International Journal on Recent Technologies in Mechanical and Electrical Engineering (IJRMEE) ISSN: 2349-7947
Volume: 3 Issue: 8 05 – 11

"Optimizing cutting parameters for minimizing surface roughness and improvement of tool life on ASTM A36 using taguchi method"

Mr. Autade A. S.[1]
Department of Mechanical Engineering
Sanjivani College of Engineering
Kopargaon, Ahmednagar, India
e-mail:ajinkyaautade09@gmail.com

Prof. Palekar S. P.[2]
Department of Mechanical Engineering
Sanjivani College of Engineering
Kopargaon, Ahmednagar, India
e-mail:palekarsnd@gmail.com

Abstract**—** The challenge of modern machining industries is mainly focused on the achievement of high quality, in terms of work piece dimensional accuracy, surface finish, high production rate, less wear on the cutting tools, economy of machining in terms of cost saving and increase the performance of the product. Therefore cutting parameters must be chosen and optimized in such a way that the surface quality and flank wear can be controlled. Grey taguchi method is applied to optimized multi-response. In this study L27 orthogonal array used to optimized turning parameters i.e. cutting speed, feed, depth of cut and corner radius. The coefficient and grades according to Grey relational analysis are evaluated using normalized experimental results of the performance characteristics. The Analyses Of Variance (ANOVA) are conducted to identify the most significant factor affecting the turning performance. The obtained results indicate that cutting speed is most effective parameter that affect on surface roughness and flank wear subsequently followed by depth of cut, feed rate and corner radius.

Keywords **—** ASTM A36, coated carbide tool, corner radius, flank wear, grey taguchi method, surface roughness.

*****

I. INTRODUCTION

There are two main practical problems that engineers face in a manufacturing process. The first is to determine the values of the process parameters that will yield the desired product quality and the second is to maximise manufacturing system performance using the available resources. And another main problem is to minimizing product cost. The decisions made by manufacturing engineers are based not only on their experience and expertise but also on conventions regarding the phenomena that take place during processing. In the machining field, many of these phenomena are highly complex and interact with a large number of factors, thus preventing high process performance from being attained. To overcome these problems, the researchers propose models that try to simulate the conditions during machining and establish cause and effect relationships between various factors and desired product characteristics. Furthermore, the technological advances in the field, for instance the ever-growing use of computer controlled machine tools, have brought up new issues to deal with, which further emphasize the need for more precise predictive models [9].

Surface roughness is a widely used index of product quality and in most cases a technical requirement for mechanical products. For improvement of tool life the flank wear is very important response to minimize. Researcher minimizing flank wear and achieving the desired surface quality is of great importance for the functional behaviour of a part. The most common strategy involves the selection of conservative process parameters, which neither guarantees the achievement of the desired surface finish nor attains high wear.

II. LITERATURE REVIEW

Nalbant et al. (2006) used the Taguchi method to find the optimal cutting parameters for surface roughness in turning. The orthogonal array, the signal-to-noise ratio, and analysis of variance are employed to study the performance characteristics in turning operations of AISI 1030 steel bars using TiN coated tools. Three cutting parameters namely, insert radius, feed rate, and depth of cut, are optimized with considerations of surface roughness. Experimental results are provided to illustrate the effectiveness of this approach.

Aslan et al. (2006) carried out an experimental study to Optimal cutting parameters by employing Taguchi techniques. They also combined effects of three cutting parameters, namely cutting speed, feed rate and depth of cut on two performance measures, flank wear (VB) and surface roughness (Ra), were investigated employing an orthogonal array and the analysis of variance (ANOVA). Optimal cutting parameters for each performance measure were obtained; also the relationship between the parameters and the performance measures were determined using multiple linear regression. Al2O3-based ceramics material are used because it is one of the most suitable cutting tool materials for machining hardened steels. However, their high degree of brittleness usually leads to inconsistent results and sudden catastrophic failures.

Motorcu (2010) investigated the surface roughness in the turning of AISI 8660 hardened alloy steels by ceramic based cutting tools in terms of main cutting parameters such as cutting speed, feed rate, depth of cut in addition to tool's nose radius, using a statistical approach. This researcher obtained results indicate that the feed rate was found to be the dominant factor among controllable factors on the surface roughness, followed by depth of cut and tool's nose radius. However, the cutting speed showed an insignificant effect. Furthermore, the interaction of feed rate/depth of cut was found to be significant on the surface finish due to surface hardening of steel. Optimal testing parameters for surface roughness could be calculated.

