Optimization of Die extrusion Parameters Using FEM

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Abstract: **The present work proposes an integrated FEA based approach to evaluate the extrusion process conditions numerically and to find the optimal process variables for the forward extrusion of Al 6061 alloy. The simulations are carried out for different ram velocities, coefficient of frictions and die angles. The simulation results of temperature, extrusion load, extrusion ratio and blank velocity are presented. Consequently optimization has been carried out for to minimize the temperature and to minimize extrusion load using Taguchi's technique. The present work deals with the different approaches; one is a statistical method, i.e., Taguchi orthogonal array and the one is an evolutionary algorithm, i.e., Particle Swarm Optimization in order to determine optimal values of logarithmic strain, die angle and friction coefficient with a purpose to find minimum Extrusion force. With the optimal values obtained in both the techniques, 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*: Aluminum, Ansys, Taguchi.**

1. Introduction

The design of extrusion die play a significant role in the optimization of extrusion process variables and in improving the mechanical properties of the product obtained such as better surface finish, tool life etc. Much research has been carried out on the development and optimum values of extrusion die variables such as Die angle, Logarithmic strain and coefficient of friction. The present work addresses an integrated FEA based approach to evaluate the extrusion process parameters numerically and to find the optimal process parameters for the forward hot extrusion of Al 6061 alloy.

The simulations are carried out for different ram speeds, initial temperatures of billet, extrusion ratios and die cross sections. The simulation results of extrusion load and stress are presented. Consequently optimization has been carried out for to minimize the extrusion load and to minimize stress using Taguchi's method. Al6061 is one of the most widely used aluminum alloys in the range from transportation components to machinery equipment. This is due to its excellent corrosion resistance to atmospheric conditions as well as sea water. The process of hot extrusion is a promising approach for the direct recycling of aluminium machining chips. In recent years, extrusion process has been applied in manufacturing of variety of the components in the forms of bars, tubes, strips, and solid and hollow profiles.

As the extrusion process studied and improved universally, still it is having some problems with the end product such as rough surface, extruder surging, thickness variation, uneven wall thickness, diameter variation and low tensile strength etc.

There are many parameters on which the extrusion process depends. To ensure successful extrusion manufacturing various process parameters must be identified, controlled, and monitored.

ANSYS gives a far reaching suite of computational fluid dynamics programming for demonstrating fluid stream and other related physical wonders. The ANSYS-FLUENT workbench15.0 is used to evaluate the behavior of fluid flowing inside the die and determine the significant parameters affecting the fluid flowing inside the die.

Definition of Extrusion

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 metal billet is placed in the billet chamber and is forced by the ram through a die.

Hot extrusion is done to eliminate the cold working effects, reduce the force required, and reduce directional properties. However cold extrusion is also possible for many metals and has become an important commercial process. The reaction of the billet with the container and the die results in high compressive stresses that effectively reduce cracking of materials during primary breakdown from ingot. This is an important reason for increased commercial adoption of extrusion in the working of metals difficult to form such as stainless steel, nickel, nickel based alloys and other high temperature materials. Lead, brass, bronze, copper, aluminum, and some of the magnesium alloys are the most commonly extruded metals.

3. Optimization methods

Taguchi method

The objective of the study is to optimize the process by applying the Taguchi method with orthogonal array robust design. Taguchi Parameter Design is a powerful and efficient method for optimizing the process, quality and performance output of manufacturing processes, thus a powerful tool for meeting this challenge. Off-line quality control is considered to be an effective approach to improve product quality at a relatively low cost. The Taguchi method is one of the conventional approaches for this purpose. This procedure eliminates the need for repeated experiments, time and conserves the material by the conventional procedure. Optimization of process parameters is done to have great control over quality, productivity and cost aspects of the process. Off-line quality control is considered to be an effective approach to improve product quality at a relatively low cost. The Taguchi method is a powerful tool for designing high quality systems.

In this method, the performance characteristic is represented by signal-to-noise (S/N) ratio and the largest value of S/N ratio is required. These are logarithmic function of desired output and serve as objective function in the optimization process. There are three types of S/N ratio as the lower-the-better, the higher-the-better, and the nominal-the-better. The S/N ratio with a lower-the-better characteristic that can be expressed as

1. Lower the better

   $\sum$)………………(1)

2. Higher the better

   $\sum$)………………(2)

3. Normal –the – better

   $\sum$)………………(3)

Where, is the ith value of measured response, n is the total number of runs and s is the standard deviation.

4. MODELING AND ANALYSIS OF AN EXTRUSION DIE

A three dimensional model of extrusion die is created in CATIA software based on the optimal values obtained in Taguchi model is imported into the ANSYS software for analysis purpose. The problem is considered as a structural analysis element type selected is SOLID 186 and the material properties for die considered as a tool steel and the work piece is considered as carbon steel.

