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Optimization of Machining Parameter on CNC Leadwell of SS304l by using Topsis Method

Shashank Rathore[1], Nitin Shukla[2]
[1]Department Of Mechanical Engineeing, Dr.C V Raman University Kota Bilaspur

Abstract: The main challenge in manufacturing industry is to optimize the energy consumption. Energy mainly consumes by machine tools in turning, drilling, boring processes, etc. The present work is to optimize the parameters cutting velocity, feed and depth of cut .while turning operation to maximize the material removal rate (MRR) and to minimize the surface roughness (SR) in a LEADWELL CNC MACHINE on AISI 304 austenitic stainless steel. Stainless steel has been chosen because it has unique properties like corrosion resistance, heat resistance, welding, Excellent weld ability by all standard fusion Heat Treatment etc. which can be taken advantage of in variety of applications in construction industries whilst at the same time being tough, hygienic, adaptable, and recyclable. Turning is one of the important and widely used machining processes in engineering industry. Experiments are design based on Taguchi orthogonal array and process parameters are optimized by using TOPSIS.
Keywords: TOPSIS, SS304L.

I. INTRODUCTION

A. Turning

Turning is a machining process to produce parts round in shape by a single point tool on lathes. The tool is fed either linearly in the direction parallel or perpendicular to the axis of rotation of the work piece, or along a specified path to produce complex rotational shapes. The primary motion of cutting in turning is the rotation of the workpiece, and the secondary motion of cutting is the feed motion.

B. Stainless Steel Material

Iron and the most common iron alloy steel are, from a corrosion view point, relatively poor materials as they rust in air, corrode in acids and scale in furnace atmosphere. In spite of this there is a group of iron base alloys, the iron-chromium-nickel alloys known as stainless steels, which are resistant to concentrated acids, alkalis and which do not scale under temperatures upto 1100˚C. The most widely used stainless steels are the austenitic 18/8 type steels, i.e. AISI 304 and AISI 304L, which form more than 50% of the global production of stainless steels. The next most widely used grades are the ferritic steels such as AISI 410 followed by the molybdenum-alloyed steels AISI 316 and AISI 316L. Together these grades make up over 80% of the total tonnage of stainless steels. Stainless steels with their excellent corrosion properties have a very broad application range. This extends to Chemical plants, Dairy and Food processing industries, Nuclear power plants, Heat exchangers, Laboratory benches and Equipments.

C. Sensitization Of Stainless Steels

In Sensitization process chromium carbides (Cr23C6) precipitate at the grain boundaries even atelevated temperatures, typically between 450 – 850° C. As a result, some chromium is lost and eventually reduces the corrosion resistance property of the Stainless steels4. This results in reduced ductility, toughness and aqueous corrosion resistance. Except the 'L' grade stainless steels all the other stainless steels are easily susceptible to sensitization**.**

TABLE 1.1 COMPOSITION OF 304L SS

ALLOY GRADE	C	Mn	P	S	Si	Cr	Ni	Mo
304L	0.01	1.638	0.023	0.002	0.412	.18.56	8.138	0.364

D. Surface Integrity

In machining, a surface can be defined as a border between a machined component and its environment. The term 'surface integrity' is used to describe the attributes of a machined surface and its relationship to functional performance.

In general, surface integrity can be divided into two aspects: the external topography of surfaces (surface finish); and the microstructure, mechanical properties and residual stresses of internal subsurface layers. Performance characteristics that are usually sensitive to surface integrity include; fatigue strength, fracture strength, corrosion rate, and tribological behavior (such as friction, wear and lubrication, and dimensional accuracy). The surface integrity plays a very important role in this functional performance, being dependent of a large number of machining parameters. The major concern of the industry is to know which combination of machining parameters provides a better surface integrity of the machined components**.**

E. TOPSIS

Topsis (technique for order preference by similarity to ideal solution) method was firstly proposed by (Hwang and Yoon 1981).
Technique for Order Preference by Similarity to Ideal Solution• Yoon and Hwang introduced the TOPSIS method based on the idea that the best alternative should have the shortest distance from the positive ideal solution and farthest distance from the negativeideal solution. method are discussed in experimental procedure topic

