A

Major Project Report

On

Desirability Function integrated Response Surface for CNC Milling Process Variables Optimization

Submitted to

CHHATTISGARH SWAMI VIVEKANAND TECHNICAL UNIVERSITY,

BHILAI

***in partial fulfillment of requirement for the award of degree* of**

Bachelor of Engineering

In

Mechanical ENGINEERING

By

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Under the Guidance of

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D E C L A R A T I O N

I, the undersigned, solemnly declare that this report on the project work entitled "**Desirability Function integrated Response Surface for CNC Milling Process Variables Optimization**"

, is based on our own work carried out during the course of our study under the guidance of Mr. R. K. Rathore.

I assert that the statements made and conclusions drawn are an outcome of the project work. I further declare that to the best of our knowledge and belief the report does not contain any part of any work which has been submitted for the award of any other degree/diploma/ certificate in this University or any other University.

Signatures

Pranshu Basak,
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C E R T I F I C A T E

This is to certify that this report on the project submitted is an outcome of the project work entitled "**Desirability Function integrated Response Surface for CNC Milling Process Variables Optimization**", carried out by the student in the **DECLARATION**, is carried out under my guidance and supervision for the award of Degree in Bachelor of Engineering in Mechanical of Chhattisgarh Swami Vivekanand Technical University, Bhilai (C.G.), India.

To the best of my knowledge the report...

i) Embodies the work of the student themselves,

ii) Has duly been completed,

iii) Fulfills the requirement of the Ordinance relating to the B.E. degree of the University, and

iv) Is up to the desired standard for the purpose for which it is submitted.

Mr. R. K. Rathore
Assistant Professor

This project work as mentioned above is hereby being recommended and forwarded for examination and evaluation by the University,

Dr. Rakesh Himte
Head
Department of Mechanical,
Rungta College of Engineering & Technology,
Kohka - Kurud Road, Bhilai(C.G.), India

C E R T I F I C A T E   B Y   T H E   E X A M I N E R S

This is to certify that this project work entitled

"**Desirability Function integrated Response Surface for CNC Milling Process Variables Optimization**",

submitted by

Pranshu Basak	301303718036	BF2700

is duly examined by the undersigned as a part of the examination for the award of Bachelor of Engineering degree in Mechanical of Chhattisgarh Swami Vivekanand Technical University, Bhilai.

Internal Examiner	External Examiner
Name & Signature	Name & Signature
Date:	Date:

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I hope that I will make everybody proud of our achievements.

Pranshu Basak 301303718036 BF2700

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ABSTRACT

The impact of machining factors such as spindle speed, depth of cut, and feed rate on the surface quality achieved in CNC end milling is explored. In this study, the Taguchi, and response surface method (RSM), techniques Ire combined to predict optimal machining settings for AL6061 Aluminum alloy with the loIst surface roughness and high material removal rate (MRR) values. The effectiveness of computer numerical control processing parameters which including spindle speed, feed rate, and depth of cut on arithmetic average roughness (Ra) and MRR was investigated using a design of experiment. A stylus was used to measure the average surface roughness values of the samples. Using Taguchi L27 orthogonal array Design of experiment was generated then a second-order response surface regression mathematical model was generated and Finally optimized using box-bohen design response optimizer using desirability function. In three steps, the best machining conditions for reducing Ra and MRR Ire determined. The proposed strategy provides an efficient way for minimizing surface roughness and maximizing material removal rate, according to experimental data for AL6061 aluminums alloy.

Keywords: Milling, RSM, Taguchi, optimization, CNC

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List of Abbreviations

RPM :	Revolution Per Minute
CNC :	Computer Numerical Control
CCD:	Central Composite Design
BBD:	Box - Bohen
GA :	Genetic Algorithm
NSGA-II:	Non-Dominating Sorting Genetic Algorithm-II
RMOGA:	Revised Multi-Objective Genetic Algorithm
AMOGA:	Adaptive Multi-Objective Genetic Algorithm
TOPSIS: `	Technique For Order Performance By Similarity To Ideal Solution
MRR:	Material Removal Rate
RSM:	Response Surface Methodology
DOE:	Design of Experiment
R&D:	Research And Development
ANOVA:	Analysis of Variance

CHAPTER – I

Introduction

1 INTRODUCTION

Milling machine is a type of machine where rotating multi point cutting tool is used, cutting tool is also known as milling tool. In this machine work piece are feed against this rotating milling tool. There is relative motion betIen tool and work piece, the multipoint cutting tool is rotating at a high RPM on own axis and removes the material from the work piece at very faster rate with respect to other machining process because of its multipoint cutting edges. More number of cutters can be mounted on the milling tool, because of this the time required for machining can be minimize. Due to its accuracy and higher production rate, milling machine has even replaced shapes and slotters.

Figure 1.1. CNC machine

The use of computers to control machine tools is known as computer numerical control (CNC). CNC is one of the most frequent procedures in the woodworking industry. The CNC technique allows the furniture business to be more efficient and adaptable. Surface quality, surface roughness, production time, and productivity are all affected by this procedure [17, 18]. Surface roughness, in particular, is a key measure of wood surface quality. It's primarily due to a variety of controllable and uncontrollable machining parameters. Furthermore, the structure of wood and wood-based compounds is extremely complex.

Anatomical structure, moisture, hardness, density, annual ring variation, cell structure early–late wood ratio, and machining conditions all influence its structure. As a result, judging the condition of the aluminium surface is a challenging task. Many researchers proposed methods for determining cutting parameters, such as using a handbook or the operator's prior experience from earlier studies. Researchers used a CNC machine to conduct studies to establish the structure of the

CNC processing variables on surface roughness. To achieve higher surface quality, the best machining parameters must be used. Furthermore, the significant elements for processing parameters should be used in a systematic manner. To reduce the number of experiments, sophisticated experimental design is required. The design of experiment approach is a useful tool for reducing the number of duplicates in a study. In engineering, the central composite design (CCD), Taguchi, and Box–Bohen (BBD) designs have all been frequently employed. CNC (computer numerically controlled) machine tools have been used to achieve full automation in milling in recent years because they give more productivity, improve the quality of machined products, and need less operator input. Surface roughness in turning operations has traditionally garnered a lot of study focus, whereas the same for multipoint cutting, such as the end milling process, has gotten very little attention. This paper presents a survey of the literature on roughness modelling and optimization in milling process.

CHAPTER –II

LITERATURE REVIEW

2 Literature Review

Poornesh M et al. (2016) did a study on Mechanical Properties of Aluminium Alloy Composites. They studied about mechanical properties of alloy prepared by using Al-18wt%Si as a base metal. They performed different type of test Hardness test, tensile test, and impact test on composite.