Here the cross section of the die is taken as square instead of circular for the simplicity of the design intension of this work is to show how the stresses and deformations are distributed on the die for the two models made by using the optimal values obtained in Taguchi. Meshing is taken as a free mesh and the extrusion force obtained from substituting as pressure is applied on the work piece.

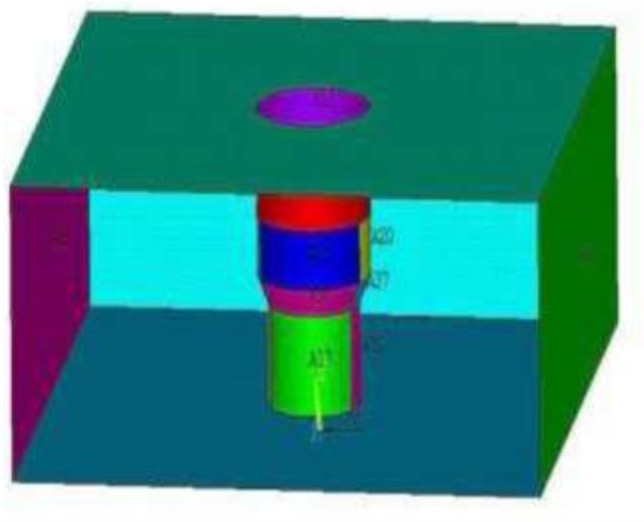

Figure 1: Model of the Extrusion Die.

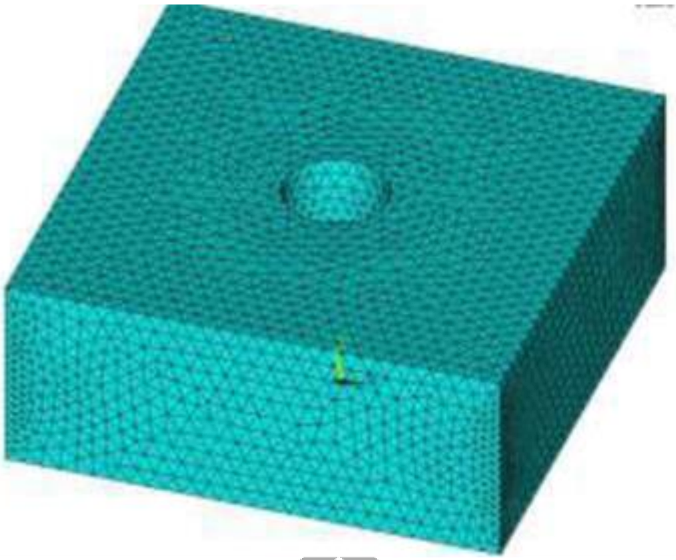

Figure 2: Meshed Model for the Extrusion Die.