F. Project Problem Definition

The objective of this work is to optimize the parameters cutting velocity, feed depth of cut while turning operation to maximize the material removal rate (MRR) and to minimize the power consumption (P), surface roughness(Ra) ,Micro hardness(HV) and cutting force (Fc) in a LEADWELL CNC MACHINE on AISI 304L austenitic stainless Steel.Optimisation process was done by TOPSIS of ranking approach.Application of regression analysis is used for finding the significant parameter.Model was developed using artificial neural network (ANN) algorithm to relate the responses with input variables

II. LITERATURE SURVEY

Generally the Taguchi method is using to optimize the performance characteristics of process parameters to achieve high quality [1, 2]. However, reports on Taguchi have been concerned with the optimization of a single performance characteristic [3].So for the more demanding multiple performance characteristics is still an interesting research problem

A. Literature Survey On Regression Analysis

Ashok Kumar Sahoo and Swastik Pradhan (2013) this paper presents the influence of process parameters. They using TAGUCHI experiment design for experiment on different parameter and also used ANOVA and least square method is adopted in regression analysis to find the coefficients of equation. And they calculated predicted value of responses parameter [4].
Carmita Camposeco-Negrete (2013) he presented to optimize cutting parameters during Turning of AISI 6061 T6 under roughing conditions in order to get the minimum energy consumption. An orthogonal array, signal to noise (S/N) ratio and analysis of variance (ANOVA) and they concluded according to influence of factor in different cases . [5].
Debabrata Mandal et al. (2007) they using soft computing techniques. Artificial neural network (ANN) with back propagation algorithm is used to model the process and regration analysis [6].
Rajesh Kumar Bhushan (2013) they used response surface methodology. Face cantered central composite Design (FCCD) for three level design and experimentally collected data were subjected to ANOVA and desirability function analysis for optimization of machining parameters [9].

B. Literature Survey On Topsis

Ashvin J et al. (2013) in this paper, application of RSM on the AISI 410 steel is carried out for turning operation. A quadratic model has been developed for surface roughness (Ra) to investigate the influence of machining parameters. [11].
Hae-Sung Yoon et al. (2013) works related to the optimization of energy consumption of machine tools have been carried Control of machining parameters for energy and cost savings in Micro-scale drilling of PCBs [12] .
B. C. Rautara et al. (2012) works related to the optimization of energy consumption in this paper response surface methodology has been applied to determine optimum parameter of machining in cnc turning operation on EN 8 steel. And the machining was carried by coted carbide tool. [13].

III.OBJECTIVES OF PROJECT WORK

Objectives of study are as follows

A. To determine the optimum input parameter (speed, feed and depth of cut) for turning process on LEADWELL CNC to maximize the MRR and surface roughness.
B. To develop model by Regration analysis and study the turning process of stainless steel 304L on CNC.
C. Modelling and Optimizing the Machining parameter by TOPSIS method

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IV. POSSIBLE OUTCOMES

A. To get machining data
B. Optimization by TOPSIS
C. To get optimum parameter to get max MRR and low surface roughness.

V. EXPERIMENTAL WORK

A. Experimental Setup

Vickers MicroHardness was measured on the surface at three location with 0.5kgf indentation using dwell time equal to 10 seconds of each sample.Cutting forces were measured by Kistler force dynamometer mounted on CNC bead .Turning tests were conducted with coated tungsten carbide inserts with an ISO designation CNMG 120404 was used. The inserts were mounted on a tool holder with an ISO designation PCLNL 1610 M12.

