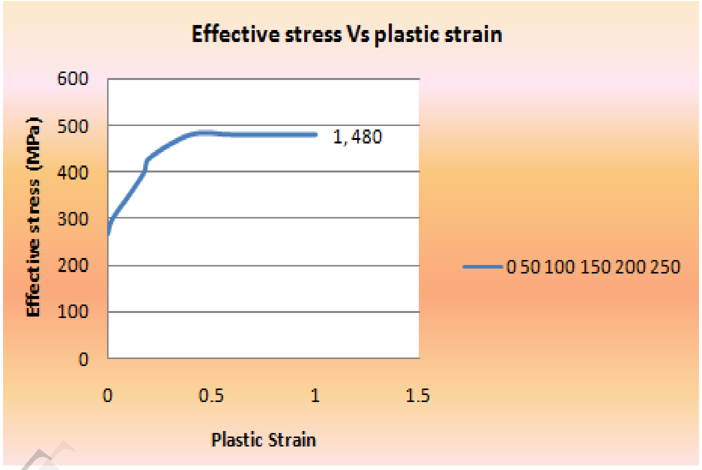

Fig.2. Effective stress Vs effective plastic strain for A36 steel.

  - By considering the following properties of A36 steel material. It is important to know the plastic flow properties of A36 steel for optimizing the process.

TABLE I. A36 STEEL MATERIAL PROPERTIES

Density (Kg/m3)	7800
Modules of elasticity (GPa)	200
Yield stress (MPa)	270
Poisson's ratio	0.3
Plastic strain failure	0.36

  - By applying variation extrusion load.
  - By applying Levly Mises flow rule.
- The metal (A36 mild steel) flow grid pattern has been simulated.

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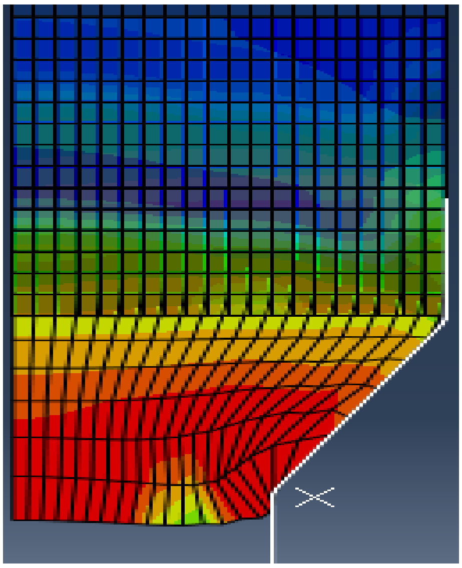

Fig.3. A36 Steel grid pattern during deformation.

- To improve the forming quality and to predict potential defect areas during extrusion 2D and 3D modelling have been developed as shown in fig.4.

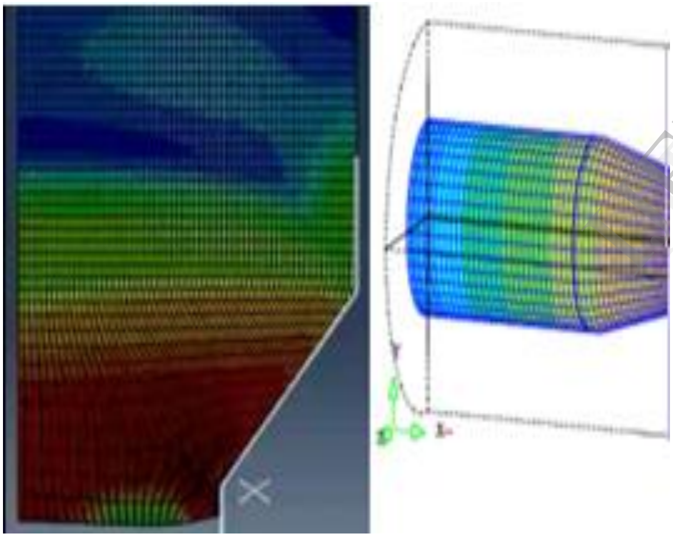

Fig.4. 2D and 3D plasticity modeling of A36 steel material.

V. RESULTS AND DISCUSSION

The purpose of computational modelling was to simulate nature A36 steel deformation (grain dislocation), stress concentration, effect of die angle on plastic stress and effect of pressure on plastic strain.

A. Permanent Deformation (Grain Dislocation)

In metal forming processes, product shapes are produced by plastic deformation. Permanent deformation is a non-reversible changing in the shape due to the deformation energy is transferred through external force. The deformation of A36 steel is homogenous due to absence of buckling and flow restriction by friction. As shown in the fig.5 plane boundary of atom is uniform during deformation but some distortion at inter of die angle.

