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Process Parameters Optimization of Rolling Process

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ABSTRACT: In the present work process parameters affecting the rolling process were optimized and corresponding output responses were computed using response surface method, Empirical mathematical models are developed for the chosen output responses and the variation of output responses with respect to input parameters was studied. Analysis is carried out and the optimum solution was found out using response optimizer and also the regression equations for every response were generated. The optimized process parameters were analyzed and the results are compared.

Key words: Process parameters, Optimization, Rolling mill

I. INTRODUCTION

The main purpose of the paper is to know Design of Experiment (DOE) is an experimental or analytical method that is commonly used to statistically signify the relationship between input parameters and output responses, where in a systematic planning of experiments, collection and analysis of data is executed. DOE finds applications in the field of Science and Engineering for process optimization and development, process management and validation tests. R. A. Fischer in 1920 introduced Experimental Design who developed the basic principles of factorial design and the associated data analysis known as ANOVA during research in improving the yield of agricultural crops.

In DOE, synergy between mathematical and statistical techniques such as Regression, ANOVA, Non-Linear optimization and Desirability functions help to optimize the quality characteristics of a manufacturing process. ANOVA helps to identify the effect of each factor versus the objective function. Among the most prominently used DOE techniques are

Factorial Design, Taguchi's method and Response Surface Methodology (RSM).and by using the different material like Aluminum strip and its alloys, material used for rollers like Pearlitic Cast Iron. Nodular cast iron is also known as ductile iron, ductile cast iron, spheroidal graphite iron, spheroidal graphite cast iron. The objective is to reduce roll pressure, roll force, roll power and also to withstand the stresses. Properties and uses of aluminum shown in the figure 1

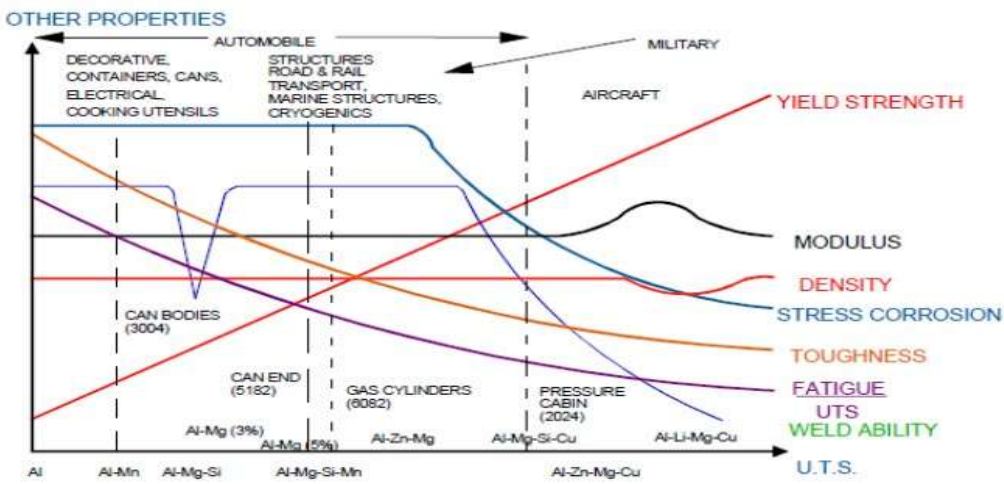

Figure 1: Properties and Uses of Aluminum

The aluminum alloys considered are AA 2024, AA 3003, and AA 6061

Table 1: Material Properties of Aluminum Alloys

AA 6061	AA 3003	AA 2024	ALLOYS MATERIAL PROPERTY
2.70×10^{3}	2.73×10^{3}	2.77×10^{3}	Density (kg/m^3)
72	75	73	Young's Modulus (GPa)
0.33	0.33	0.33	Poisson's ratio
48	148	99	Tensile Yield Strength (M Pa)
115	130	140	Tensile Ultimate Strength (M Pa)
23.5×10^{-6}	23.2×10^{-6}	22.8×10^{-6}	Thermal Expansion (°C)
180	162	190	Thermal Conductivity (w/m k)

Table 2: Material Properties of Nodular Cast Iron

Nodular Pearlitic Cast Iron	Material Property
7.2×10^{6}	Density (kg/mm^3)
2.9E+11	Young's Modulus (Pa)
0.211	Poisson's ratio
6.2E+08	Tensile Yield Strength (Pa)
8.3E+08	Tensile Ultimate Strength (Pa)
8E+06	Thermal Expansion (°C)
0.0323	Thermal Conductivity (w/mm °C)

