Modeling and Optimization of Extrusion Process Parameters of AA6061 using Taguchi Method

K. Ramya[1], K. Sreedevi[2]

[1]M.Tech student, Dept. Of Mechanical Engineering, ANUCET, Guntur, India
ramya.kgj@gmail.com

[2]Assistant Professor, Dept. Of Mechanical Engineering, ANUCET, Guntur, India
sreedevikonda2014@gmail.com

---***---

Abstract – *In the present study an attempt was made to predict the extrusion load and stress during the hot extrusion process of 6061 Aluminium Alloy by using Deform-3D simulation. The influence of extrusion process parameters namely, extrusion ratio, ram speed, initial temperature of billet and cross section of die on the responses extrusion load and stress were investigated. Some of the most significant design parameters such as coefficient of friction and heat transfer coefficient are considered. The geometries of the die, container, ram and billet were generated in CATIA and for analysis Deform-3D is used which is a FEM based simulation process. Taguhci's L_{16} design is employed to simulate the experiments for each set of chosen extrusion variables via Finite Element Analysis solver. Analysis of variance (ANOVA) is adopted to check the significance of input variables on the output responses. Then, the optimal parameters are determined using Taguchi method.*

***Key Words*: Extrusion, Finite Element Analysis, Extrusion load, stress, Optimization and Taguchi.**

1. INTRODUCTION

Al6061 is one of the most widely used aluminum alloys in the range from transportation components to machinery equipments. 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. Many authors have been performed the investigations to understanding the thermo-mechanical behavior of the aluminum blanks as well as the dies during extrusion process. They concluded as the extrusion of aluminium through FEM simulation as a powerful tool to predict the thermo-mechanical changes occurring inside the billet material.

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.

1.1 Hot extrusion process by Deform-3D simulation

The geometry of the machining chips is an important factor in the chip compaction strategy. The chips were compacted into a thick-walled steel tube forming billets of 30 mm diameter and 80 mm length [1]. The geometries of the die, container, ram and billet were generated in CATIA. And meshes in DEFROM 3D which is a FEM based process simulation system designed to analyze various forming and heat treatment processes. Fig1. Shows the initial meshing of billet.

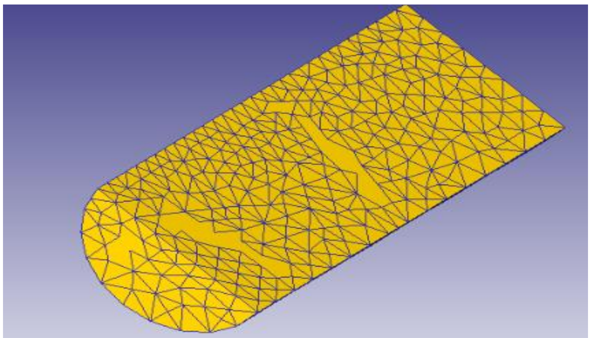


Fig-1: Meshing of billet in Deform-3D

This billet was characterized by a diameter of 30mm and a length of 80 mm. It was meshed by means of 6000 solid tetrahedral elements. The mesh generation is very important for the accuracy of the simulation. The mesh is reformulated at nearly every time step, in order to manage the material deformation. The physical and thermal properties of the billet and tooling used in the simulations were given in Table-1.

Table-1: Properties of the billet and tooling

Properties of the material	**AA6061**
Friction coefficient between billet and ram/ billet and die	0.3
Friction coefficient between billet and container	0.9
Heat transfer coefficient (N/s mm ^{0}C)	4