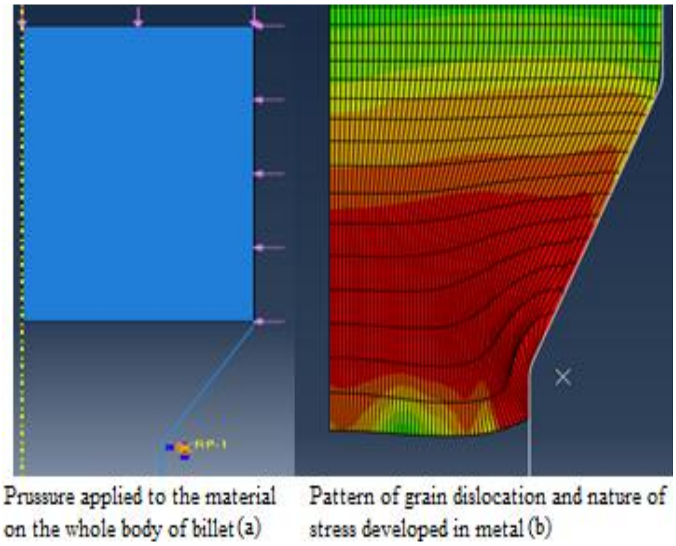

Fig.5. Physical modeling of A36 steel material deformation.

B. Area of Stress Concentration

A main purpose of computational modelling minimizing a labour effort and predict the quality of products. Stress concentration is localized stress that can be considerable over than the average even in the uniformly load applied across the section. This is due to abrupt changes in the geometry. As shown in Fig.6 the area of stress concentration is near to die angle (red coloured portion).

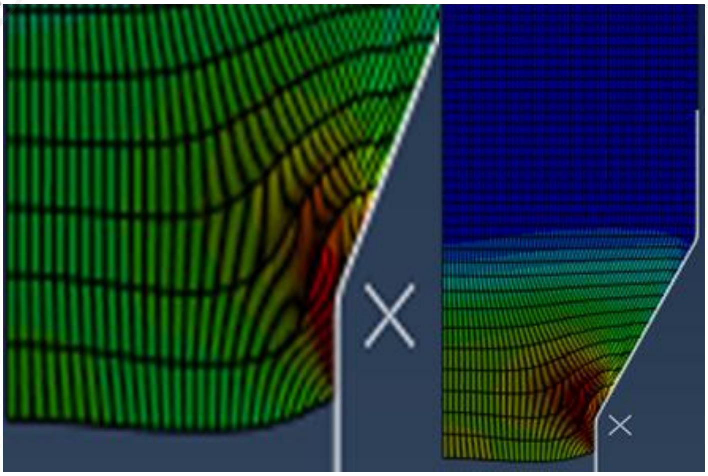

Fig.6. Area of stress concentrations.

C. Effect of Die Angle on Plastic Stress

Figure 7 shows in extrusion geometry consisting of a 3D cylindrical billet of diameter D = 60 millimeter which is extruded through a die exit diameter d= 20 millimeter. Die angles of θ = 10, 15, 20, 25, 30, 40 or 45 degrees were used for the simulations. At 30, 40 and 45 degree stress levels are increased. This indicates that the die angle has great impact on the quality of products under hydrostatic extrusion. So the little die angle is recommended for homogenous deformation and stress free products.

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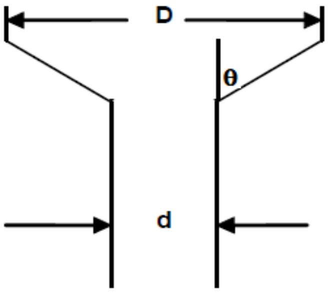

Fig.7. Schematic diagram of hydrostatic extrusion geometry.

D. Effect of Pressure Distribution on Plastic Strain

In hydrostatic extrusion sources of pressure is formed from the fluid that leads to deformation of metal. The effect of pressure on plastic strain and internal billet deformation is analyzed by using two cases with constant load 900MPa and varying load direction. Figure 8 shows different plastic strain during the pressure applied over the whole of the billet and pressure applied only from back side. The pressure applied from back side only when the diameter of the billet almost near to the diameter of the wall. In this case coefficient of friction is zero because the oil in hydrostatic extrusion services as the lubrication on the wall.

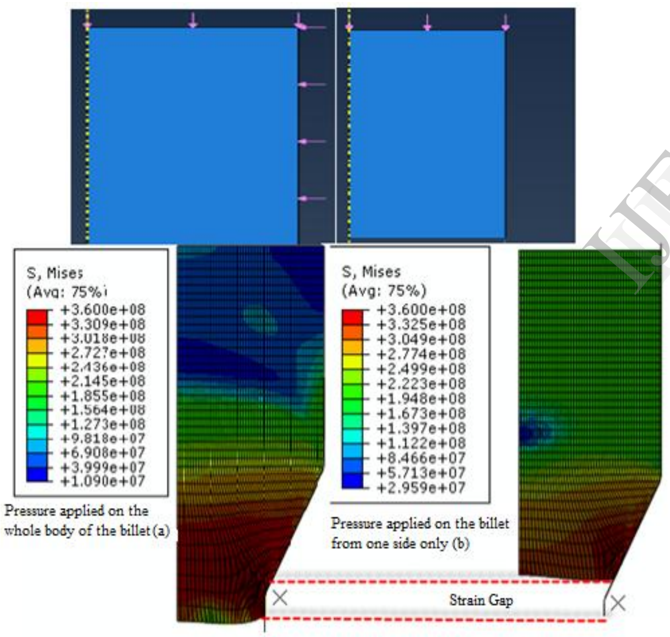

Fig.8. Schematically representation of strain difference due to load direction.