Moreover, the second order regression model also shows that the predicted values were very close to the experimental one for surface roughness.

Davis et al. (2012) carried out experimental study to optimize the cutting parameters like depth of cut, feed rate, and spindle speed in turning EN24 steel. In this study, the turning operation are carried out on EN24 steel by carbide P-30 cutting tool in dry condition and the combination of the optimal levels of the parameters are obtained. In order to study the performance characteristics in turning operation the Signal-to-Noise ratio and Analysis of Variance are employed. As a result of the analysis none of the factor are found to be significant. Taguchi method has shown that feed rate followed by Spindle speed and depth of cut are the combination of the optimal levels of factors while turning EN24 steel by carbide cutting tool in dry cutting condition.

Makadia and Nanavati (2012) used Design of experiments to study the effect of the main turning parameters such as feed rate, tool nose radius, cutting speed and depth of cut on the surface roughness of AISI 410 steel. A mathematical prediction model of the surface roughness has been developed in terms of above parameters. The effect of these parameters on the surface roughness has been investigated by using Response Surface Methodology (RSM). The developed prediction equation shows that the feed rate is the main factor followed by tool nose radius influences the surface roughness. The surface roughness was found to increase with the increase in the feed and it decreased with increase in the tool nose radius. The verification experiment is carried out to check the validity of the developed model that predicted surface roughness within 6% error.

Verma et al. (2012) carried out the analysis of optimum cutting conditions to get lowest surface roughness in turning ASTM A242 Type-1 Alloys Steel by Taguchi method. Taguchi method has shown that the cutting speed has significant role to play in producing lower surface roughness about 57.47% followed by feed rate about 16.27%. The Depth of Cut has lesser role on surface roughness from the tests. The results obtained by this method will be useful to other researches for similar type of study and may be eye opening for further research on tool vibrations, cutting forces etc.

Ramya et.al. (2014) In this experimental work turning parameters on EN-8 steel with different parameters such as Cutting speed, feed and depth of cut are greatly influenced by response parameters. The experimental design was formed based on Taguchi’s Technique. An orthogonal array and Analysis of Variance (ANOVA) are employed to investigate the Turning conditions and machining was done using coated tool insert.

Krishankant et al. (2012) carried out an optimization of turning process by the effects of machining parameters applying Taguchi methods to improve the quality of manufactured goods, and engineering development of designs for studying variation. EN24 steel is used as the work piece material for carrying out the experimentation to optimize the Material Removal Rate. Operating range is found by experimenting with top spindle speed and taking the lower levels of other parameters. Taguchi orthogonal array is designed with three levels of turning parameters with the help of software Minitab 15.

Sahin and Motorcu (2004) presents a study of the development of a surface roughness model for turning of mild steel with coated carbide tools. The model is developed in terms of cutting speed, feed rate and depth of cut, using response surface methodology. Machining tests were carried out with TiN-coated carbide cutting tools under various cutting conditions. First-order and second-order model predicting equations for surface roughness have been established by using the experimental data. The established equation shows that the feed rate was main influencing factor on the surface roughness. It increased with increasing the feed rate but decreased with increasing the cutting speed and the depth of cut, respectively. In addition, analysis of variance for the second-order model shows that the interaction terms and the square terms are statistically insignificant. The predicted surface roughness of the samples has been found to lie close to that of the experimentally observed ones with 95% confident intervals. Moreover, it is seen that the first-order effect of feed rate and cutting speed is significant while depth of cut is insignificant.

Khoshdarregi and Altintas (2015) presented generalized mechanics model of multi-point thread turning operations The cross section of the chip is determined from the thread profiles of the current and previous teeth as well as the in feed settings of the tool. The chip is discretized along the cutting edge, and the cutting force coefficients are evaluated for each element considering the changes in effective oblique cutting angles and chip thickness. The non-linear Kienzle force model is used to account for the effect of edge radius at low chip thickness values. Total cutting forces are obtained by resolving the elemental forces in the insert coordinate system, and integrating them along the engaged teeth.

Gaur and Singh (2015) used taguchi method to optimize the cutting forces in Turning Operation of 20MnCr5 alloy steel using Tungsten Carbide inserts. Three process parameters namely, cutting speed, feed rate, and depth of cut, have been selected for investigation. Experiments were conducted on the basis of Taguchi’s L9 orthogonal array. The Signal to noise ratio (SNR) and the analysis of variance (ANOVA) are applied to optimize the effects of the selected process parameters on Cutting forces. The results reveal that feed rate is the most influencing factor followed by depth of cut and cutting speed.