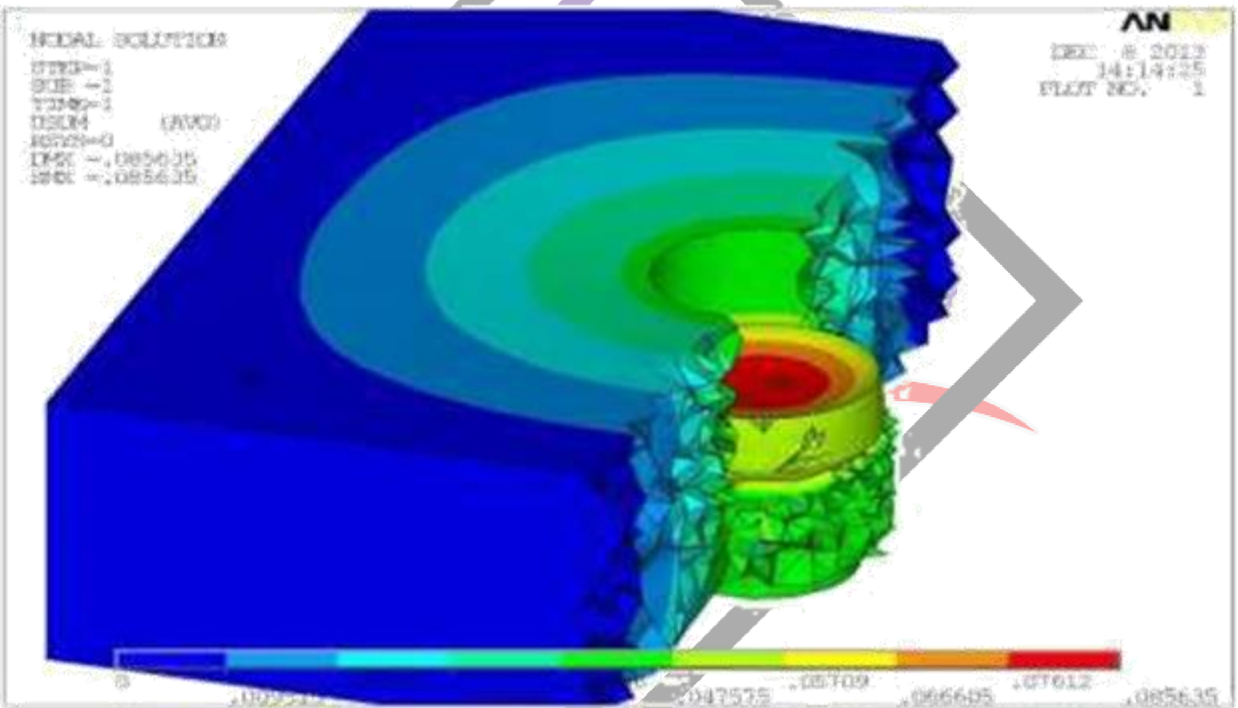

Figure 3: Deformations on the Extrusion Die-Taguchi Model.

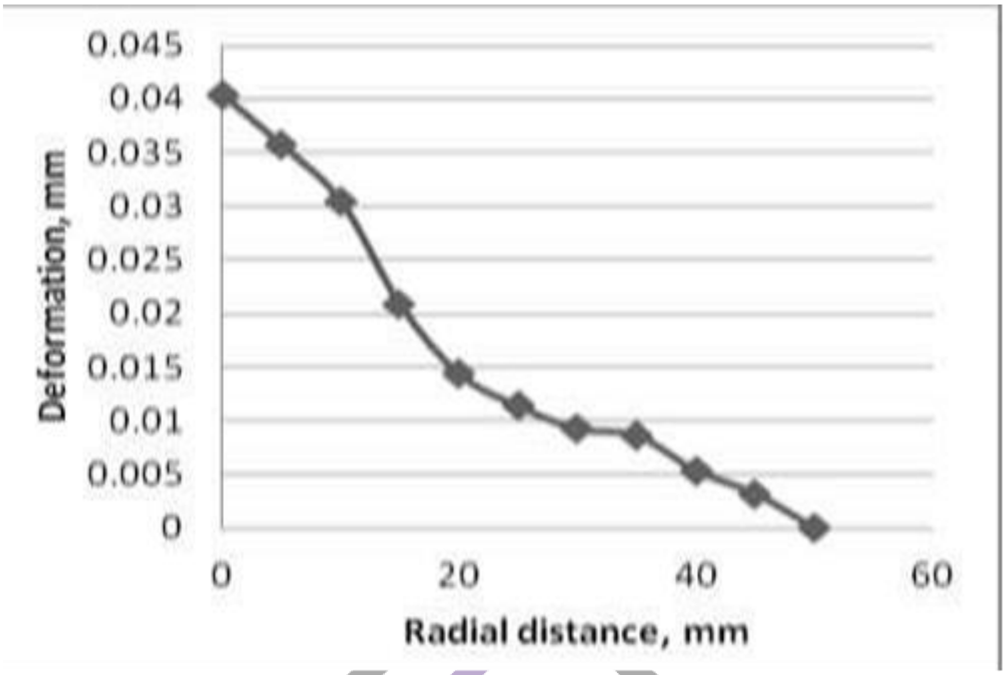

Figure 4: Deformation Distribution along the Radial Direction.

Von-Mises Stresses on the extrusion die for the model developed by using the optimal values obtained from Taguchi model. The stresses is distributed along the hole edge of the die to the die edge.