E. Deformation Rate

1) Stress Rate

As shown in the Fig.9 stress rate is analyzed. The result indicate that as rate of deformation increase, stress development in metarial also increase with constant load. Stress increase as the time increase in the extrusion process but once the stress increment arrive at certain point, there is longer stress development in the A36 steel material. If there is no further reduction of dimension in the process, metal start to recovers from the stress.

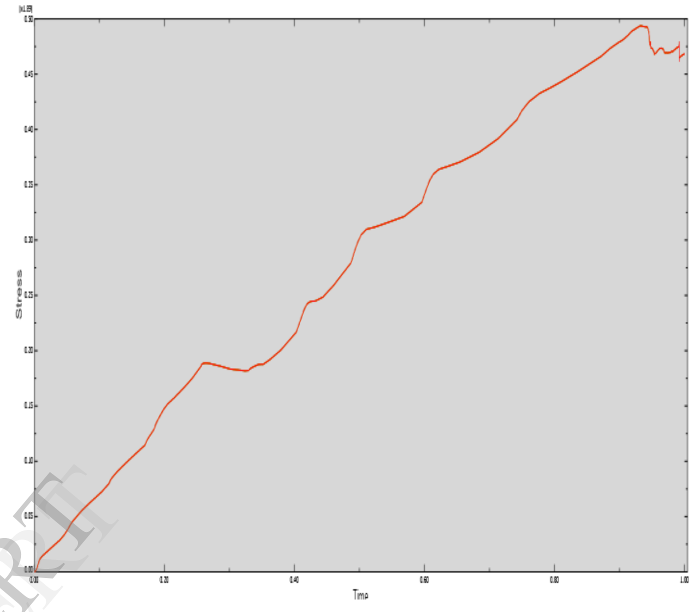

Fig.9. Schematically representation of stress Vs time.

2) Strain Rate

Strain rate is directly related to the stress and time. A greater rate of deformation of the A36 steel will mean a higher strain rate. As shown in fig.10 even stress developed at certain level corresponding to certain time but a metal no undergoing to strain deformation.

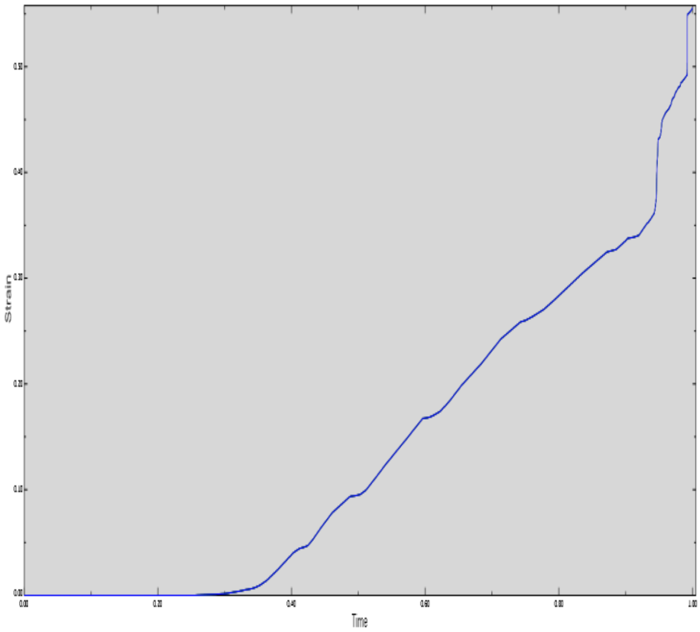

Fig.10. Schematically representation of strain Vs time.

VI. CONCLUSION

A successful computational modelling of A36 steel material under hydrostatic was carried out with purpose analyzing plasticity deformation and effect of die angle on the extrusion. Deformation load was determined by incorporation of yield stress and other property of A36 steel material. Die angle is significant roll play on the homogeneity deformation under extrusion process. Extruded part of A36 steel material start to recover from the stress (stress free condition) from central portion at the end of die orifice. This is indicate the material of end product can possess uniform mechanical properties.

In general, modelling of plastic deformation has a potential to predict metal flow and grain dislocation in extrusion process. Among different extrusion technology hydrostatic extrusion is the automated for production of:-

- Large length/deformation ratio.
- Homogeneity deformation.

A36 mild steel is common engineering material, it is deform under hydrostatic extrusion effectively.

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