"OPTIMIZATION OF DIE EXTRUTION PARAMETER-FEM"

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ABSTRACT: -

The process of extrusion plays a vital role in the production process of different parts in various environments. the extrusion temperature and load has significant on quality and cost of the extruded parts respectively. Hence, development of economical process conditions is found as vital. Forward extrusion model is developed to analyze the process responses temperature, extrusion load, extrusion ratio and blank velocity for different process designs. there is lot of variations in the production of parts during extrusion with conventional processes to the latest automation in the manufacturing. There is a need to develop different die designs by varying input processes variables for the extrusion process in an optimum manner. The purpose of the present paper is to determine the optimization of extrusion process variables at minimum extrusion force. The present work deals with the FEM approache, in order to determine optimal values of logarithmic strain, die angle and friction coefficient with a purpose to find minimum Extrusion force and the obtained results are compared with those in existing literature.The obtained results lead to the lower energy consumption, better tool life, better formability of the work material, and the better quality of the finished extruded part. With the optimal values obtained in the technique, a three dimensional model is developed and analysis is carried out on ANSYS platform. Based on the ANSYS results optimal values or the extrusion process variables are determined.

Keywords:-Extrusion, finite element analysis, temperature distribution, extrusion load, frictional coefficient,

optimization,

1. INTRODUCTION

Extrusion can be defined as the process of subjecting a material to compression so that it is forced to flow through a confined space past a suitable opening called the die. The metal is forced through the die and the cross-section of the die determines the shape properties of the resulting product. Extrusion may be done either on cold metal or on heated metal. One of the analogies that can be offered to the process of extrusion is that of squeezing a tube of toothpaste.

The finite element analysis method represents an extension of matrix method for the analysis of framed structures to the analysis of the continuum structure. The basic philosophy of this method is to replace the structure i.e. the continuum having an infinite or unlimited number of unknowns by a mathematical model, which has a limited or finite number of unknowns at certain chosen discrete points. This method is extremely powerful as it helps to accurately analyze structures with complex geometrical properties and loading condition. In finite element method, a structure or a continuum is discredited and idealized by using a mathematical model, which is an assembly or subdivision or discrete elements. These elements known as finite elements are assumed to be interconnected only at the joints called nodes. Simple functions such as polynomials are chosen in terms of unknown displacements and or their derivative at the nodes to the approximate over the variation of the actual displacements over each finite element. The external loading is also transformed into equivalent forces applied at the nodes. The behavior of each element and later as an assembly of these elements is obtained by relating their response to that of the nodes in such way that the following basic conditions are satisfied at each node.

- The equation of equilibrium.
- The compatibility of displacements.
- The material constitutive relationship.

2. LITERATURE REVIEW

In this chapter we search few selected research paper related to Extrusion process using Finite Element Analysis Method.

[1] Halvorsen and Aukrust studied the buckling or waving of extruded flat sections using Lagrangian FEM software, MSC Super Form. They performed some extrusion experiments to verify both the simulations and the mechanisms observed in the FEM simulations

[2] Kumar, S. And Prasad, S.K. Performed finite element simulation of hot extrusion for copper-clad aluminum rod to expect the distributions of temperature, powerful pressure, and powerful pressure charge and imply stress for various sheath thickness, die go out diameter and die temperature and validated with experiments. It is found that consequences of the FEM simulation using DEFORM software agreed properly with the experimental results. Have proposed combined higher certain/slab technique to compare 8 extraordinary die shapes, particularly, flow-covered (1/3 and fourth- order polynomial, cosine and modified elliptical, hyperbolic, conical and additionally offered the mixed top sure method/FEM to examine four special die shapes, specifically, stream-covered, cosine, hyperbolic and conical.

[3]Bouzakis et al. simulated the flow of wet ground clay ram extrusion device and by a FEM based model, considering the von Mises criterion for the flow stress, the associative flow rule and the rigid–viscoplastic constitutive equation. The friction between clay and die is approached by the Tresca boundary condition, which proves a more realistic approach than the Coulomb friction law for the contact conditions between a plastically deforming material and a rigid surface. It is found that no sticking areas appear on the mandrel surface.