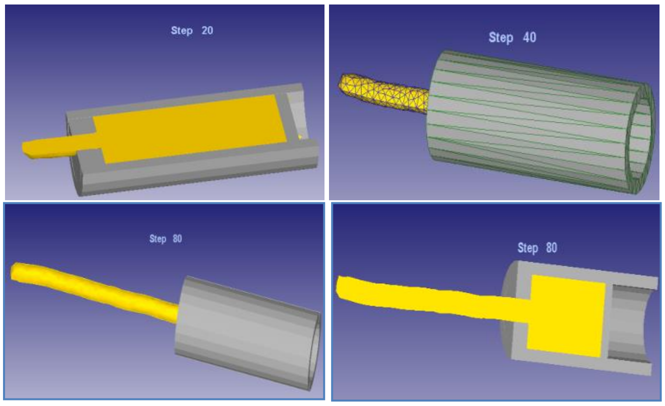


Fig-2: Pattern movement location of extrusion simulation

At the time of simulation the temperatures of ram, die and container are maintained at a temperature 20^{0}C less than the billet. Number of simulations was done for different billet temperatures as 430^{0}C, 450^{0}C, 480^{0}C and 500^{0}C at various ram speeds as 1, 1.5, 2 and 2.5 mm/sec for different extrusion ratios as 10:1, 15:1, 20:1and 25:1 for round and square die cross sections by using DEFORM-3D. For every simulation we obtained extrusion load and stress graphs.

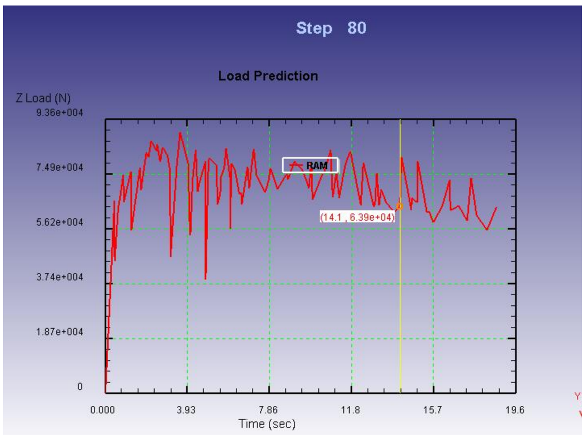


Fig-3: Load vs. Time plot of billet at 500^{0}C with circular die of extrusion ratio 10:1 at 2.5 mm/sec ram speed

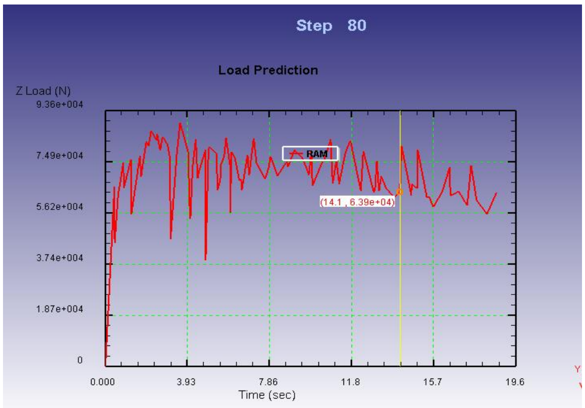


Fig-4: Load vs. Time plot of billet at 500^{0}C with circular die of extrusion ratio 25:1 at 2.5 mm/sec ram speed

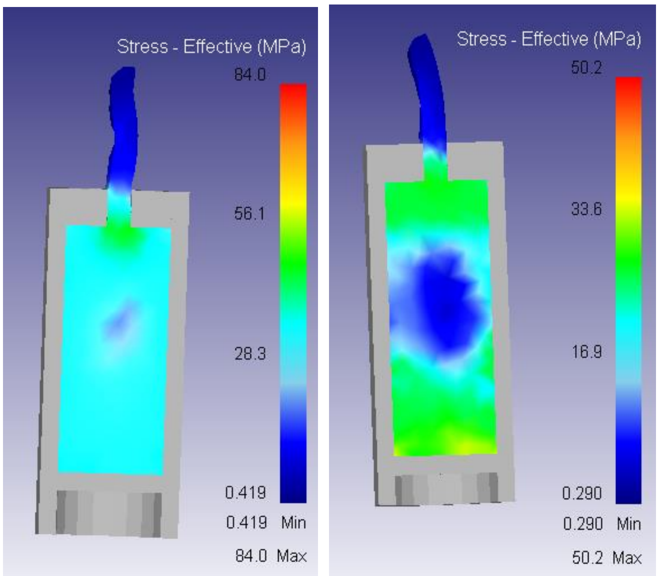


Fig-5: Effective stress distributions of billet at different initial temperatures 430^{0}C and 480^{0}C respectively with square die of extrusion ratio 15:1 with 1.5 mm/sec ram speed

1.2 Implementation of Taguchi Method

Taguchi's methods are one of the widely used methods to solve the optimization problems of multiple objectives and are influenced by multiple variables. It was developed to minimize the cost and time of experimentations when the process has large number of combinations by providing a systematic approach to the design of experiments. Hence, it became an extensively adopted method to solve some complex problems in manufacturing. In this method, the performance characteristic is represented by signal-tonoise (S/N) ratio and the largest value of S/N ratio is required.