Debnath et al. (2015) studied the effect of various cutting fluid levels and cutting parameters on surface roughness and tool wear. Taguchi orthogonal array was employed to minimize the number of experiments. The experiments were carried out on mild steel bar using a TiCN + Al2O3 + TiN coated carbide tool insert in the CNC turning process. The effect of feed rate was found to be the dominant factor contributing 34.3% to surface roughness of the work-piece. The flow rate of the cutting fluid also showed a significant contribution (33.1%).

Vikas et al. (2014) studied various input parameters like Pulse ON time, Pulse OFF time, Discharge Current and Voltage over the Surface Roughness for an EN41 material. For five different output of surface roughness are taken and optimized accordingly, using the Grey Taguchi method.

III. OBJECTIVES

1. Literature reviews of turning process parameters.
2. Identify the performance characteristics and select process parameters to be evaluated
3. Determine the number of levels for the process parameters and possible interactions between the process parameters.
4. Select the appropriate orthogonal array and assignment of process parameters to the orthogonal array.
5. Conduct the experiments based on the arrangement of the orthogonal array.
6. Optimization of process parameters using Design of Experiments (DOE).
7. Analyze the experimental results using the S/N ratio and ANOVA.
8. Verify the optimal process parameters through the confirmation experiment.

IV. METHODS

A. *Taguchi method*

The Taguchi method developed by Genichi Taguchi (1990) was the most important statistical tool for the optimization of the single output parameter. It considers a set of different number of input parameters, may it be an L27 orthogonal array or an L9 orthogonal array depending upon the degree of accuracy needed. Taguchi is a set of methodologies by different properties of material and machining process has been taken into account of design shape [9].

Step of Taguchi method follows as:
1. Selection of the factors to be evaluated.
2. Selection of the number of levels.
3. Selection of the appropriate orthogonal array.
4. Assignment of factors to the columns.
5. Conduct the experiment.
6. Analyze the result, predict the optimum level.
7. Perform the verification experiment and plan the future action.

TABLE I
MACHINING PARAMETERS LEVELS

Parameters	**Units**	**Level 1**	**Level2**	**Level3**
Cutting Speed *(Vc)*	m/min	175	250	325
Feed *(F)*	mm/rev	0.05	0.1	0.2
Depth of cut *(Dc)*	mm	0.25	0.5	1.0
Corner radius *(R)*	mm	0.4	0.8	1.2

Taguchi's methodology involves use of specially constructed tables called "Orthogonal Array" (OA) which requires very less number of experimental runs in designing which are consistent and very easy. We have L27 "Orthogonal Array" (OA) shown in Table 2.

TABLE II
ORTHOGONAL ARRAY L27

Test No.	**Vc**	**F**	**Dc**	**R**
1	1	1	1	1
2	1	1	2	2
3	1	1	3	3
4	1	2	1	2
5	1	2	2	3
6	1	2	3	1
7	1	3	1	3
8	1	3	2	1
9	1	3	3	2
10	2	1	1	1
11	2	1	2	2
12	2	1	3	3
13	2	2	1	2
14	2	2	2	3
15	2	2	3	1
16	2	3	1	3
17	2	3	2	1
18	2	3	3	2
19	3	1	1	1
20	3	1	2	2
21	3	1	3	3
22	3	2	1	2
23	3	2	2	3
24	3	2	3	1
25	3	3	1	3
26	3	3	2	1
27	3	3	3	2

B. *Grey Taguchi Approach*

The Grey Taguchi Approach is an advanced form of the Taguchi method, which emphasizes on the optimization of more than one output parameters, rather than optimizing a single output parameter as in case of the Taguchi method. It considers a set of different number of input parameters, depending upon the degree of accuracy needed. The number of experiments chosen in this study is an L27 orthogonal array comprising the input parameters are cutting speed *(Vc)*, feed *(F)*, Depth of cut (*Dc*) and corner radius (*R*). Two-output parameters of the surface roughness and flank wear, namely Ra and VB are considered and converted into a single output parameter, called the Grade. The calculation of the grade requires the calculation of the normalized, Δ and Grey relational coefficient (ξ) values for each of the output parameters of the surface roughness and flank wear. The average of the grey relational coefficient (ξ) values for output parameters gives the value of the grade of the entire output parameters. Based on the grade calculated, the corresponding S/N ratio is obtained through the following formula [13].