[4] Lee et al. studied the effect of bearing lengths for the control of material flow in the die in hot extrusion. They used the three-dimensional non-steady analysis using the thermo-rigid– viscoplastic element method that includes an automatic remeshing module. It was found that the design equation determined bearing lengths that resulted in a fairly uniform exit velocity distribution throughout the extruded section. From the results of this study, it was found that the proposed design equation can be effectively used to estimate appropriate bearing lengths.

[5] Lof and Blokhuis presented a method for the simulation of the extrusion of complex profiles, which can be used in an industrial environment. They modeled bearing area with an equivalent bearing model to describe the resistance in the bearing without using a large number of elements. The developed a specialized pre-processor to avoid the time-consuming and complex work necessary for the development of the FEM model for a particular die.

[6]Chanda et al. investigated the effect of process parameter namely iso-speed and step wise ram speed on extrusion pressure the thermal response of the work piece and stress state of round bar using computer simulation. They found that step wise ram speed decrease enables the temperature to reach steady state which corresponds to nearly constant exit temperature.

[7]Duana et al. explored the complicated interactions between die design, forming parameters (i.e. ram speed, container temperature, billet temperature and extrusion ratio) and the product qualities (extrudate shape, surface condition and microstructure) by the use of finite element modelling (FEM). The various models (such as recrystallisation, damage criteria, etc.) have been integrated into the commercial codes, FORGE2 and FORGE3, through user routines. They found that the use of an expansion chamber can significantly reduce the degree of non-uniformity in terms of the extruded product shape and properties. The character of the complex material flow is also identifiable, which is very useful to help improve die design.

[8]Gang et al. performed a 3D computer simulations to determine the effects of the ram speed and the billet temperature on the extrusion temperature and the peak extrusion pressure The ram speed and the billet temperature are the primary process variables that determine the quality of the extruded magnesium profile and the productivity of the extrusion operation. The optimization of the extrusion process concerns the interplay between these two variables in relation to the extrudate temperature and the peak extrusion pressure. The 3D computer simulations were performed to determine the effects of the ram speed and the billet temperature on the extrudate temperature and the peak extrusion pressure, thereby providing guidelines for the process optimization and minimizing the number of trial extrusion runs needed for the process optimization. A case study on the extrusion of an AZ31 X-shaped profile was conducted. The correlations between the process variables and the response from the deformed material, extrudate temperature and peak extrusion pressure were established from the 3D FEM simulations and verified by the experiment. The research opens up a way to rational selection of the process variables for ensured quality and maximum productivity of the magnesium extrusion

[9]Li et al.presented a results from a series of pocket designs that were modelled using finite element method (FEM) to systematically investigate the influence of the pocket design parameters on the metal flow In extrusion die design, it has become increasingly common to use „„pocket"" technology to balance the metal flow. They studied the effects of pocket angle and size on metal flow and it is shown that pocket angle plays an important role influencing metal flow velocity, whilst pocket volume has much less effect on velocity.

3. METHODLOGY

Finite element analysis modeling is done using DEFORM-3D Version 6.1(sp1). DEFORM-3D is a Finite Element Method (FEM) based process simulation system designed to analyze various forming and heat treatment processes. By simulating manufacturing processes on a computer, this advanced tool allows designers and engineers to:

1. Reduce the need for costly shop floor trials and redesign of tooling and processes

2. Improve tool and die design to reduce production and material costs

3. Shorten lead time in bringing a new product to market

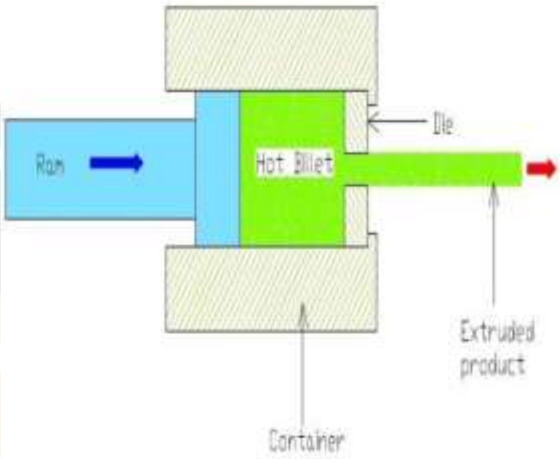

Fig:3.1 Extrusion process and operation Fig.3.2 Extrusion die

Unlike general purpose FEM codes, DEFORM is tailored for deformation modelling. A user friendly graphical user interface provides easy data preparation and analysis so engineers can focus on forming, not on learning a cumbersome computer system.