Table-2: Extrusion process parameters and levels

Parameter	Code	levels			
		1	2	3	4
Extrusion Ratio	E	10:1	15:1	20:1	25:1
Billet Temp (^{0}C)	T	430	450	480	500
Die Cross section	C,S	C	S	C	S
Ram Speed(mm/sec)	S	1	1.5	2	2.5

Table-3: Simulation results of Extrusion process using Taguchi

S.NO	Extrusion Ratio	Billet Temp (^{0}C)	Die cross section	Ram vel (mm/sec)	Max Load (N)	Max Stress (MPa)
1	10:1	430	C	1	166.67	39.72
2	10:1	450	S	1.5	172.46	35.82
3	10:1	480	C	2	156.66	30.72
4	10:1	500	S	2.5	51.86	11.43
5	15:1	430	S	2	210.75	40.90
6	15:1	450	C	2.5	182.55	38.30
7	15:1	480	S	1	161.12	31.20
8	15:1	500	C	1.5	153.96	29.58
9	20:1	430	C	2.5	220.84	40.90
10	20:1	450	S	2	237.76	36.58
11	20:1	480	C	1.5	192.34	31.68
12	20:1	500	S	1	175.13	29.38
13	25:1	430	S	1.5	242.21	39.94
14	25:1	480	C	1	212.23	35.62
15	25:1	480	S	2.5	205.11	33.52
16	25:1	500	C	2	196.50	30.14

2. ANOVA

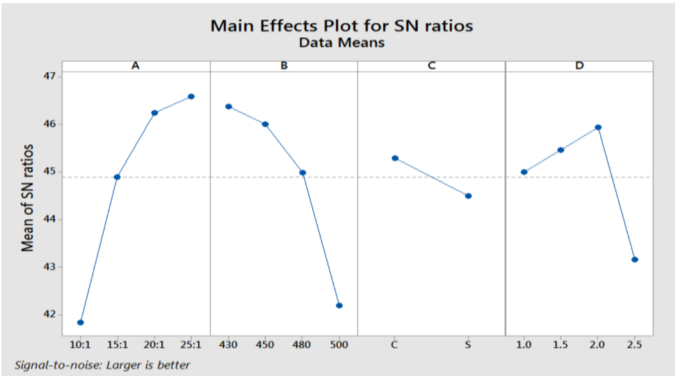
ANOVA is employed for the obtained FEA results. Table 4 and Table 5 represent the ANOVA of extrusion load and stress respectively. From Table 4, it can be found that extrusion ratio and initial billet temperature are more significant for extrusion load. From Table 5, initial billet temperature is more effecting extrusion stress.

Table -4: ANOVA analysis for extrusion load

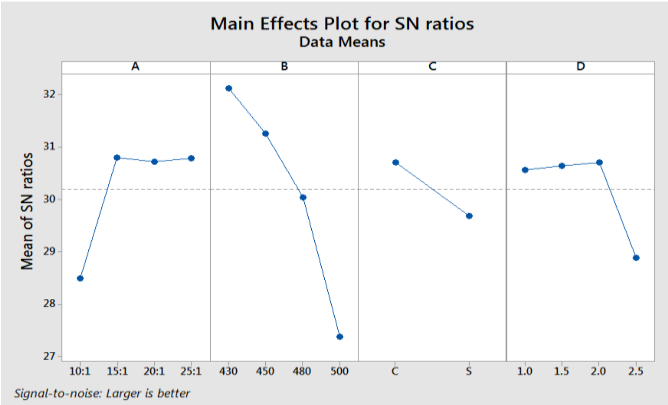
Source	DF	Seq SS	Adj SS	Adj MS	F	P
A	3	14688.7	14688.7	4896.2	9.59	0.048
B	3	10309.0	10309.0	3436.3	6.73	0.076
C	3	665.4	665.4	221.8	0.43	0.744
D	3	2770.9	2770.9	923.6	1.81	0.319
Error	3	1532.2	1532.2	510.7		
Total	15	29966.2				