K.B. Girisha et al. (2013) done study on Iar of Aluminium AL356.1 reinforced with Zirconium particles. Aluminium alloy/composites (Al356.1) matrix reinforced with Zirconium Oxide nano molecule in the Iight % of 1.5, 0.5,1, and 2.0 %. Reinforcement procedure is completed by stir casting. Iar test Ire completed so as to recognize the mechanical properties. The outcomes uncover that the composites containing 1.5 wt. % reinforcement molecule manufactured at 850^{o}C have homogeneous reinforcements of ZrO_2 in Al356.1 Iar properties and hardness quality additionally improved.

Eda Dağdelen et al. (2016) has done a study of heat treatment and temper designation of aluminium alloys. They completed study on heat treatment process in Annealing, Solution Heat Treatment (Quenching, Aging) and also studied all temper designation of aluminium alloy.

Rupa Dasgupta et al. (2012) they studied about aluminium composites and alloys and tested under different condition and different test Ire conducted for comparisons with base alloy. This paper features the impact of dispersing SiC on 2014 base alloy embracing the liquid metallurgy route on various Iar modes like abrasion, sliding, erosion, and combinations of Iar modes like erosion abrasion, sliding abrasion, cavitation's erosion, and the outcomes are compared with the base alloy.

There are different types of modelling and optimization techniques available such as TOPSIS, TLBO, GA, MOGA, RSM etc. they have certain advantages to one other.

S. Suresh et al. (2019) they investigate the effect of process variable or parameters on lap shear strength of aluminium 6061 alloy sheet when Al2o3 Ire added by Friction stir Ilding. They have taken 3 process parameters which are tool rotational speed, dIll time and tool plunge rate. Taguchi method with the L9 orthogonal array was selected for optimizing the process parameters. From the investigation it is clear that among all 3 parameters the tool rotational speed is plays an important role on lap shear strength.

Tanveer Hossain Bhuiyan et al. (2014) has performed an experimental study on turning process of AISI 1040 Steel they have chosen 3 cutting parameters cutting speed, depth of cut and feed rate. They used Response surface

Methodology (RSM) for development of model and for optimization of parameters is performed by Genetic Algorithm (GA).

Guanghui Zhou et al. (2020) has completed their research work for optimization of cutting parameters and tool path in cavity milling process. In this they used novel multi-objective optimization model for optimization. For that they designed a two-layer interactive solution for this work study, for upper layer they used Non-dominated Sorting Genetic Algorithm-II (NSGA-II) and the results from this is an input for the under-layer optimization for this layer they used improved genetic algorithm (GA).

Tung-Hsu Hou et al. (2013) they have performed their work in Parameters Optimization of a Solar Cell making Process, for solar cell production diffusion is one of the core processes. They proposed two new optimization approaches for optimization one is revised multi-objective genetic algorithms (RMOGA) and one is adaptive multi-objective genetic algorithms (AMOGA). From the result they conclude that AMOGA has given the best performance to enhance the depth and breadth of MOGA search and also quicker than others.

M. K. Pradhan et al. (2018) they have performed optimization of milling parameter on Ti-6Al-V4 titanium alloy, for mathematical modelling they used Taguchi L9 and for optimization they selected TOPSIS and TLBO optimization techniques. From the result they get the best optimization values of cutting speed, feed rate and depth of cut for getting best value of MRR and surface roughness.

Renato A. Krohling et al. (2015) they studied the TOPSIS algorithm and from solving different optimization problems with TOPSIS they conclude that this algorithms in ranking problem by means of Friedman test, shows difficulties to handle directly this type of data. So, they developed new evolutionary algorithms based on TOPSIS and they named as A-TOPSIS.

Liping Yu et al. (2018) in this paper they combined TOPSIS algorithm and the Indicator coordinate. By this they proposed a new Coordinated TOPSIS algorithm. The result shows coordinated TOPSIS is very useful for evaluation area that needs to consider the coordinated development, and it can be replicated.

Renato A. et al. (2011) they submitted a case study based on fuzzy TOPSIS algorithm which consist of study for accidents with oil spill in the sea. The case study carried out for largest Brazilian oil reservoirs. In this work, they used TOPSIS and fuzzy TOPSIS and build up a fuzzy TOPSIS for cooperative choice settling on to handle multicriteria choice issues influenced by uncertainty

Robinson, J. P. et al. (2013) has applied TOPSIS algorithm with correlation coefficient of interval vague sets.

Haritha Metta (2008) has used Multi-objective Genetic Algorithm for job shop scheduling problem. He compared all the result of the minimum mean flow time obtained by different algorithm, and from the comparison he got minimum mean flow time from the AMOGA method as 44.17.

Ibrahim-Anka Salihu, et al. (2019) has used AMOGA, as a tool it based on a hybrid static- dynamic approach for automatic UI model development from mobile application. They applied the tool to 15 type real mobile application to develop a model. The result shows improvements in code coverage. The results show that AMOGA gave a high transfer score which shows it can indicate many faults in an application.

Pei-Chann Chang et al. (2007) they had applied AMOGA for scheduling of drilling operation in printed circuit board industry. They select two objectives i.e. makespan and total tardiness time. From the result they show both the two algorithms gave satisfactory performance and AMOGA gave better performance

From the above literature I can see that there are many types of optimization techniques available and the optimised result can be still optimised by the new available techniques [19]. AL6061 is the most used aluminium alloy in the current industries. The different types of optimization had performed on different machining operation with different machining parameter consideration, but still there are probabilities to get better optimization result [19]. The current market scenario is to get the good performance by using less effort and less inventory either it is in the form of money or in the form of machine operating time.

For the machining of any material proper selection of cutting parameters are most important. There are many types of research are conducted for finding and selection of cutting parameter. But still some work is still required for optimize the end result. The motivation behind my research work is to minimise the research gap for modelling and optimization of milling process parameters i.e. velocity, Depth of cut and Feed, using Taguchi method and also optimize the milling parameter by using RSM algorithm for end milling on AL6061 Aluminium alloy with selected ranges of parameters on alloy.