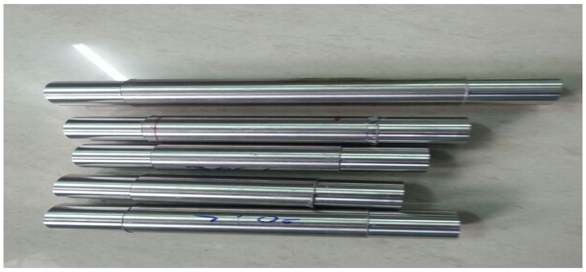

Fig 5.1 work piece material after turning

B.Material

SS304L of diameter 26 mm and cutting length 20mm

TABLE 5.1 PHYSICAL PROPERTIES OF 304LGRADE STAINLESS STEEL

Density (kg/m3)	Density (kg/m3)	Elastic Modulus (GPa)	Mean Coefficient of Thermal Expansion (µm/m/°C)			Thermal Conductivity (W/m.K)		Specific Heat 0-100°C (J/kg.K)	Electrical Resistivity (nΩ.m)
304L	8000	193	100°C	315° C	538°C	100 °C	500 °C	500	720
			17.2	17.8	18.4	16.2	21.25		

C. Machine

LEADWELL CNC turning center with maximum speed of 4500 rpm

TABLE 5.2 SPECIFICATION OF MACHINE

Max swing diameter	330mm
Max swing one slide diameter	136mm
Max turning diameter	136mm
turning length	150mm
Travel - x axis	230mm
y axis	230mm
Spindle motor power	7.5kw
No of tools	6
Feed range	0-24000mm/min

D. Experimental Parameter And Design

Here the performance study of CNC Turning is proposed to make on stainless steel 304L .the experiment Has been done on LEAD WELL CNC leth. The work piece material used in 304L .because its wide use in industry. Tool material used for turning is carbide in the form of rhombus .its contain four cutting edge. The code of insert is CNMG120404 made by tungsten carbide in .this experiment the cutting condition used as controlling parameter are speed (m/min) ,feed(mm/rev) depth of cut. its varies in between there level,(level 1,2,3) and response parameter is surface roughness(micro mm),and metal removal rate(mm^3/min)

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E. Experimental results

TABLE 5.3 ORTHOGONAL DESIGN WITH EXPERIMENTAL RESPONSE VALUE

s. no.	Speed	Feed	DOC	Ra	MRR
1	100	0.1	0.3	1.133	2.355
2	100	0.15	0.6	1.500	4.71
3	100	0.2	0.9	2.007	7.067
4	150	0.1	0.6	1.110	7.06
5	150	0.15	0.9	1.013	10.59
6	150	0.2	0.3	2.353	3.53
7	200	0.1	0.9	1.490	14.13
8	200	0.15	0.3	1.497	4.71
9	200	0.2	0.6	2.077	9.42

The most valuable use of regression is in making predictions. The general purpose of multiple regressions is to learn more about the relationship between several independent or predictor variables and a dependent or criterion variable.
It can be used for a variety of purposes such as analyzing of experimental, ordinal, or categorical data. The data presented in Table 4 have been used to build the multiple regression model

Exp. No	speed	feed	doc	Ra	MRR
1	100	0.1	0.3	1.182763	1.76488
2	100	0.1	0.45	1.124452	3.530875
3	100	0.1	0.6	1.06614	5.29687
4	100	0.1	0.75	1.007829	7.062865
5	100	0.1	0.9	0.949518	8.82886
6	100	0.125	0.3	1.366666	1.47088
7	100	0.125	0.45	1.270649	3.236875
8	100	0.125	0.6	1.174633	5.00287
9	100	0.125	0.75	1.078616	6.768865
10	100	0.125	0.9	0.982599	8.53486
11	100	0.15	0.3	1.706608	1.17688
12	100	0.15	0.45	1.572886	2.942875
13	100	0.15	0.6	1.439164	4.70887
14	100	0.15	0.75	1.305442	6.474865
15	100	0.15	0.9	1.17172	8.24086
16	100	0.2	0.3	2.854609	0.58888
17	100	0.2	0.45	2.645476	2.354875
18	100	0.2	0.6	2.436342	4.12087
19	100	0.2	0.75	2.227209	5.886865
20	100	0.2	0.9	2.018076	7.65286
21	125	0.1	0.3	1.077916	2.942213
22	125	0.1	0.45	1.042733	4.708208
23	125	0.1	0.6	1.007549	6.474203
24	125	0.1	0.75	0.972366	8.240198
25	125	0.1	0.9	0.937182	10.00619
26	125	0.125	0.3	1.214747	2.648213
27	125	0.125	0.45	1.141858	4.414208
28	125	0.125	0.6	1.068969	6.180203
29	125	0.125	0.75	0.99608	7.946198
30	125	0.125	0.9	0.923191	9.712193