Material selection was done in required fields and these were used in further chapters for the optimization and analysis of the rolling process The input parameters are:

- Coefficient of friction
- % reduction
- Rolling speed (RPM)
- Material property (Yield Strength (M Pa))

The output parameters we get from the input values are:

- Roll pressure (M Pa)
- Roll force (N)
- Roll power (KW)
- Strip velocity (m/s) ● Strain

By using the different methods like optimization of process parameters using response surface methodology, response optimization, prediction of responses by fuzzy logic, static structural fe analysis carried out using ANSYS 15.0.and CATIA V5 R19

II. SIMULATION VS THEORITICAL CALCULATION

2.1 THEORITICAL CALUATION: The mathematical modeling of rolling process is numerous. In each, the equations of arc of contact, reduction in thickness and the parameters coefficient of friction, yield stress, velocity, are

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used to calculate roll pressure, roll force, roll power, strip velocity, strain.

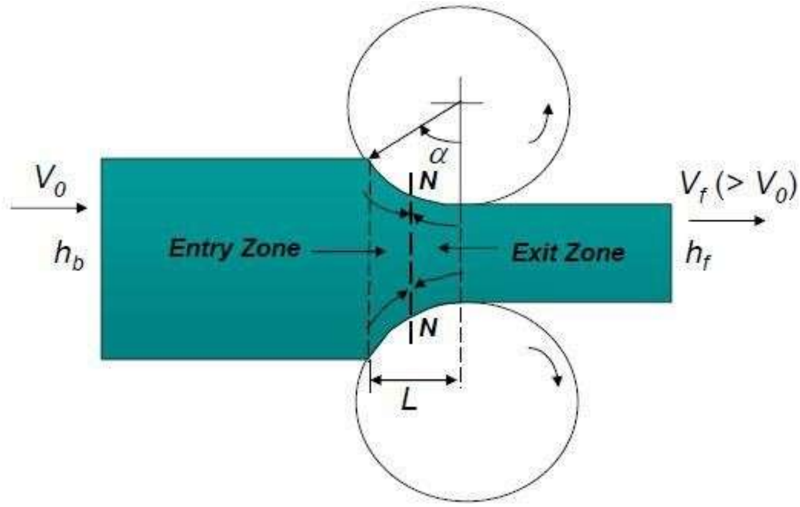

Figure 2:

Now for calculating the roll pressure, roll force, roll power, strip velocity let us consider the four input parameters coefficient of friction, % reduction, rolling speed, material strength at three different levels shown in Table 3.

Table 3: Factors and Levels

HIGH	MEDIUM	LOW	PARAMETERS
0.3	0.2	0.1	Coefficient of friction
30	20	10	% reduction
300	200	100	Rolling speed (RPM)
150	100	50	Material Strength (M Pa)

Table 4: 27 Combinations of the Input Parameters

Material Strength (MPa)	Rolling speed (RPM)	% Reduction	Coefficient of friction
100	200	10	0.1
100	200	10	0.3
100	200	30	0.1
100	200	30	0.3
50	100	20	0.2
50	300	20	0.2
150	100	20	0.2
150	300	20	0.2
100	100	20	0.1

100	100	20	0.3
100	300	20	0.1
100	300	20	0.3
50	200	10	0.2
50	200	30	0.2
150	200	10	0.2
150	200	30	0.2
50	200	20	0.1
50	200	20	0.3
150	200	20	0.1
150	200	20	0.3
100	100	10	0.2
100	100	30	0.2
100	300	10	0.2
100	300	30	0.2
100	200	20	0.2
100	200	20	0.2
100	200	20	0.2

Table 5: Input and Output Parameter Values

Strain	Strip Velocity (m/s)	Roll Power (KW)	Roll Force (KN)	Roll Pressure (MPa)	Material property (N/mm^2)	Rolling speed (rpm)	% Reduction	Coefficient of friction
0.1	6.283	22.757	62.734	120.733	100	200	10	0.1
0.1	6.283	24.741	68.204	131.259	100	200	10	0.3
0.3	6.283	71.058	113.092	125.658	100	200	30	0.1
0.3	6.283	82.581	131.432	146.035	100	200	30	0.3
0.2	3.141	12.363	48.199	65.591	50	100	20	0.2
0.2	9.424	37.090	48.199	65.591	50	300	20	0.2
0.2	3.141	37.090	144.599	196.775	150	100	20	0.2
0.2	9.424	111.272	144.599	196.775	150	300	20	0.2
0.2	3.141	23.246	90.625	123.326	100	100	20	0.1
0.2	3.141	26.208	102.172	139.040	100	100	20	0.3
0.2	9.424	69.739	90.625	123.326	100	300	20	0.1
0.2	9.424	78.624	102.172	139.040	100	300	20	0.3
0.1	6.283	11.874	32.734	62.998	50	200	10	0.2
0.3	6.283	38.409	61.131	67.923	50	200	30	0.2