The DEFORM-3D consists of three major components:

- Pre-processor :- Used for creating assembly or modifying the data required to analyze the simulation, generating mesh and for generating the required database file.
- Simulation engine :- Used for performing the numerical calculations required to analyze the process, and writing the results to the database file. The simulation engine reads the database file, performs the actual solution calculation, and appends the appropriate solution data to the database file.
- Post-processor :- Used for reading the database file from the simulation engine and displaying the results graphically and for extracting numerical data.

Simulation procedure:-

FEM simulation is carried out using DEFORM-3D Version 6.1(sp1). As discussed above DEFORM-3D consist of three main components. We stared with pre-processor in which we define the object of 30mm diameter and 50mm length. We generate the mesh of 10, 0000 element. We define other part of setup like Punch and container. The geometry of the extrusion die is imported in the form of STL file generated in AutoCAD. A material data is created using pure lead properties. After setting the whole setup a database (.DB) is generated. The simulation engine reads the database file generated in pre-processor and performs the actual solution calculations, and writes the result in database file. In post-processor, we read all the results, draw graphs, take picture of the workpiece at different steps and at different properties like stain, strain rate, velocity, displacement etc.

4 DIE PROFILE DESIGN

In this chapter we derive an extrusion die profile foe square section from round billet using cosine function. First of all a mathematical equation of the die profile is derived. Then using MATLAB 7.0.1 we calculate the co-ordinate of the die profile. The generated co-ordinates were used in AutoCAD 2008 to generate solid model of the die profile.

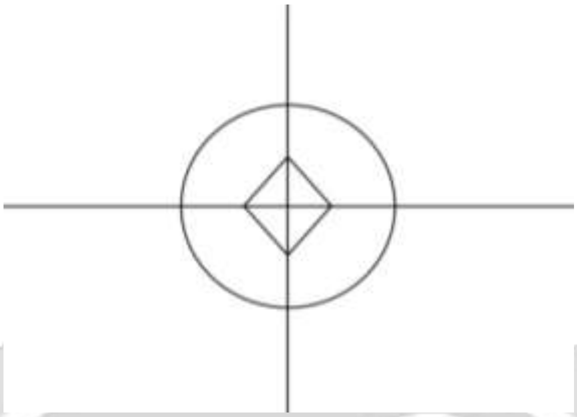

Fig: Cross-sectional view of the die profile

4.1 Solid Modelling

MATLAB 7.1 was used to generate the no fo points using above generated die profile equation. The generated points were used to create solid model using AutoCAD 2008. Solid model generated from AutoCAD 2008 were shown in the followin figures.