31	125	0.15	0.3	1.507616	2.354213
32	125	0.15	0.45	1.397022	4.120208
33	125	0.15	0.6	1.286428	5.886203
34	125	0.15	0.75	1.175833	7.652198
35	125	0.15	0.9	1.065239	9.418193
36	125	0.2	0.3	2.561472	1.766213
37	125	0.2	0.45	2.375467	3.532208
38	125	0.2	0.6	2.189461	5.298203
39	125	0.2	0.75	2.003456	7.064198
40	125	0.2	0.9	1.81745	8.830193
41	150	0.1	0.3	1.073275	4.119545
42	150	0.1	0.45	1.061219	5.88554
43	150	0.1	0.6	1.049163	7.651535
44	150	0.1	0.75	1.037108	9.41753
45	150	0.1	0.9	1.025052	11.18353
46	150	0.125	0.3	1.163033	3.825545
47	150	0.125	0.45	1.113272	5.59154
48	150	0.125	0.6	1.063511	7.357535
49	150	0.125	0.75	1.01375	9.12353
50	150	0.125	0.9	0.963988	10.88953
51	150	0.15	0.3	1.40883	3.531545
52	150	0.15	0.45	1.321364	5.29754
53	150	0.15	0.6	1.233897	7.063535
54	150	0.15	0.75	1.14643	8.82953
55	150	0.15	0.9	1.058963	10.59553
56	150	0.2	0.3	2.368541	2.943545
57	150	0.2	0.45	2.205663	4.70954
58	150	0.2	0.6	2.042785	6.475535
59	150	0.2	0.75	1.879908	8.24153
60	150	0.2	0.9	1.71703	10.00753
61	175	0.1	0.3	1.168839	5.296878
62	175	0.1	0.45	1.179911	7.062873
63	175	0.1	0.6	1.190983	8.828868
64	175	0.1	0.75	1.202055	10.59486
65	175	0.1	0.9	1.213127	12.36086

66	175	0.125	0.3	1.211525	5.002878
67	175	0.125	0.45	1.184892	6.768873
68	175	0.125	0.6	1.158258	8.534868
69	175	0.125	0.75	1.131625	10.30086
70	175	0.125	0.9	1.104991	12.06686
71	175	0.15	0.3	1.41025	4.708878
72	175	0.15	0.45	1.345911	6.474873
73	175	0.15	0.6	1.281572	8.240868
74	175	0.15	0.75	1.217233	10.00686
75	175	0.15	0.9	1.152894	11.77286
76	175	0.2	0.3	2.275815	4.120878
77	175	0.2	0.45	2.136065	5.886873
78	175	0.2	0.6	1.996315	7.652868
79	175	0.2	0.75	1.856565	9.418863
80	175	0.2	0.9	1.716815	11.18486
81	200	0.1	0.3	1.364609	6.47421
82	200	0.1	0.45	1.398809	8.240205
83	200	0.1	0.6	1.433009	10.0062
84	200	0.1	0.75	1.467209	11.7722
85	200	0.1	0.9	1.501408	13.53819
86	200	0.125	0.3	1.360223	6.18021
87	200	0.125	0.45	1.356717	7.946205
88	200	0.125	0.6	1.353211	9.7122
89	200	0.125	0.75	1.349705	11.4782
90	200	0.125	0.9	1.3462	13.24419
91	200	0.15	0.3	1.511875	5.88621
92	200	0.15	0.45	1.470664	7.652205
93	200	0.15	0.6	1.429452	9.4182
94	200	0.15	0.75	1.388241	11.1842
95	200	0.15	0.9	1.34703	12.95019
96	200	0.2	0.3	2.283295	5.29821
97	200	0.2	0.45	2.166673	7.064205
98	200	0.2	0.6	2.050051	8.8302
99	200	0.2	0.75	1.933429	10.5962
100	200	0.2	0.9	1.816806	12.36219