$$S/N_s \text{Ratio (Smaller is the better)} := -10\log\left(\frac{1}{n}\sum_{i=1}^{n}\frac{1}{y_i^2}\right) \quad (1)$$

Normalized value $X_z(a)$ criterion can be expressed as:

$$X_z(a) = \frac{\max Yi(a) - Yi(a)}{\max Yi(a) - \min Yi(a)} \quad (2)$$

The value of Δ can be calculated as follows:

Δ = 1- Normalized value of the response (3)

The grey relational coefficient $\xi_z(a)$ can be expressed as follows:

$$\xi_z(a) = \frac{\Delta\min + \Psi\Delta\max}{\Delta oi(a) + \Psi\Delta\max} \quad (4)$$

Where, Ψ is the distinguishing coefficient, whose value varies from 0 to 1 and is generally considered to weaken the effect of larger value of Δmax .In the present study, it is Taken to be 0.5.

After averaging grey relational coefficient, the grey relational grade Yi is computed as:

$$Yi = \frac{1}{n}\sum_{i=1}^{n}\xi_z(a) \quad (5)$$

Optimization of the complicated multiple process responses is converted into optimization of single grey relational grade.

V. EXPERIMENTATION

The goal of this experimental work is to investigate the effects of cutting parameters on surface roughness and tool wear, and to establish a correlation between them. In order for this, cutting speed, feed rate, depth of cut and corner nose radius were chosen as process parameters.

The work material is ASTM A36 steel in the form of round bars with 76 mm diameter and 25 mm cutting length. Chemical composition of work material is given in Table 3. ASTM A36 steel is used in the production of bearing plates, rings, cams, gears, forging dies, pressure cups, jigs and fixtures, etc.

Fig. 1: Work piece

TABLE III
CHEMICAL COMPOSITION OF ASTM A36

C	Cu	Fe	Mn	P	Si	S
0.26%	0.20%	98.0%	1.03%	0.04%	0.28%	0.05%

The turning tests were conducted in dry conditions on JYOTI DX200-5A CNC lathe having a maximum spindle speed of 2500 rpm and a maximum power of 15 kW.

Fig. 2: JYOTI DX 200-5A CNC lathe

A. Cutting tool:

The different cutting tool inserts used for experimentation with coated carbide their specifications shown in table no.4

Fig. 3: Selected insert for experimentation

TABLE IV
INSERT SPECIFICATION

ISO Catalogue no.	Nose radius (mm)	Nose angle (deg.)	Flank face (mm)
TNMG 160404 SH	0.4	15°	0.2
TNMG 160408 MA	0.8	22°	0.23
TNMG 160412 MH	1.2	16°	0.25

Coated carbide inserts currently represents 70-80% of all cutting tool inserts. Its success as a tool material is due to its unique combination of wear resistance and toughness, and its ability to be formed in complex shapes. Cutting tool materials have different combinations of hardness, toughness and wear resistance, and are divided into numerous grades with specific properties.

Three types of Cutting inserts are used for this kind of experimental investigation namely.

Where,
T=Insert shape
N=Insert clearance angle
M=Tolerance class
G=insert features
16=size
04=thickness
04, 08, 12=corner radius
SH, MA, MH=chip breaker (optional)

B. *Measurements:*

The tool flank wear is being measured on optical microscope and surface of work piece is being measured by Surftest SJ-210. The detection measurement range from -200 µm to +160 µm, diamond stylus material and tip radius is 5 µm.

VI. RESULTS AND DISCUSSION

A. *Test performance:*

The experimentally obtained values of Surface roughness (Ra), and Flank wear (VB) are also presented in Table 5. In this section, the use of the OA with the GRA for determining the optimal process parameters is reported step by step. The optimal process parameters with consideration of the multiple performance characteristics are obtained and verified.