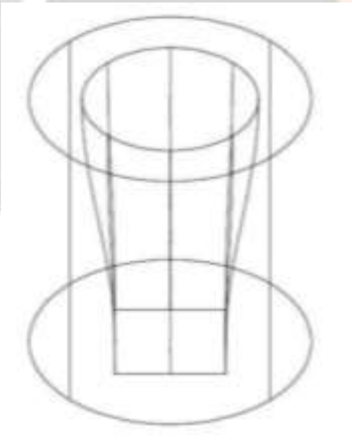

Fig. wire-frame model

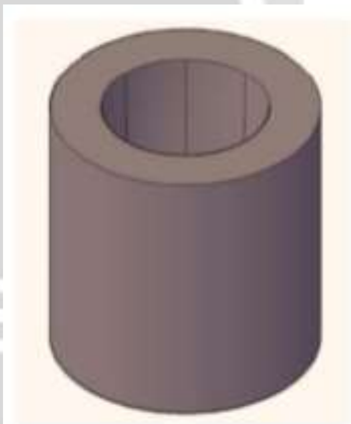

fig. Solid model

Fig. wire-frame longitudinal view

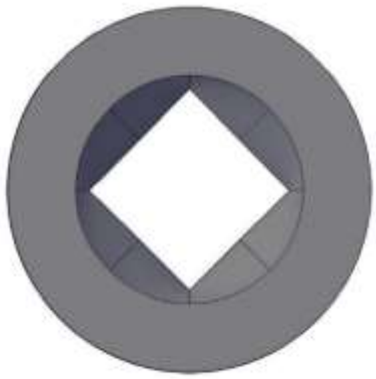

Fig.Top view

Fig.Bottom view

Fig.STL file

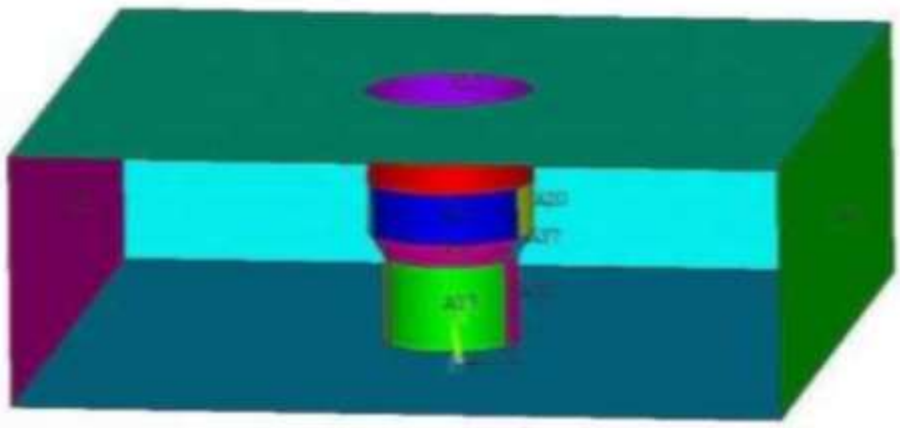

Fig. Model Of Die Extrusion

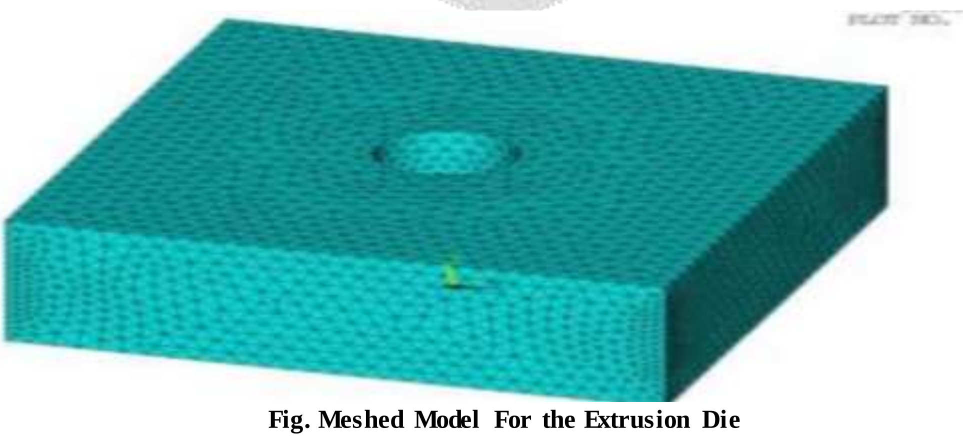

Fig. Meshed Model For the Extrusion Die

5 CALCULATION AND OBSERVATION

Let,
R= radius of the billet.

(√2)A = length of the side of the square.

N= max. no. of steps in steps in the transverse direction for particular value of Z.
P=any step between 0 and N in the transverse direction for particular value of Z.
L=length of the die
X, Y & Z are the co–ordinate axes in three mutually perpendicular directions

Let us consider the cross-sectional view of the extrusion de which extrudes the round billet to square, Taking section of die in first quadrant, we find that circular cross section changing to linear according to cosine function in longitudinal directional n no. of steps.

At the entrance the die profile is circular with equation

x2+y2=R2 ----------------(1)

Where, R= radius of the circular billet at entrance of the die.
And x&y are the co-ordinate axes.

Because, cross-section of the die is changing continuously from round to square according to the cosine function, so any cross-section between the entrance and exit will be different from circular and linear.

So, at the exit of the die, profile will be linear with equation

x+y = A -------------------- (2)
Where A= intersection of edge of the die exit on x & y axes.

And x&y are the co- ordinate axes.