F. Regression

By using Mini tab following formula is used to calculate for Response parameter
Development of regression model
Ra= (2.67582 - 0.0165495* speed - 10.1828*feed + 0.0000801645* speed*speed - 0.075316 *speed*feed+ 0.00616739 *speed*doc + 124.831*feed*feed - 10.0548* feed*doc)
MRR= (-5.30044 + 0.0470933*speed - 11.76*feed + 11.7733*doc)

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G. Optimization By Using Topsis Technique

The step involved in TOPSIS method is as follows In weighted normalized matrix the weighted for surface roughness is 0.2 ,MRR (0.2), Fc (0 .2) ,P(.3) and HV(.1) is taking for calculation of matrix data. Total sum of different response weights is zero.

This step involves the development of matrix format. The row of this matrix is allocated to one alternative and each column to one attribute. The decision making matrix can be expressed as:

$$D = \begin{matrix} A_1 \\ A_2 \\ . \\ A_i \\ . \\ A_m \end{matrix} \begin{pmatrix} X_{11} & X_{12} & . & X_{1j} & X_{1n} \\ X_{21} & X_{22} & . & X_{2j} & \\ X_{2n} & & & & \\ . & . & . & . & . \\ X_{i1} & X_{i2} & . & X_{ij} & . \\ . & . & . & . & . \\ X_{m1} & X_{m2} & . & X_{mj} & \end{pmatrix}$$

1) *Step 1:* Construct normalized decision matrix.

$$Rij = \frac{xij}{\sqrt{\sum_{i=0}^{n} xij^2}}$$

2) *Step2.*Calculate the weighted normalized decision matrix v = [vij] . The weighted normalized value vij is calculated as
vij = (wj)*(Rij) i=1,2……m,j=1,2,… n where wj is the weight of the jth attribute and $\sum_{j=1}^{n} wj = 1$

3) *Step 3.* Determine the positive ideal solution (PIS) V+ and negative ideal solution (NIS) V□.

$$V+ = \{(\max v_{ij} \mid j \in J), (\min v_{ij} \mid j \in J'), i=1,2\ldots m\} = \{V1+, V2+\ldots\ldots Vn+\}$$

$$V- = \{(\min v_{ij} \mid j \in J), (\max v_{ij} \mid j \in J'), i=1, 2\ldots m\} = \{V1-, V2-\ldots\ldots Vn-\}$$

Where J is a set of benefit attributes and J' is a set of cost attributes.

4) *Step 4.* Calculate the separation measures, using the n□dimensional Euclidean distance.

The separation of each alternative from the positive ideal solution i=I, 2….m

$$s + i = \sqrt{\sum_{j=1}^{n} (vij - v + j)\text{^}2}$$

The separation of each alternative from the negative ideal solution

$$s - i = \sqrt{\sum_{j=1}^{n} (vij - v - j)\text{^}2}$$

Calculate the relative closeness to the ideal solution

$$Ci = \frac{s-i}{s-i+s+i} \qquad 0 \le Ci \le 1$$

Rank the alternatives with respect to Ci in descending order.

By using experimental data decision matrix is designed.

TABLE SEPARATION VALUE AND IDEAL SOLUTION

V^+_{MRR}	0.018969
V^-_{MRR}	0.000825
V^+_{RA}	0.006378
V^-_{RA}	0.01972

Positive ideal solution (PIS) V+ and negative ideal solution (NIS) V-

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VI. RESULTS AND DISCUSSION

According to Taguchi philosophy the use of loss function to measure the deviation between the experimental value and the desired value which is further transformed into signal-to-noise ratio (S/N). Basically, there are three types of categories in the evaluation of signal-to-noise ratio i.e.

Lower-the-better (LB), higher-the-better (HB) and nominal- the-better (NB) [20]. The objective of paper is to optimize the process parameter for MRR, and surface roughness (Ra). And for finding MRR higher the better has been taken to calculate the signal to noice ratio .and lower-the-better characteristic has been taken to calculate the other response parameter.