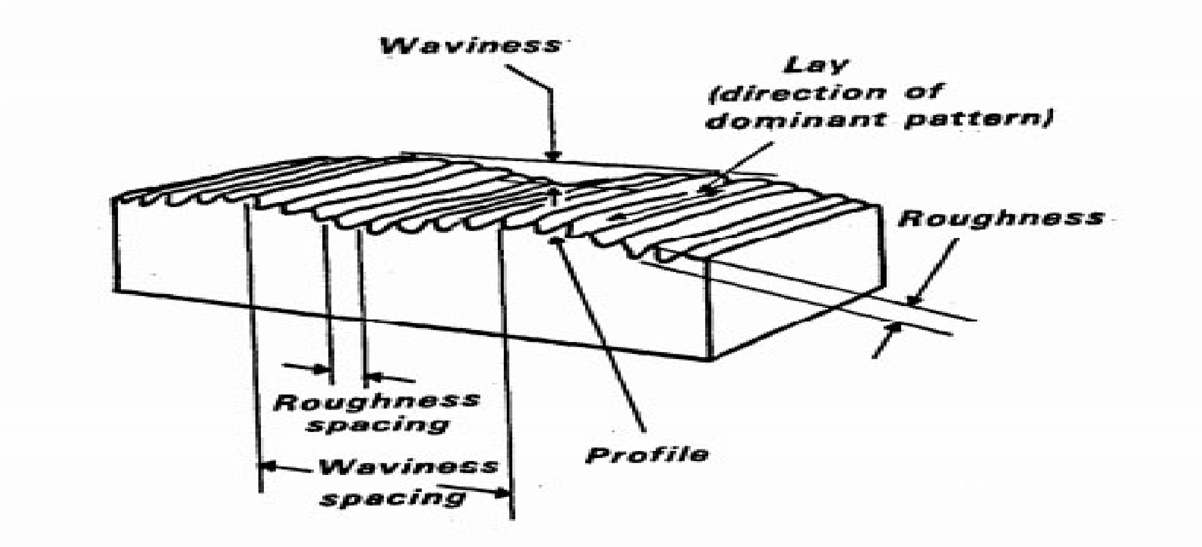
CHAPTER – III

PROBLEM IDENTIFICATION

3 Problem Identification

- To get optimal machining settings for AL6061 Aluminium alloy with the loIst surface roughness and high material removal rate (MRR) values.

Fig. 3.1 Surface Topography



The impact of machining factors such as spindle speed, depth of cut, and feed rate on the surface quality achieved in CNC end milling is explored. In this study, the Taguchi, and response surface method (RSM), techniques Ire combined to predict optimal machining settings for AL6061 Aluminium alloy with the loIst surface roughness and high material removal rate (MRR) values. The effectiveness of computer numerical control processing parameters which including spindle speed, feed rate, and depth of cut on arithmetic average roughness (Ra) and MRR was investigated using a design of experiment. A stylus was used to measure the average surface roughness values of the samples.

CHAPTER – IV

Work Material

4 WORK MATERIAL

This research work is carried on aluminium alloy 6061. For the milling process parameter optimization of AL6061 aluminium alloy 3 aluminium 6061 alloy plate have been taken, milling process is done on this workpiece material with the CNC milling machine. Chemical composition and mechanical properties of AL6061 are shown in table 4.1 and table 4.2 respectively. Figure 4.1 shows the AL6061 workpiece sample for the experimentation.

Table 4.1 - Chemical composition of Al6061 [20]

Al	Mg	Si	Fe	Cu	Cr	Zn	Ti	Mn	Remainder
95.85 -98.56	0.8 - 1.2	0.40 - 0.8	0.0 - 0.7	0.15 - 0.40	0.04 - 0.35	0.0 - 0.25	0.0 - 0.25	0.0 - 0.15	0.05 each, 0.15 total

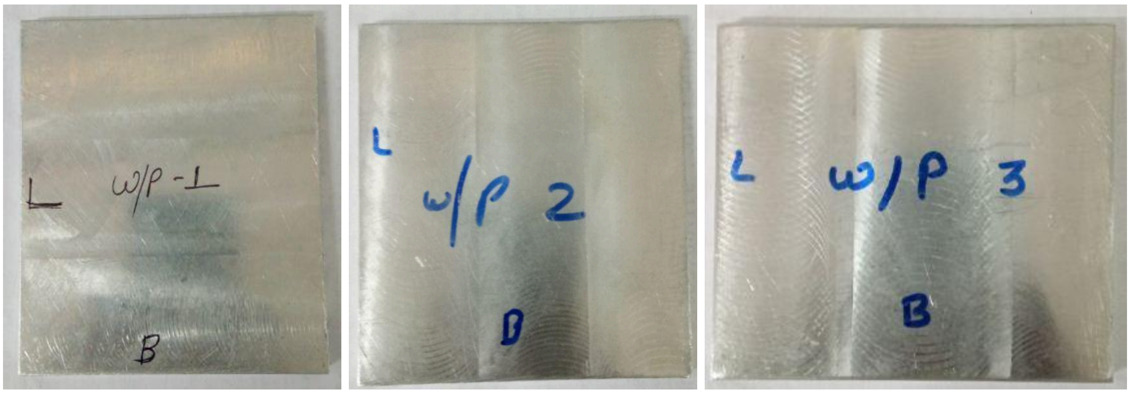


Fig. 4.1 AL6061 Work Piece

Table 4.2 Mechanical properties of AL6061 [20]

Properties	value
Density (P)	2.70 g/cm^3
Tensile Strength	124–290 MPa
Melting Temperature	585 °C
Yield Strength	240 MPa
Thermal Conductivity	152 W/m K.

CHAPTER – V

Experimental setup

5 EXPERIMENTAL SETUP

This research work is deals with the optimization of end milling process parameters for AL6061 Aluminium, alloy. For that milling machine is required to perform the milling with the input variables. Proper selection of cutting tool is also a big task, because the process is affected by the tool material also. The details of CNC milling machine are as follows:

Brand name- Ace Micromatic

Model name- MCV-350

Controller- FANUC Series oi-MF

Software used- NX

Number of AXIS- X, Y, and Z axis

The machine used for the experimentation is shown in the figure 5.1.

Fig. 5.1 CNC Milling Machine

For Iight of the work piece before and after the machining a Iight measurement device is needed. An electronic Iight measurement device is used and shown in the figure 5.2. Iight measurement is required for MMR calculation after experiment. For surface roughness calculations Mitutoyo surface roughness tester sj-210 is used. The surface roughness tester is shown in figure 5.3

Fig. 5.2 Iight Measurement Fig. 5.3 Mitutoyo Surface Roughness Tester Sj-210

After studying different published articles and research paper the cobalt bonded cemented carbide tool for end milling operation is selected. Tool is having 4 flutes with 16 mm diameter. The cutting tool used is shown in figure 5.4.

Table 5.1 Description of Cutter

Diameter	16mm
Brand	ASPHALT
Number of Flutes	4
End Type	Square End

Fig. 5.4 Cutting Tool

Cutting fluid or coolant is play a major role in any machining operation, the cutting fluid minimises friction generated at the contact surface, and also minimises the heat generated at that portion. Removal of the chips is also a major process, this process decreases failure of work piece and cutting tool, this work is also done by the cutting fluid or coolant. In this process the servo way – 68 lubricating oil is used. Properties of these oil is given in the table. 5.2.