Table -5: ANOVA analysis for extrusion stress

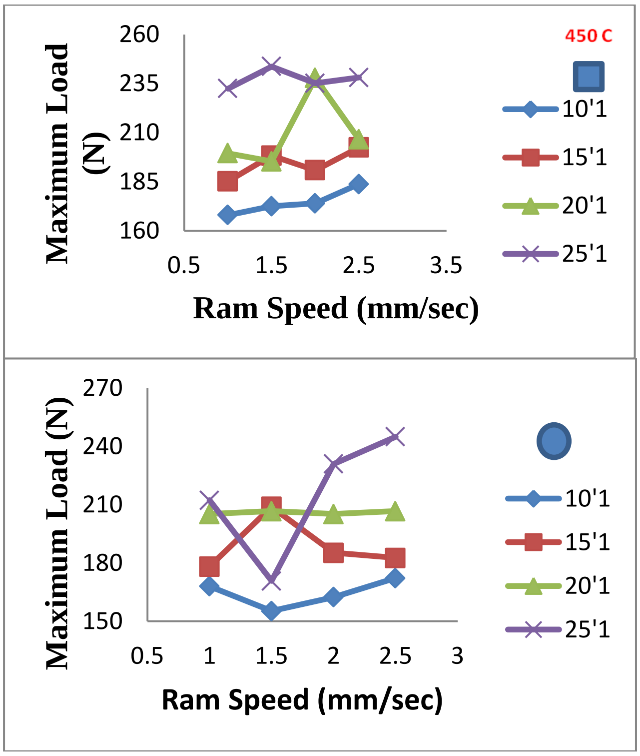
Source	DF	Seq SS	Adj SS	Adj MS	F	P
A	3	87.39	87.39	29.13	1.29	0.420
B	3	518.33	518.33	172.78	7.65	0.064
C	3	73.52	73.52	24.51	1.09	0.474
D	3	32.15	32.15	10.72	0.47	0.722
Error	3	67.72	67.72	22.57		
Total	15	779.11				



Graph-1: S/N ratios plot for extrusion load



Graph-2: S/N ratios plot for extrusion stress



Graph-3: Ram speed vs. Maximum load for billet at 450⁰C initial temperature with square and circular dies respectively.

3. CONCLUSIONS

The finite element analysis of extrusion load and stress during the extrusion of aluminium 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 Taguchi's L_{16} design matrix. ANOVA is employed to identify the significance of variables on the responses. 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. Optimum model has found using taguchi method in MINI TAB software for square shape, high initial billet temperature 500⁰C is best processing parameters in extrusion process with minimum reduction ratio 10:1 at high ram speed 2.5 mm/sec is required.

REFERENCES

[1] T. Chanda, J. Zhou, J. Duszczyk, "FEM analysis of aluminium extrusion through square and round dies" , Mater. Des. 21 (2000) 323–335.

[2] Tella Babu Rao, A.Gopala Krishna, "Design and Optimization of Extrusion process using FEA and Taguchi Method", IJERT, ISSN: 2278-0181 ,Vol. 1 Issue 8, October – 2012.

[3] L. Li, J. Zhou, J. Duszczyk, "Prediction of temperature evolution during the extrusion of 7075 aluminium alloy at various ram speeds by means of 3D FEM simulation", Journal of Materials Processing Technology 145 (2004) 360–370.

[4] S. N. Ab Rahim, M. A. Lajis, S. Ariffin, "Effect Of Extrusion Speed And Temperature On Hot Extrusion Process Of 6061 Aluminum Alloy Chip", ARPN Journal of Engineering and Applied Sciences, vol. 11, no. 4, february 2016.

[5] Hsiang SH, Lin YW. "Investigation of influence of process parameters on hot extrusion of magnesium alloy tubes". J. Mat. Proc. Tech., 192-193, 2007, 292–299.

[6]A text book of Manufacturing Technology (Manufacturing Processes) by R.K. Rajput.