The optimal parameters were chosen based on higher S/N ratio as signal represents desirable value and noise represents undesirable value. Next, statistical analysis of variance (ANOVA) was conducted to study the significance of process parameters on responses based on their P-value and F-value at 95% confidence level.

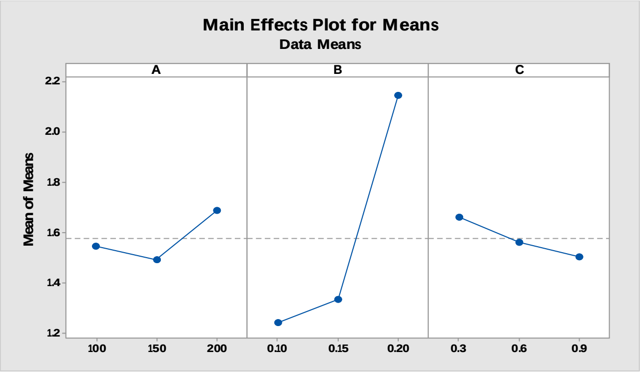

Figure 6.1 main effect plot (Ra) for mean

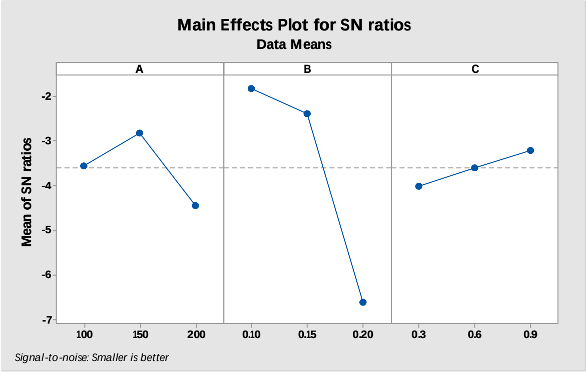

Fig 6.2 main effect plot for S/N ratio

From the above figure 6.1 we can see that as cutting speed increases from 100 to 150 m/min there is linearly decreases in surface roughness and it follows the reverse trend up to cutting speed value of 200m/min. According to main effect plots, average surface roughness is the lowest at levels speed 2, feed 1, DOC 3.

In the above figure 6.2 the s/n ratio of the surface roughness for corresponding parameter like speed, feed and DOC are most favorable at the point at A2, B1 and C3. So with the help of s/n ration graph and mean graph conclude that for minimum surface roughness the velocity should be average and feed should be minimum.

Fig 6.3 main effect plot (MRR) for means

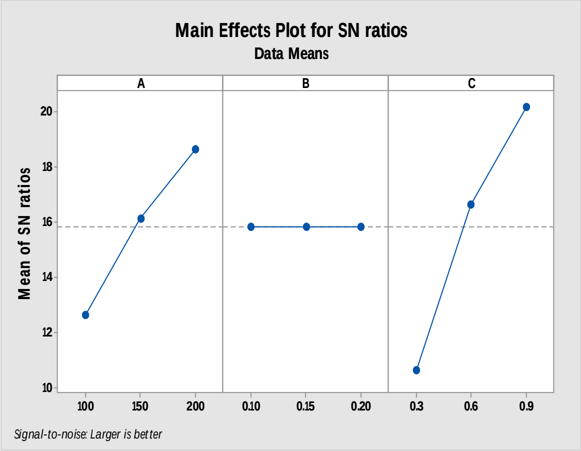

Fig 6.3 main effect plot (MRR) for S/N ratios

From the above figure6.3 we can see that as cutting speed increases from 100 to 150 m/min there is linearly increase in MRR and it follows the same trend up to cutting speed value of 200m/min . According to main effect plots, average MRR is the highest at levels speed3, feed1, and doc3 and the below figure 6.4 shows the data S/N ratio of MRR with respect to speed feed and DOC.

In the below figure 6.5 dark blue shaded areas show the lowest the surface roughness and darker green showed the higher surface roughness. And figure 6.4 contours plot of MRR vs A, B dark green show the High MRR and its value lies close to feed 0.10 and speed about 200 m/min.