Table 5.2 Properties of lubricating oil

Cutting fluid name	Manufacturer company	Kin. Viscosity cSt at 40ºC	Flash Point COC, ºC, Min.
Servo Way – 68	Indian oil	62 – 74	**170**

For the optimization of the milling output (minimization of surface roughness and maximization of MRR) three input parameters for end milling operations which are - feed, depth of cut and cutting velocity are selected. These are taken in a 3 level of input parameters as shown in table 5.3.

Table 5.3 Three level of input parameters

parameter	1 level	2 level	3 level
speed RPM	580	920	1700
feed mm/min	26	41	55
depth of cut mm	1.2	1.8	2.6

CHAPTER – VI

Methodology

6 METHODOLOGY

This method is used for mathematical modelling of the experimental data. By the Regression analysis I can create an equation or formula to examine statistical connection betIen input variable (predictor variable) and output variable (response). In statistical analysis, RSM regression is also a way for relationship modelling of independent & dependent variable.

Regression equation is giving the relation betIen input and output variable and so that the output behaviour can be calculated by using generated mathematical equation. For this purpose, Minitab software ®19 is used to generate mathematical equations and also for optimization.

Design of experiment (DOE)

Taguchi method is a statistical method, which is used for improvement in quality of products. According to Taguchi "Quality is the loss imparted to society from the time a product is shipped". Practical experimental methods are commonly costly and tedious and achieving the goal of planning with least number of directed tests is constantly a necessity. In this technique for the test condition an orthogonal array is spread out, which is for the most a developed table which guarantees straight imposition and consistency of the analysis or experimental design. by using Taguchi method, I can chive our results in short time with minimum cost.

Figure 6.1. Cost definition [2]

The Taguchi method of quality control is **an approach to engineering that emphasizes the roles of research and development (R&D), and product design and development in reducing the occurrence of defects and failures in manufactured goods.**

It involves three steps as:

- System design.
- Parameter design.
- Tolerance design.

CHAPTER –VII

MODELLING AND OPTIMIZATION

7. MODELLING AND OPTIMIZATION

Taguchi also gives the definition of signal to noise ratio (S/N). It is a performance measure, and objective is to maximize S/N by proper parameter selection. For the optimization purpose three input parameters and two output responses have been selected. The design of experiment (DOE) is conducted by Taguchi's L27 Orthogonal Array by using Minitab software ®19. Based on the 27 cases generated using Taguchi the experimentation is carried out on the CNC machine for the output response observation. The input parameters and output responses are shown in table 7.1. The input and output parameters are abbreviated as S, F, D, MRR, Ra for cutting speed, feed, depth of cut, material removal rate, and surface roughness respectively.

Table 7.1 Design of experiment and out Responses

S. No.	Cutting Speed (RPM)	Feed (mm/min)	Depth of Cut (mm)	MRR (mm^3/min)	Surface Roughness (µa)
1	580	26	1.2	408.424443	0.283
2	580	26	1.2	408.499202	0.193
3	580	26	1.2	412.650093	0.155
4	580	41	1.8	1291.64851	0.174
5	580	41	1.8	1288.94653	0.25
6	580	41	1.8	1298.4413	0.2
7	580	55	2.6	2039.73391	0.136

8	580	55	2.6	2040.86845	0.14
9	580	55	2.6	2047.20407	0.156
10	920	26	1.8	710.713049	0.175
11	920	26	1.8	706.207373	0.235
12	920	26	1.8	708.920188	0.214
13	920	41	2.6	1730.20056	0.195
14	920	41	2.6	1734.69087	0.15
15	920	41	2.6	1749.11817	0.192
16	920	55	1.2	1160.13072	0.187
17	920	55	1.2	1162.01423	0.217
18	920	55	1.2	1170.98166	0.273
19	1700	26	2.6	958.549671	0.198
20	1700	26	2.6	954.616588	0.238
21	1700	26	2.6	953.004892	0.281
22	1700	41	1.2	710.222222	0.176
23	1700	41	1.2	715.352449	0.166
24	1700	41	1.2	720.082632	0.189
25	1700	55	1.8	1469.02042	0.197
26	1700	55	1.8	1471.49009	0.194
27	1700	55	1.8	1472.13727	0.223

Regression Modelling using Response Surface Methodology (RSM)

The results obtained from the Taguchi and the 27 experiments are used for the regression mathematical modelling using Response surface methodology. This Regression is relating the process parameters to the response and generates a Mathematical equation. By this Mathematical equation all constraints can be formulated and further optimization can be performed by using Evolutionary algorithms. Regression means the effect analysis of variance is a tool to point out the effect of Error on Response/ output parameters, Main factor and interaction factor. The coded coefficients of MRR with respect to process parameter is shown in table 7.2 and table 7.3 represents the ANOVA analysis for MRR for full quadratic equation.

Table 7.2 Coded Coefficients

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	1260.16	3.01	418.33	0.000	
S	-101.39	1.16	-87.18	0.000	1.06
F	441.57	1.50	294.14	0.000	1.68

D	434.28	1.47	294.79	0.000	1.63
S*S	-19.26	2.43	-7.91	0.000	1.05
F*F	-108.22	2.35	-46.14	0.000	1.36
D*D	-7.83	2.40	-3.26	0.004	1.37
S*F	60.13	1.96	30.71	0.000	2.05
S*D	-0.65	1.95	-0.33	0.743	2.06

Table 7.3 Analysis of Variance for MRR

Source	**DF**	**Adj SS**	**Adj MS**	**F-Value**	**P-Value**
Model	8	6699655	837457	34636.21	0.000
Linear	3	3687238	1229079	50833.25	0.000
S	1	183785	183785	7601.14	0.000
F	1	2091863	2091863	86516.94	0.000
D	1	2101216	2101216	86903.76	0.000
Square	3	53303	17768	734.85	0.000
S*S	1	1514	1514	62.63	0.000
F*F	1	51481	51481	2129.21	0.000
D*D	1	258	258	10.66	0.004
2-Way Interaction	2	22833	11416	472.17	0.000
S*F	1	22804	22804	943.15	0.000
S*D	1	3	3	0.11	0.743
Error	18	435	24		
Total	26	6700090			

Table 7.4 Model Summary

S	**R-sq**	**R-sq(adj)**	**R-sq(pred)**

4.91718	99.99%	99.99%	99.99%

Table 7.4 shows the RSM full quadratic regression model summary for the MRR, which shows a high curve fitting capability as the value of R square is 99.99%. P- Value tells about the significance of parameters it should be ≤0.05 and the Rsq(adj) value should be ≥ 70%, here the values are 99.99% that is far better the required limit.