0.1	6.283	35.624	98.204	188.994	150	200	10	0.2
0.3	6.283	115.229	183.393	203.770	150	200	30	0.2
0.2	6.283	23.246	45.312	61.663	50	200	20	0.1
0.2	6.283	26.208	51.086	69.520	50	200	20	0.3
0.2	6.283	69.739	135.938	184.990	150	200	20	0.1
0.2	6.283	78.624	153.259	208.560	150	200	20	0.3
0.1	3.141	11.874	65.469	125.996	100	100	10	0.2
0.3	3.141	38.409	122.262	135.847	100	100	30	0.2
0.1	9.424	35.624	65.469	125.996	100	300	10	0.2
0.3	9.424	115.229	122.262	135.847	100	300	30	0.2
0.2	6.283	49.454	96.399	131.183	100	200	20	0.2
0.2	6.283	49.454	96.399	131.183	100	200	20	0.2
0.2	6.283	49.454	96.399	131.183	100	200	20	0.2

2.2 SIMULATION RESULTS
2.2.1 STATIC ANALYSIS ON ROLLING PROCESS BY NUMERICAL SIMULATION

A solid model of a roller and billet was modelled in CATIA V5 R19 is imported into ANSYS work bench 15.0 in IGES format. The imported design is shown in figure 6.

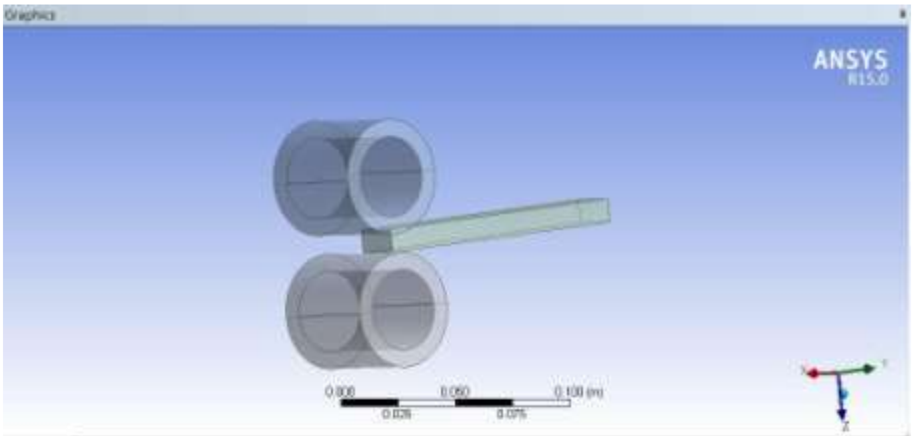

Figure 6: Imported CATIA Model

Meshing for the model was done by sweep method using quadrilateral elements of size 5mm. face sizing and edge sizing also considered by taking number of divisions as 15.
The meshed model is shown in the figure 7

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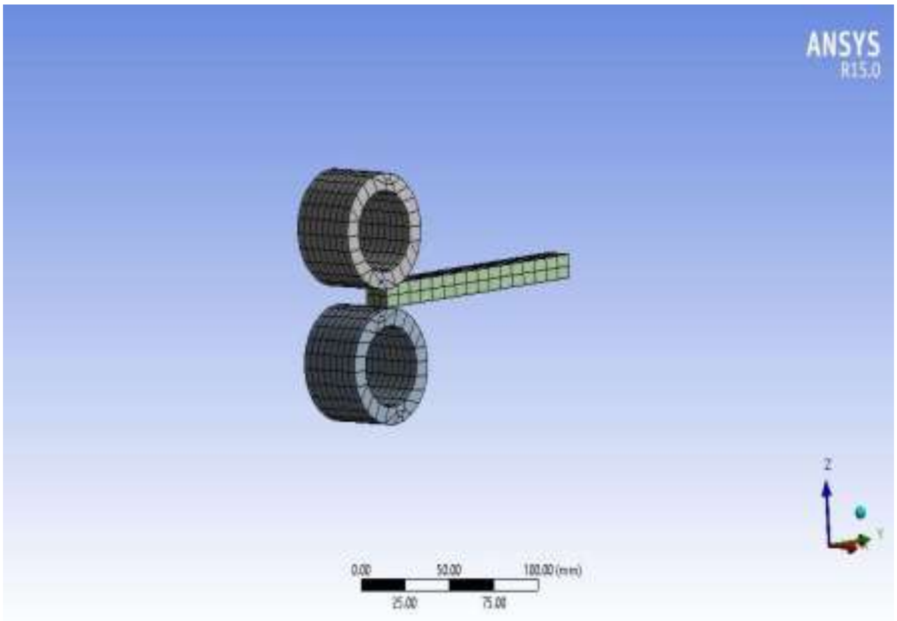