Now, after (p) steps (p<N) co-ordinate of any point on circular cross-section will be

T(x,y) =[R*√(1-P/N), R*P/N]

Similarly,
after (p) steps (p<N) co-ordinate of any point on linear cross-section will be

T(x,y) =[A*(1-P/N), A*P/N]

So, general equation of any point on the cross-section using cosine function will be

$$x = \left[\frac{R*\sqrt{\left(1-\frac{P}{N}\right)} + A\left(1-\frac{P}{N}\right)}{2}\right] + \left[\frac{R*\sqrt{\left(1-\frac{P}{N}\right)} - A\left(1-\frac{P}{N}\right)}{2}\right]\cos\left(\frac{\pi z}{L}\right) \quad -(3)$$

And,

$$y = \left[\frac{R * \sqrt{(P/N)} + A\left(\frac{P}{N}\right)}{2}\right] + \left[\frac{R * \sqrt{(\frac{P}{N})} - A\left(\frac{P}{N}\right)}{2}\right]\cos\left(\frac{\pi z}{L}\right) \quad ---(4)$$

Where P = 0, 1, 2, 3, 4… N

Hence, According to the equation (3) & (4), for every value of Z (0<Z<L) we will get N no. of value of X&Y

Now percentage fraction of reduction (1-Q)

$$\frac{\pi R^2 - 2A^2}{\pi R^2} = 1 - Q$$

Where,

$$Q = \frac{2A^2}{\pi R^2}$$

$$A = R\sqrt{(\frac{\pi Q}{2})} \quad ----------- (5)$$

Case 1: At Z= 0

From equation (3) & (4) we will get N no of values of X&Y

$$X = R * \sqrt{(1 - \frac{P}{N})}$$

$$Y = A\left(1 - \frac{P}{N}\right)$$

And cross-section will be circular which is shown in the fig

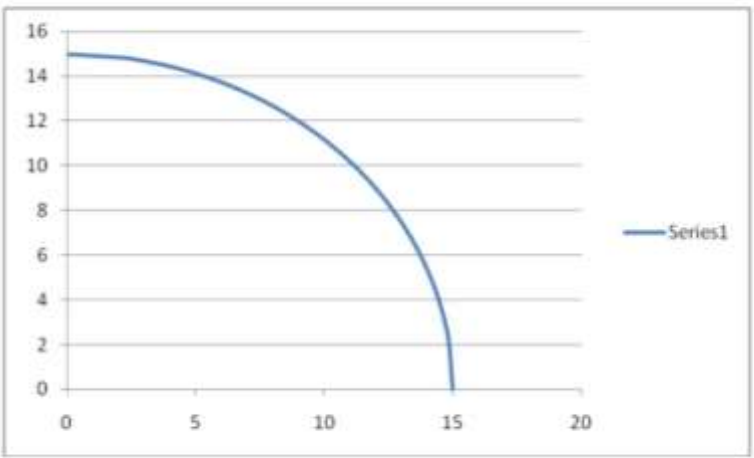

Fig: Cross-sectional of die profile at entrance in one quadrant

Case 2: At Z= L

From equation (3) & (4) we will get N no of values of X&Y

$$X= R * \sqrt{(P/N)}$$

$$Y= A\left(\frac{P}{N}\right)$$

And cross-section will be linear which is shown in the fig.