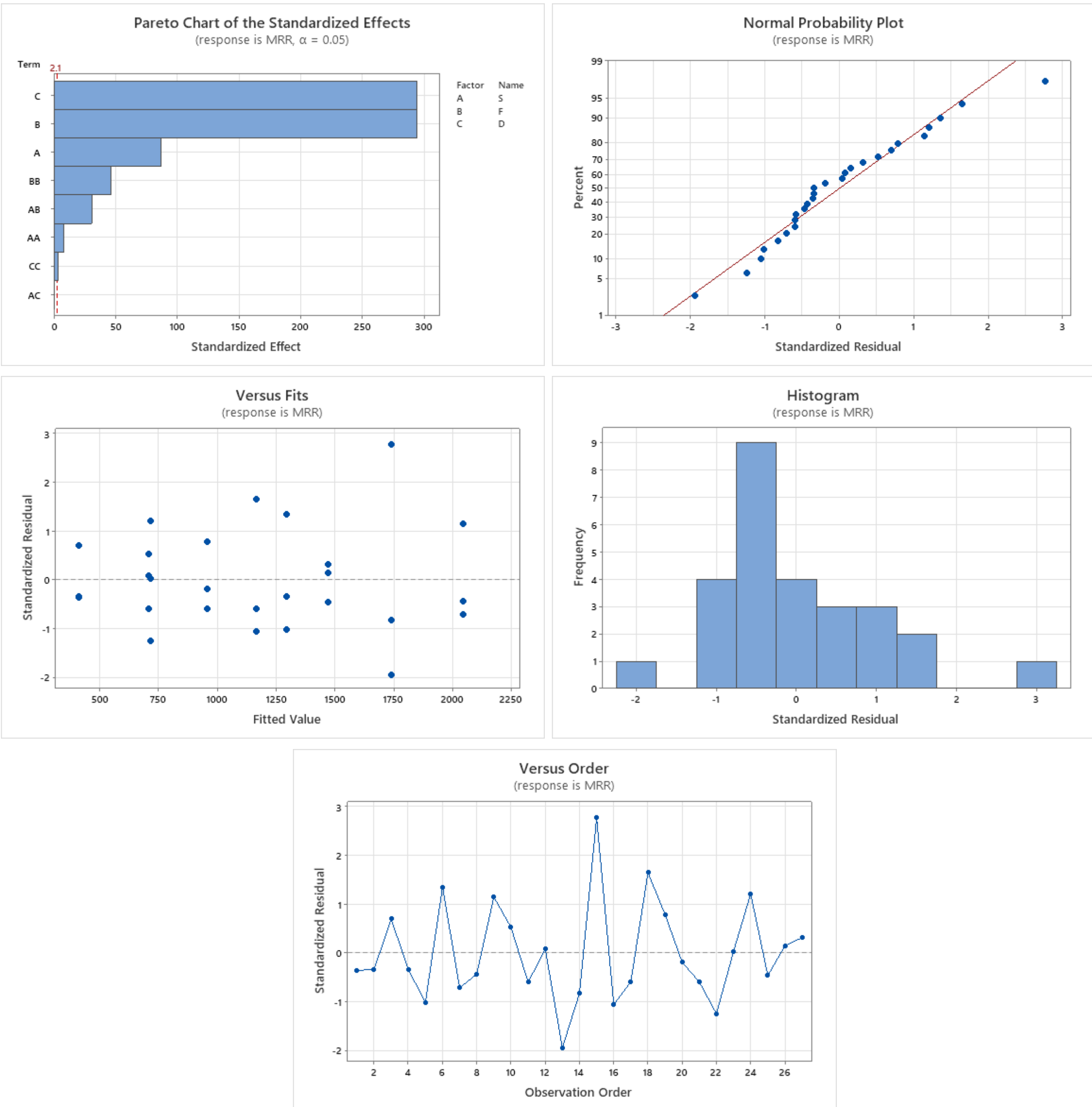


Fig. 7.1 Residual Plot for MRR

Figure 7.1 represents the 5 Residual plots for pareto standardized effect, normal probability plot, verses fit, histogram and verses order graphs. I can conclude that- in Normal probability plot are experimental result lie nearer to the probability line drown, which shows the readings are linear. From versus fit graph almost all value lies betIen 500 to 1500 hence it concludes that obtained values are in good agreement. Histogram show the frequency of the test result and the versus order plot shows the variation from positive and negative residual this shows calculated value are correct.

Table 7.5 Fits and Diagnostics for Unusual Observations

Obs	MRR	Fit	Resid	Std Resid	
15	1749.12	1738.00	11.11	2.77	R

Table 7.5 shows the fits and the diagnostics calculation for the coded MRR observation. Figure 7.1 represents the surface plots for MRR with respect to its input parameter combinations for representing the correlation among the input and the output parameters.