Figure 7: Meshing of the Design

Static analysis was performed by rotating the rollers and translating the strip. The maximum von-mises (equivalent) stress induced in the strip is 627.25 N/mm^2 as shown in figure 8

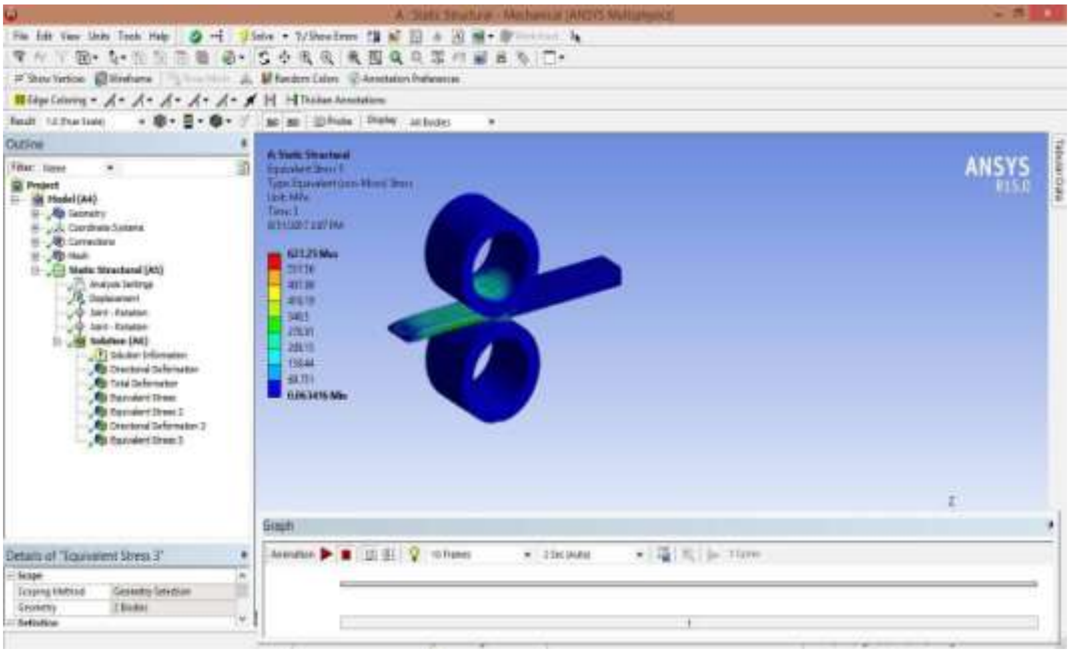

Figure 8: Stress Analysis

After the stress analysis is carried out, the theoretical calculations and the analytical stress values are compared and the error is observed.

Calculation of the stress:

$$\text{Stress on the strip} = \frac{\text{roll force}}{l \times b}$$

Stress = 694.04 M Pa

Table 9. Comparison of Theoretical and Analytical values

Stress Value In Mpa		**% Error**
Theoretical	**By ANSYS**	
694.04	627.25	9.62

Overall % error is found to be 9.62% and the very reason for having a margin of 9.62% error with the theoretical and ANSYS results is due to the series of assumptions that are followed in the theoretical calculations for which exact analytical solution is very difficult process.

III. CONCLUSIONS

- The present thesis deals with modeling of rollers and billet in CATIA V5R19 software and is imported into ANSYS workbench 15.0 to carry out static analysis.
- The process parameters affecting the rolling process were optimized and corresponding output responses were computed using response surface method in MINITAB 14.
- ANOVA analysis is carried out and the optimum solution was found out using response optimizer and also the regression equations for every response were generated.
- The predicted output responses for the corresponding optimum input parameters are

Roll Pressure = 93.8538 MPa, Roll Force = 47.9088 KN, Roll Power = 12.7137 KW, Strip Velocity = 4.1019 m/s, Strain = 0.1598

- In static analysis the stress induced in the billet was found and the overall % error is found to be 9.62% and the very reason for having a margin of 9.62% error with the theoretical and ANSYS results is due to the series of assumptions that are followed in the theoretical calculations for which exact analytical solution is very difficult process.

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