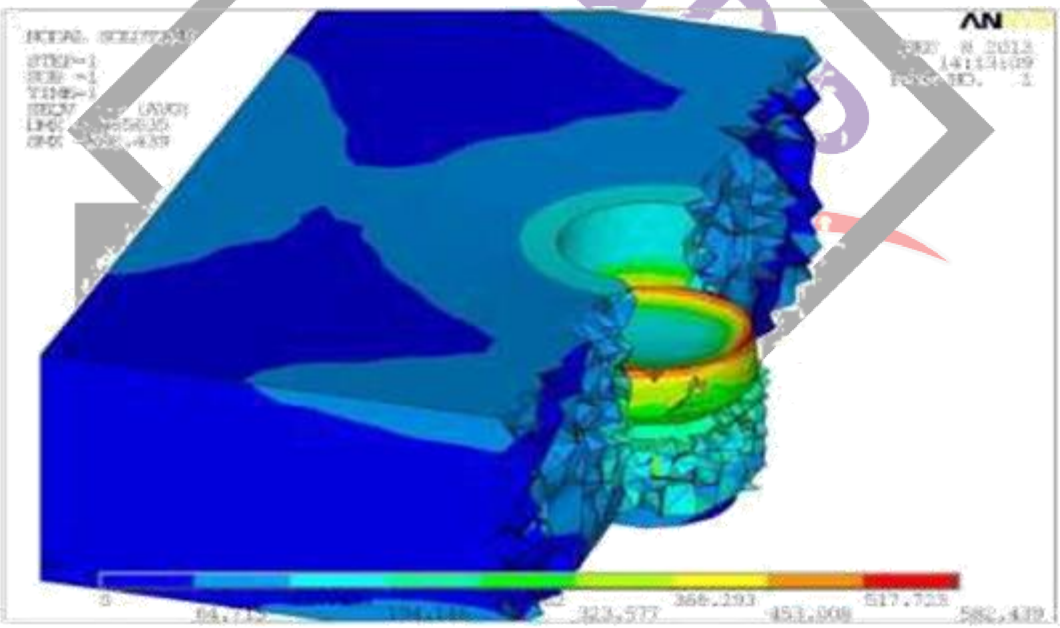

Figure 5: Von-Mises Stresses on the Extrusion Die-Taguchi Model.

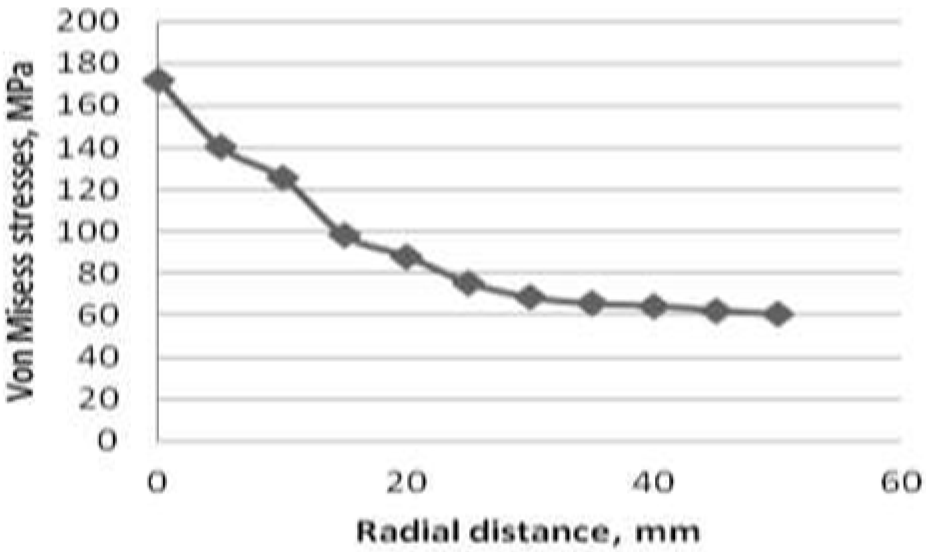

Figure 6: Von Mises Stresses Distribution along the Radial Direction.

Table 1: Physical properties of work material

Properties	
Work material	Al6061
Density (kg/m3)	2690
Young's Modulus (N/mm2)	69000
Poisson's ratio	0.293
Coefficient of thermal expansion (1/0C)	23.6E-06
Specific heat (N/mm2/0C)	2.39
Thermal conductivity (W/m/0C)	180

Table 2: Simulation results of Extrusion

sl.no	Pv (mm/s) X1	COF (μ) X2	α (deg.) X3	T (0c) Y1	P (kN) Y2
1	1	0.1	30	86.6	124
2	1	0.15	45	80.9	129
3	1	0.2	60	70.4	309
4	1.5	0.1	45	105	272
5	1.5	0.15	60	88	347
6	1.5	0.2	30	114	312
7	2	0.1	60	106	392
8	2	0.15	30	134	368
9	2	0.2	45	130	382

Table 3: S/N ratio for responses

Exp.No.	η(Y1)	η (Y2)
1	38.77039	41.86843
2	38.15897	47.19671
3	36.95145	49.79917
4	40.42379	48.69138
5	38.89952	50.80659
6	40.50612	51.88785
7	41.13810	49.88309
8	42.54210	51.31696
9	42.27887	51.64127

5. CONCLUSION

The finite element analysis of temperature and extrusion load during the extrusion of aluminum 6061 alloy is carried out in the present work. The optimal set of extrusion variables for the chosen responses was obtained. The experimental runs were conducted based on the Taguch method. Also, the percentage of contributions of each variable on each response was represented graphically. The set of optimal process variables was obtained with the help of Taguchi optimization method on the basis of maximum S/N ratio. These optimal process variables help to extrude the chosen aluminum alloy with minimum Die exit temperature and using minimum extrusion load. Hence, the quality of the extruded product improved with minimum energy.

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