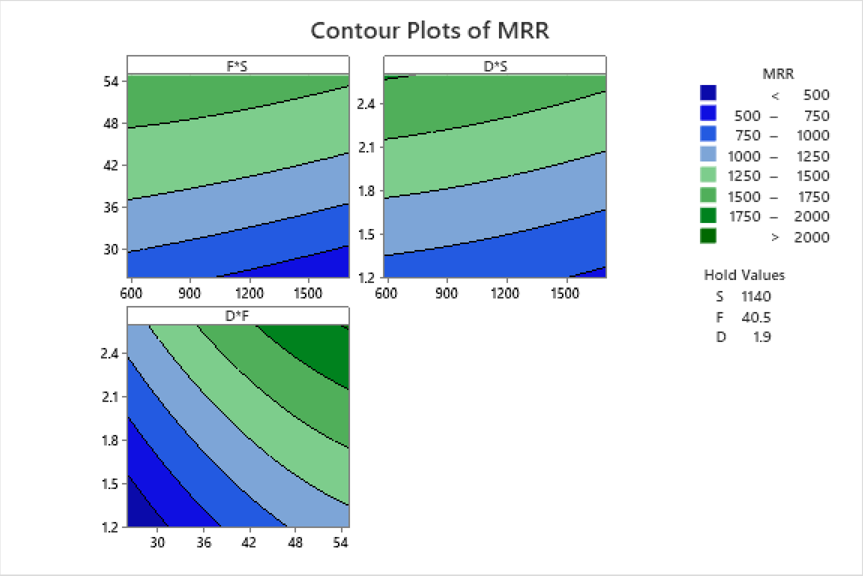


Fig. 7.2 Surface plot for MRR

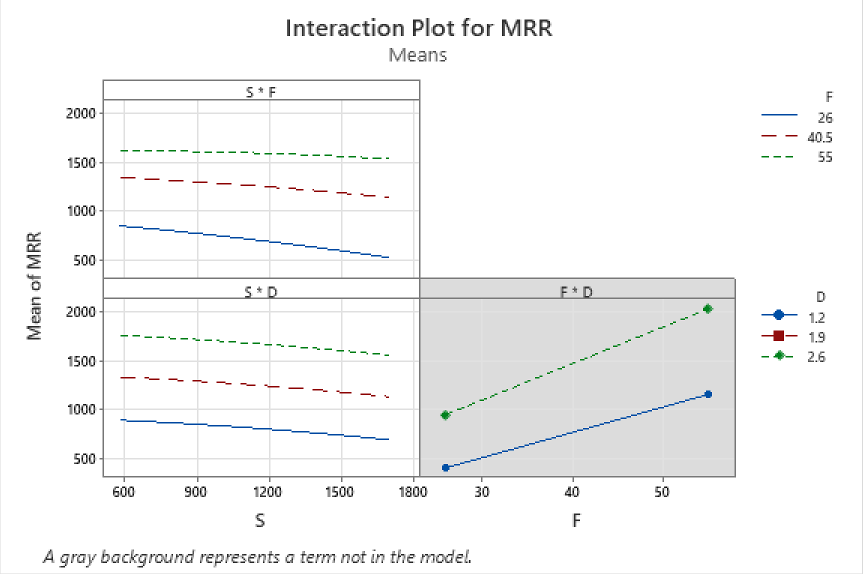


Fig. 7.3 Interaction plot for MRR

Figure 7.2 represents the interaction plot for the input variable and the statistical means of MRR. The regression equation generated for MRR through the RSM is shown in equation 1.

$$MRR = -1589.1 - 0.3377\,S + 63.703\,F + 683.0\,D - 0.000061\,S*S - 0.5147\,F*F - 15.98\,D*D + 0.007405\,S*F - 0.00166\,S*D \quad \ldots\ldots(1)$$

After the generation of regression equation for MRR now the ANOVA will be generated for surface roughness (Ra). The ANOVA for Ra is shown in the table 7.6. Table 7.6 is generated by considering the RSM 3^k factorial Box-Behan design.

Table 7.6 Analysis of Variance Ra

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	8	0.019621	0.002453	1.92	0.119
Linear	3	0.003390	0.001130	0.88	0.468
S	1	0.002442	0.002442	1.91	0.184
F	1	0.000084	0.000084	0.07	0.801
D	1	0.000764	0.000764	0.60	0.449
Square	3	0.002108	0.000703	0.55	0.655
S*S	1	0.000675	0.000675	0.53	0.477
F*F	1	0.000220	0.000220	0.17	0.683
D*D	1	0.001206	0.001206	0.94	0.344
2-Way Interaction	2	0.010351	0.005176	4.05	0.035
S*F	1	0.000753	0.000753	0.59	0.453
S*D	1	0.009460	0.009460	7.40	0.014
Error	18	0.023002	0.001278		
Total	26	0.042623			

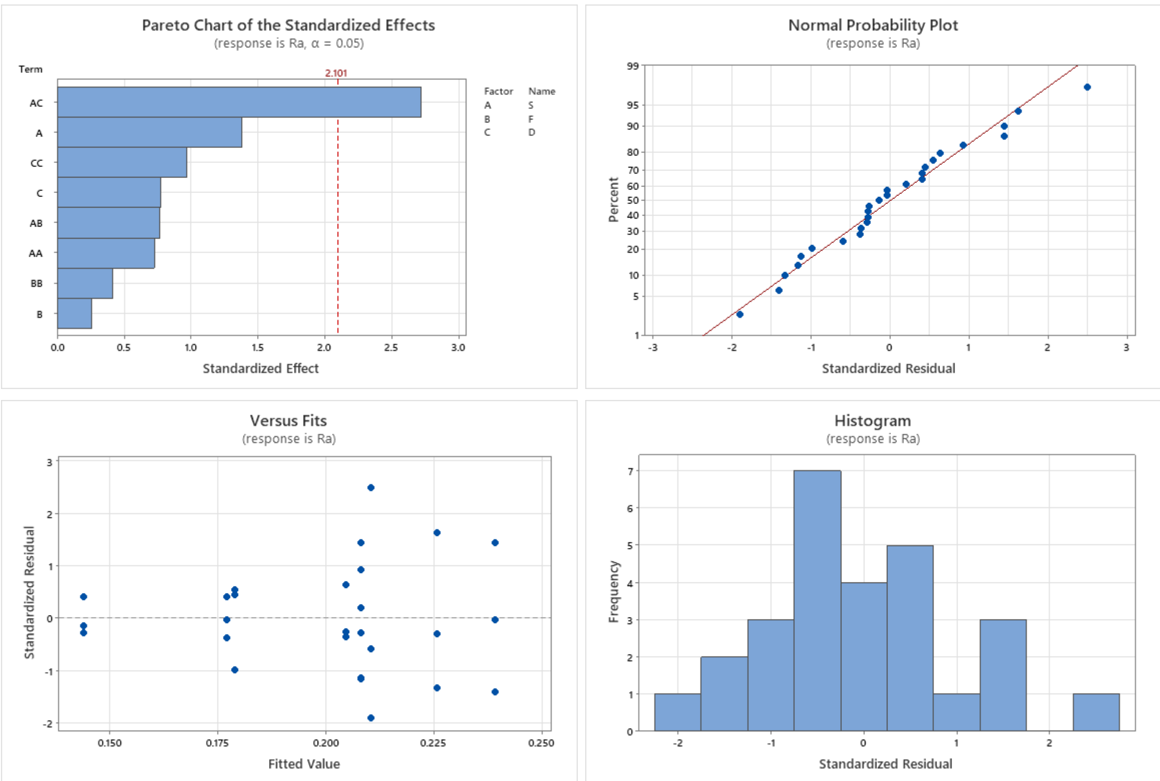
Table 7.7 Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0.0357476	***96.03%***	***95.05%***	***96.00%***

Table 7.8 Fits and Diagnostics for Unusual Observations

Obs	Ra	Fit	Resid	Std Resid	
1	0.2830	0.2103	0.0727	2.49	R

Table 7.7 and 7.8 represents the RSM regression model summary and the fits and diagnostics observations tables. Here the value of R-sq is 96.03% represents a good curve fitting model for further calculation of optimum response variables.



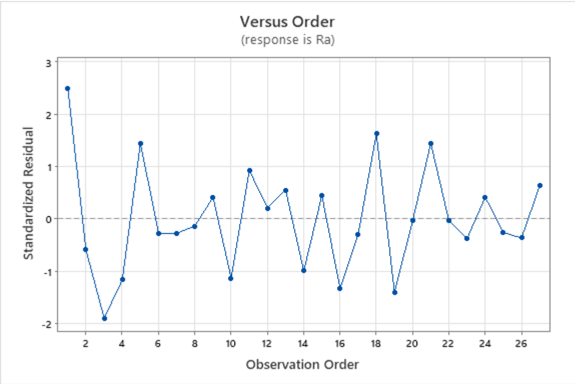


Fig. 7.4 Residual plot For Ra

Figure 7.4 represents the 5 Residual plots for pareto standardized effect, normal probability plot, verses fit, histogram and verses order graphs for surface roughness (Ra).