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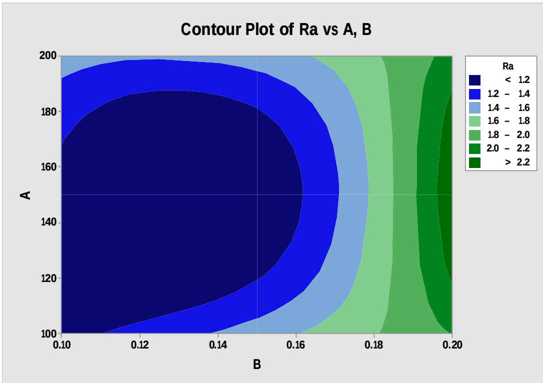

Figure 6.4 contour Plot of Ra Vs A, B

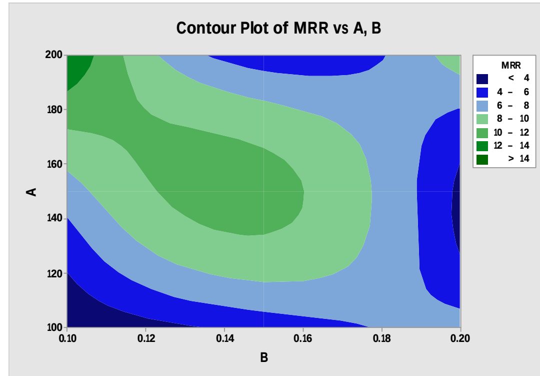

Figure 6.5 contour Plot of MRR Vs A, B

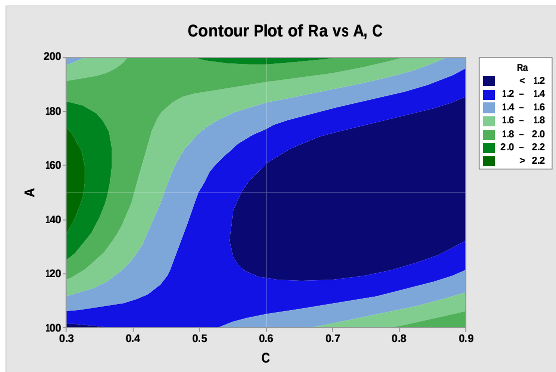

Figure 6.6 contours Plot of Ra Vs A, C

A. *Conformation Or Validation Test*

The confirming test is very important in verifying the improvement of machining performance characteristics in the analysis of optimization. In this study,

Comparing Results of Initial and Optimal levels			
Level	Initial(single optimization) A3,B3,C3 (MRR) A2,B1,C3(Ra)	validation	Experimental (A1,B3,C1)
MRR		2.89406	2.854602
Ra		0.63420	0.58888
topsis			0.710746

B. *Confirmation Test*

The experimental confirmation test is the final step in verifying the results drawn based on Taguchi's design approach. The optimal conditions are set for the significant factors and a selected number of experiments are run under specified cutting conditions. The average of the results from the confirmation experiment is compared with the predicted average based on the parameters and levels tested. The confirmation experiment is a crucial step and is highly recommended by Taguchi to verify the experimental results. In this study, a confirmation experiment was conducted by utilizing the levels of the optimal process parameters (A1B3C1) for metal removal rate and Ra in the CNC machining of SS 304L and obtained 2.854602 mm^3/min and Ra 0.58888 micro mm respectively .but the difference between initial and final is concerned with single and multi-response optimization. Initial optimization followed by Taguchi method but the final followed by TOPSIS. It is found that the required performance characteristics in the machining process have great improvements through this TOPSIS technique.

VII. CONCLUSION

By using TOPSIS experimental data decision matrix has been developed. The weighted normalized decision matrix is constructed. In this approach, the distance values of each alternative from ideal and anti-ideal solutions are calculated by using concept of ranking method finally, the closeness coefficients are defined to attain the ranking order of all alternative combination of different machining parameter. And optimum value of among all combination is speed 100 m/min, feed 0.2 mm/rev and depth of cut is 0.3mm.