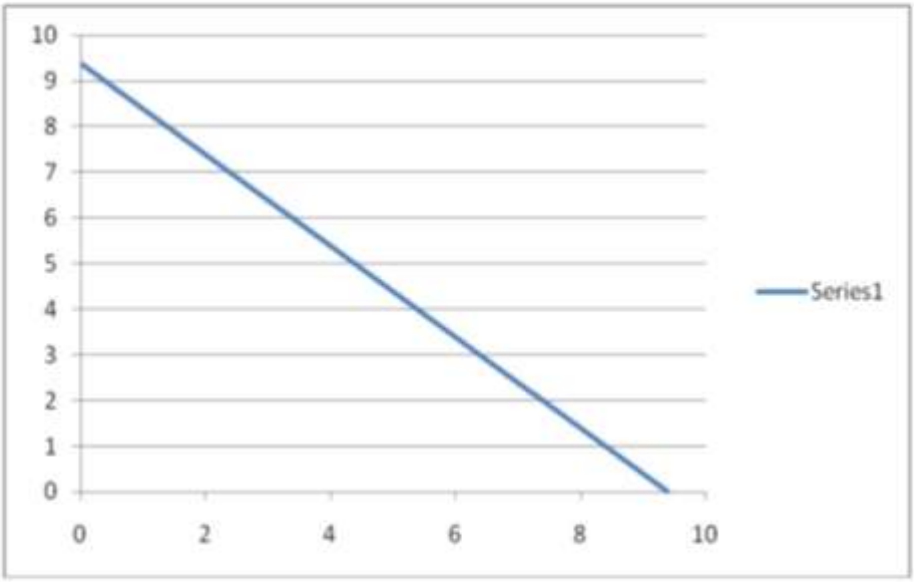

Fig: Cross-sectional of die profile at exit in one quadrant

Case 3: At Z=L/2

From equation (3) & (4) we will get N no of values of X&Y

$$x = \left[\frac{R*\sqrt{(1)-\frac{P}{N}}+A\left(1-\frac{P}{N}\right)}{2}\right] + \left[\frac{R*\sqrt{(1)-\frac{P}{N}}-A\left(1-\frac{P}{N}\right)}{2}\right]\cos\left(\frac{2\pi z}{L}\right) \quad ---(3)$$

And

$$y = \left[\frac{R*\sqrt{(P/N)}+A\left(\frac{P}{N}\right)}{2}\right] + \left[\frac{R*\sqrt{(\frac{P}{N})}-A\left(\frac{P}{N}\right)}{2}\right]\cos\left(\frac{2\pi z}{L}\right) \quad ---(4)$$

And cross-section will be in between circular & linear which is shown in the fig.