The regression equation generated for Ra through the RSM is shown in equation 2.

Ra = 0.134 - 0.000018 S + 0.00445 F + 0.007 D - 0.000000 S*S - 0.000034 F*F
-0.0346 D*D
- 0.000001 S*F
+ 0.000098 S*D……………………………………………………(2)

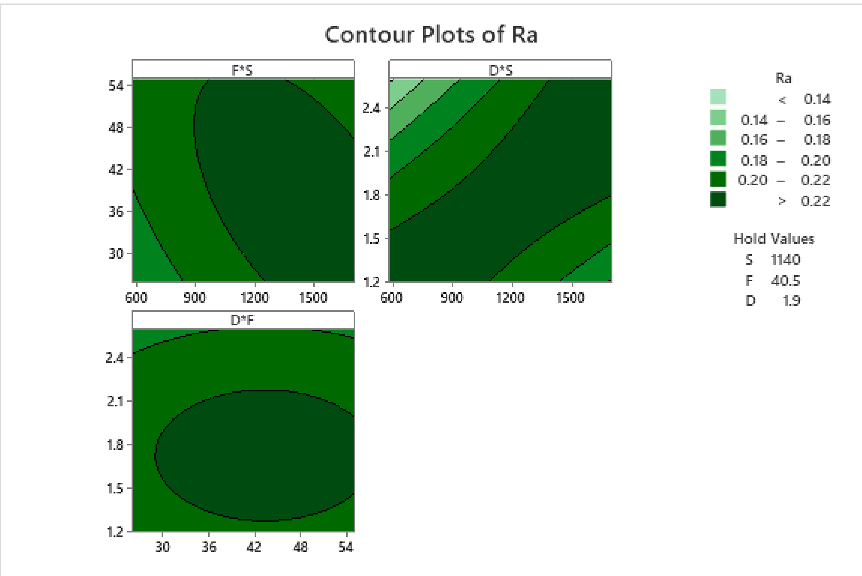


Fig. 7.5 Surface plot for Ra

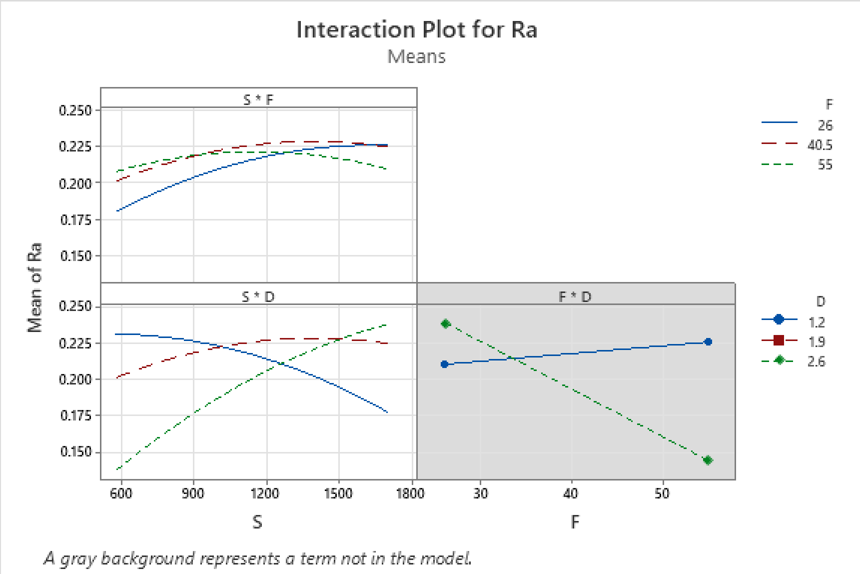


Fig. 7.6 Interaction plot for Ra

Figure 7.5 represents the surface plots for Ra with respect to its input parameter combinations for representing the correlation among the input and the output parameters. Figure 7.6 represents the interaction plot for the input variable and the statistical means of Ra.

Optimization by Surface Response Optimizer

The RSM regression equations for MRR and Ra responses will be utilized to optimized the output responses. The MRR is required to be high whereas the surface roughness needs to loIr. For the required condition the setting parameters are defined and shown in table 7.9.

Table 7.9 Goal setting Parameters

Response	Goal	LoIr	Target	Upper	light	Importance
Ra	Minimum		0.14	0.283	1	1
MRR	Maximum	408.424	2047.20		1	1

Table 7.10 shows the three feasible candidates of optimum results for multi-objective optimization with the help of response surface optimizer with desirability function. Also the table 7.10 depicts the composite desirability value as 0.971 for the solution 1 which shows a very good optimum values for the output responses MRR and RA.

Table 7.10 Optimum Result

Solution	S	F	D	Ra Fit	MRR Fit	Composite Desirability
1	580	55.0000	2.60000	0.144000	2042.60	0.971042
2	580	26.0000	2.60000	0.116564	1279.72	0.729160
3	580	50.6518	2.09826	0.192682	1678.85	0.690147

Table 7.11 Multiple Response Prediction

Variable	Setting
S	580
F	55
D	2.6

Response	Fit	SE Fit	95% CI	95% PI
Ra	0.1440	0.0206	(0.1006, 0.1874)	(0.0573, 0.2307)
MRR	2042.60	2.84	(2036.64, 2048.57)	(2030.67, 2054.53)

Table 7.11 shows the optimum value of Ra and MRR as 0.1440 µa and 2042.60 mm^3/min respectively for the input parameter combination as 580 rpm spindle speed, 55 mm/min feed rate, and 2.6 mm depth of cut.