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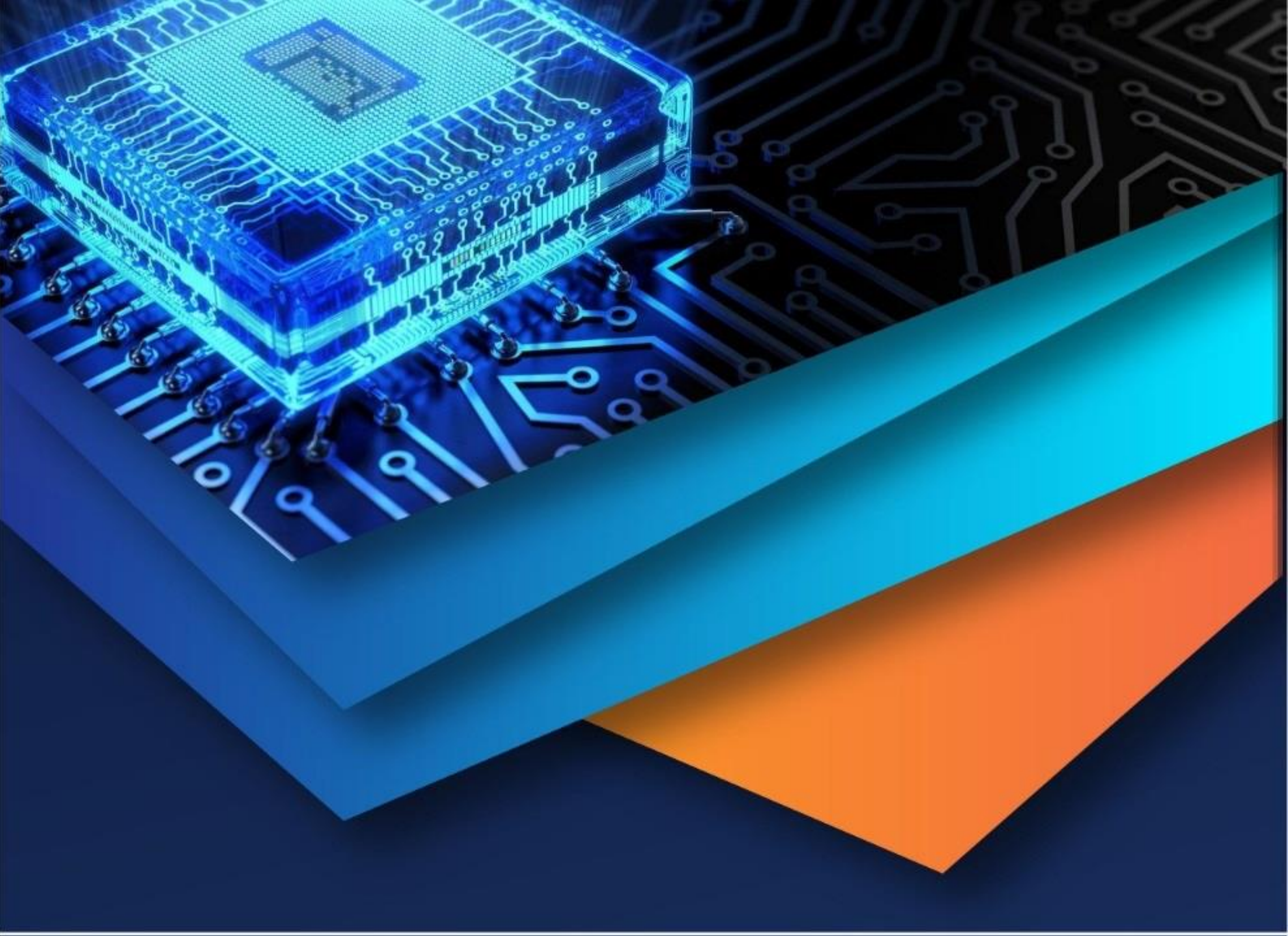

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SRA JIF

IMPACT FACTOR: 7.129

TOGETHER WE REACH THE GOAL

IMPACT FACTOR: 7.429

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