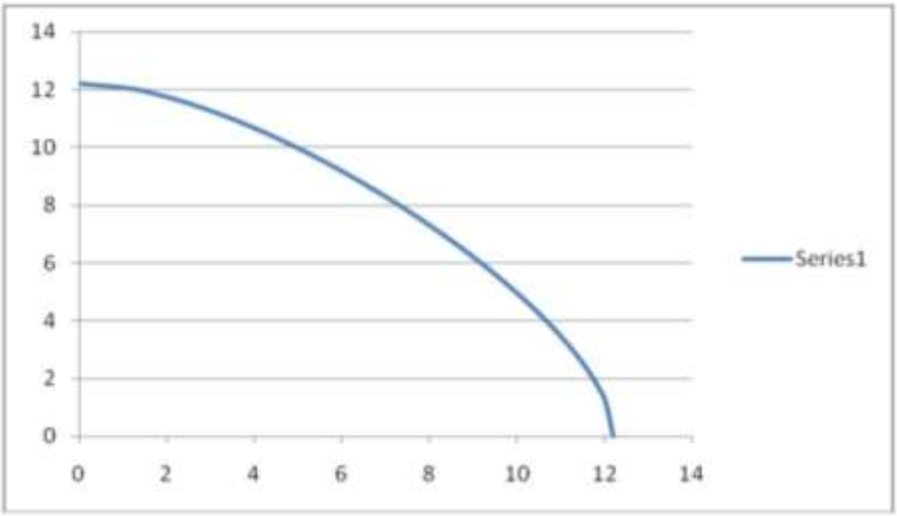

Fig: Cross-sectional of die profile at mid point in one quadrant

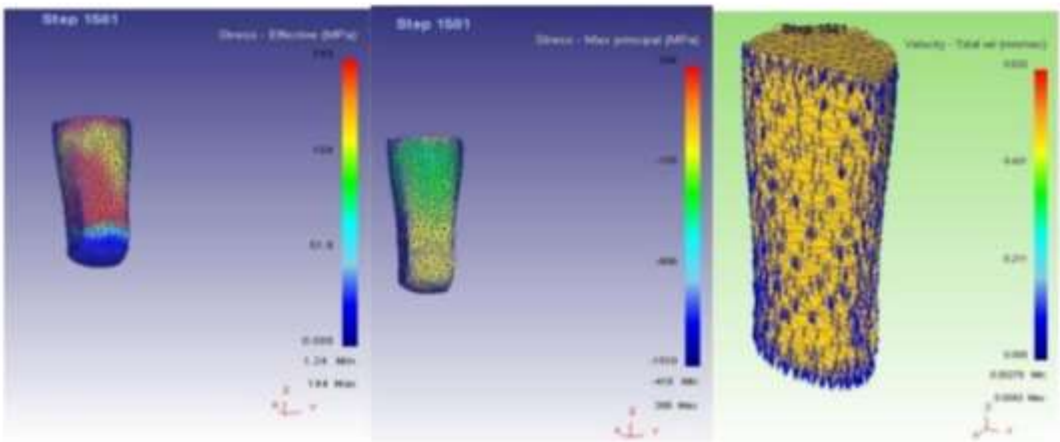

Fig:. Effective stress, principal stress and velocity field at last step of extrusion

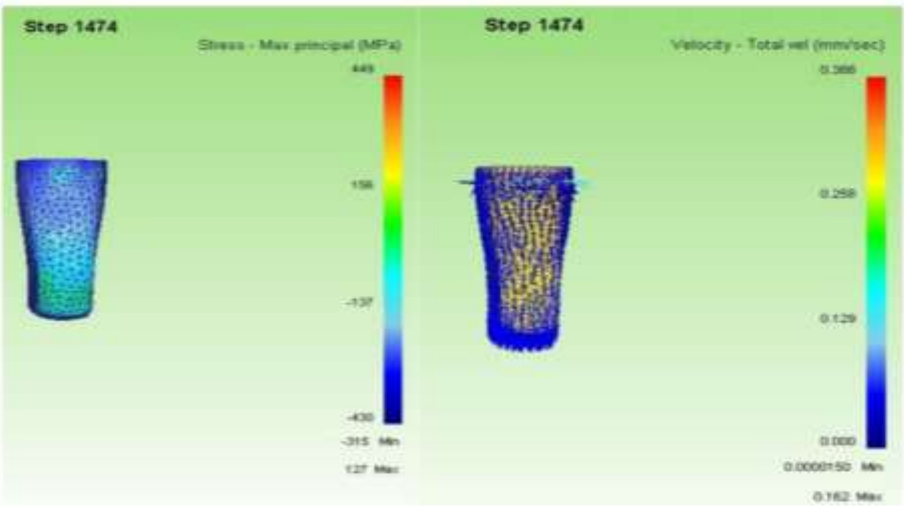

Figure 35. Principal stress and velocity field at last step of extrusion

6.ADVANTAGES OF EXTRUSION

Among the different metal forming processes, extrusion has definite advantages over others for the production of three dimensional section shapes. Now it is becoming essential to pay greater attention to the extrusion of section rod from round stock, as this operation offers the promises of an economic production route. The process is also attractive because press machines are readily available and the necessity to purchase expensive section stock corresponding to a multiplicity of required sections is eliminated.

There are many advantage of extrusion as follows

- Uniform cross-sectional area over a long length.
- Low cost of dies making it economical to make small quantities of a shape.
- Good surface finish.
- Strain and hardness are increased due to strain hardening

7.APPLICATIONS OF EXTRUSION

Extrusion is one of the most important methods of metal forming process with we can produce many product of high industrial applications with good quality. Some of the applications of the extrusion process are given bellow

- Helicopter blades
- Turbine blades
- Wingspans
- Columns used for creating structures
- Construction material

8.LIMITATIONS OF EXTRUSION

Every process has some limitation; extrusion has also some limitation as given bellow

- Most materials require high temperature and pressure, which makes the equipment costly.
- Die material should be able to withstand the load, high temperature, and wear.
- In the case of steel, the equipment is costlier due to the magnitude of temperature to which the metal must be heated (2300 F).
- Indirect extrusion complicates the handling of the extruded parts.
- Extrusion is limited to only a few metals and cannot be done on any metal chosen.

9.CONCLUSION

In this project I found that-

- A non-linear converging die profile has been designed for extrusion of square section from round billet using cosine function. The extrusion load increases with increase in reduction and friction factor.
- Load in case of split test is less as compared to solid work material under same experimental condition.
- The extrusion load for non-linear converging die is less as compared to linear converging die under same simulation condition.
- The flow of material in non-linear converging die appears to be gradual specially in higher reduction.

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