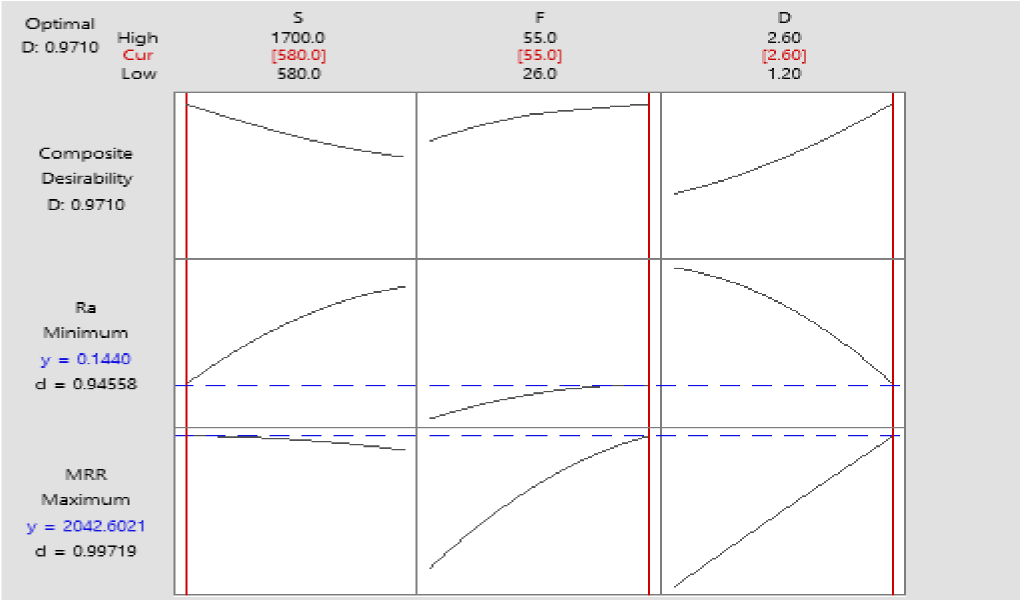


Fig. 7.7 Variation of Output response vs. Input parameters

Figure 7.7 shows the result obtained for Output parameters with respect to optimum input parameter with the desirability function for response surface optimizer. This input and output parameters are further tested in the CNC machine experimentally and the result shows in agreement with predicted optimum values with 2% variations.

CHAPTER – VII

CONCLUSIONS

8. CONCLUSIONS

This research work is basically working on optimization of milling process parameters on End milling process. Here 3 input variable and 2 output response Ire selected. Input variables are cutting speed, Feed rate, and Depth of cut and Output responses are Material removal rate and Surface roughness.

The research work is carried out for Aluminium 6061-T6 alloy material, to provides the best output result, which can be used in milling process of the material. The Aluminium is the most used alloy in the present day in daily life as Ill as in industry. Aluminium is used due to its light Iight due to less density as Ill as due to its oxidization resistance property. End milling process is vastly used process in the industry now these days. The output response MRR and Ra are extremely important parameters for milling process.

In this work the design of experiment is done by using Taguchi L27 method to get the combination of input parameter to explore the proper design space. Regression analysis has also been performed on using RSM and the optimization of the responses Ire carried out using multi-objective response surface optimizer to enhance MRR and reduce the Ra values. This research work provides a very important method the perform the milling operation for the AL6061 material.

CHAPTER – IX

REFERENCES

9. References

[1] Pooernesh, M., Harish, N., & Aithal, K. (2016). Study of mechanical properties of aluminium alloy composites. *American Journal of Materials Science*, *6*(4), 72-76.

[2] Girisha, K. B., & Chittappa, H. C. (2013). Preparation, characterization and Iar study of aluminium alloy (Al 356.1) reinforced with zirconium nano particles. *Int. J Innova. Res Sci Eng. Techno*, *2*, 3627-3637.

[3] Dağdelen, E., & Ulus, A. (2016). Aluminum Sheet Production: Heat Treatment of Aluminium and Temper Designations of Aluminium Alloys. *Uluslararası Metalurji ve Malzeme Kongresi*, 681-684.

[4] Dasgupta, R. (2012). Aluminium alloy-based metal matrix composites: a potential material for Iar resistant applications. *International Scholarly Research Notices*, *2012*.

[5] Suresh, S., Venkatesan, K., & Rajesh, S. (2019). Optimization of process parameters for friction stir spot Ilding of AA6061/Al2O3 by Taguchi method. In *AIP Conference Proceedings* (Vol. 2128, No. 1, p. 030018). AIP Publishing LLC.

[6] Bhuiyan, T. H., & Ahmed, I. (2014). Optimization of cutting parameters in turning process. *SAE International Journal of Materials and Manufacturing*, *7*(1), 233-239.

[7] Zhou, G., Zhang, C., Lu, F., & Zhang, J. (2020). Integrated optimization of cutting parameters and tool path for cavity milling considering carbon emissions. *Journal of Cleaner Production*, *250*, 119454.

[8] Hou, T. H., Lin, K. Y., & Lin, C. (2013). Application of a revised multi-objective genetic algorithm to parameters optimization of a solar cell manufacturing process. In *2013 Ninth International Conference on Natural Computation (ICNC)* (pp. 412-417). IEEE.

[9] Pradhan, M. K., & Tiwari, A. (2018). Modelling and optimisation of end milling parameters on Ti-6Al-4V titanium alloy using TLBO algorithm and TOPSIS algorithm. *International Journal of Machining and Machinability of Materials*, *20*(6), 513-535.

[10] Krohling, R. A., & Pacheco, A. G. (2015). A-TOPSIS–an approach based on TOPSIS for ranking evolutionary algorithms. *Procedia Computer Science*, *55*, 308-317.

[11] Yu, L., Yang, W., Duan, Y., & Long, X. (2018). A study on the application of coordinated TOPSIS in evaluation of robotics academic journals. *Mathematical Problems in Engineering*, *2018*.

[12] Krohling, R. A., & Campanharo, V. C. (2011). Fuzzy TOPSIS for group decision making: A case study for accidents with oil spill in the sea. *Expert Systems with applications*, *38*(4), 4190-4197.

[13] Robinson, J. P., & Amirtharaj, E. H. (2013). A Strategic TOPSIS algorithm with correlation coefficient of interval vague sets. *International Journal of Computing Algorithm*, *2*, 314-331.

[14] Metta, H. (2008). Adaptive, multi-objective job shop scheduling using genetic algorithms.

[15] Salihu, I. A., Ibrahim, R., Ahmed, B. S., Zamli, K. Z., & Usman, A. (2019). AMOGA: A static-dynamic model generation strategy for mobile apps testing. *IEEE Access*, *7*, 17158-17173.

[16] Chang, P. C., Hsieh, J. C., & Wang, C. Y. (2007). Adaptive multi-objective genetic algorithms for scheduling of drilling operation in printed circuit board industry. *Applied soft computing*, *7*(3), 800-806.

[17] Dewangan, S., & Rathore, R. K. (2019). Review on Cutting Process Parameter for Surface Roughness during Turning Operation. *parameters*, *6*(03).

[18] Dewangan, S., & Rathore, R. K. (2019). Analysis of Cutting Process Parameter during Turning of EN 31 for Minimum Surface Roughness Using Taguchi Method. *International Research Journal of Engineering and Technology (IRJET).*, *6*, 832-834.

[19] Rathore, R. K., Sarda, A., & Chandrakar, R. (2012). An Approach to optimize ANN Meta model with Multi Objective Genetic Algorithm for multi-disciplinary shape optimization. *International Journal of Soft Computing and Engineering (IJSCE) ISSN*, 2231-2307.

[20] Ajinkya Ramrao Yadav, Rahul D. Selke, Navnath S. Kalyankar, (2020). Study and Comparative Analysis of Effect of SiC and Graphite Composite on Aluminiun using RSM Methodology. *International Journal of Engineering Research & Technology (IJERT),* 09, 12 (December 2020)

CHAPTER- X

BIBLIOGRAPHY

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