TABLE V
EXPERIMENTAL LAYOUT USING AN L27 ORTHOGONAL ARRAY AND PERFORMANCE RESULTS

Ex no.	Input parameters				Response	
	Vc	F	Dc	R	VB(mm)	Ra(µm)
1	175	0.05	0.25	0.4	0.27	2.112
2	175	0.05	0.5	0.8	0.24	1.4602
3	175	0.05	1.0	1.2	0.25	0.8814
4	175	0.1	0.25	0.8	0.2	0.8308
5	175	0.1	0.5	1.2	0.26	2.6127
6	175	0.1	1.0	0.4	0.1	2.4406
7	175	0.2	0.25	1.2	0.22	1.5404
8	175	0.2	0.5	0.4	0.29	1.3485
9	175	0.2	1.0	0.8	0.5	1.5549
10	250	0.05	0.25	0.4	0.05	1.1765
11	250	0.05	0.5	0.8	0.19	0.9184
12	250	0.05	1.0	1.2	0.2	1.1513
13	250	0.1	0.25	0.8	0.06	0.5754
14	250	0.1	0.5	1.2	0.07	1.758
15	250	0.1	1.0	0.4	0.22	1.6014
16	250	0.2	0.25	1.2	0.21	1.409
17	250	0.2	0.5	0.4	0.03	1.263
18	250	0.2	1.0	0.8	0.23	1.3742
19	325	0.05	0.25	0.4	0.08	0.9298
20	325	0.05	0.5	0.8	0.07	0.9466
21	325	0.05	1.0	1.2	0.25	0.792
22	325	0.1	0.25	0.8	0.12	0.5888
23	325	0.1	0.5	1.2	0.11	0.8485
24	325	0.1	1.0	0.4	0.12	0.676
25	325	0.2	0.25	1.2	0.19	1.5068
26	325	0.2	0.5	0.4	0.06	1.7363
27	325	0.2	1.0	0.8	0.05	1.7777

TABLE VI
NORMALIZED VALUE AND GREY RELATION COEFFICIENT

Ex no.	Flank wear VB (mm)	Surface Roughness Ra(µm)	Normalize VB	Normalize Ra	GREY coeff. (VB)	GREY coeff. (Ra)
1	0.27	2.112	0.4893	0.2457	0.4947	0.3986
2	0.24	1.4602	0.5531	0.5656	0.5280	0.5351
3	0.25	0.8814	0.5319	0.8498	0.5164	0.7689
4	0.2	0.8308	0.6382	0.8746	0.5802	0.7995
5	0.26	2.6127	0.5106	0	0.5053	0.3333
6	0.1	2.4406	0.8510	0.0844	0.7704	0.3532
7	0.22	1.5404	0.5957	0.5263	0.5529	0.5135
8	0.29	1.3485	0.4468	0.6205	0.4747	0.5685
9	0.5	1.5549	0	0.5192	0.3333	0.5097
10	0.05	1.1765	0.9574	0.7049	0.9215	0.6288
11	0.19	0.9184	0.6595	0.8316	0.5949	0.7480
12	0.2	1.1513	0.6382	0.7173	0.5802	0.6388
13	0.06	0.5754	0.9361	1	0.8867	1
14	0.07	1.758	0.9148	0.4195	0.8545	0.4627
15	0.22	1.6014	0.5957	0.4963	0.5529	0.4982
16	0.21	1.409	0.6170	0.5908	0.5662	0.5499
17	0.03	1.263	1	0.6624	1	0.5970
18	0.23	1.3742	0.5744	0.6079	0.5402	0.5604
19	0.08	0.9298	0.8936	0.8260	0.8245	0.7418
20	0.07	0.9466	0.9148	0.8177	0.8545	0.7329
21	0.25	0.792	0.5319	0.8936	0.5164	0.8246
22	0.12	0.5888	0.8085	0.9934	0.7230	0.9870
23	0.11	0.8485	0.8297	0.8659	0.7460	0.7885
24	0.12	0.676	0.8085	0.9506	0.7230	0.9101
25	0.19	1.5068	0.6595	0.5428	0.5949	0.5223
26	0.06	1.7363	0.9361	0.4301	0.8867	0.4673
27	0.05	1.7777	0.9574	0.4098	0.9215	0.4586

ISSN: 2349-7947
05 – 11

Grey relation grade is find out and give ranking for obtaining the optimal condition and shown in table 7.

TABLE VII
GREY RELATION GRADE AND THEIR ORDER

Ex. No.	Grey relation grade	Order
1	0.4466933	25
2	0.5316249	22
3	0.6427396	15
4	0.6898919	10
5	0.4193548	27
6	0.5618588	17
7	0.5332321	21
8	0.5216349	24
9	0.4215649	26
10	0.775231	7
11	0.6715182	12
12	0.6095396	16
13	0.9433962	1
14	0.6586526	14
15	0.5255719	23
16	0.5581089	19
17	0.7985055	4
18	0.5503565	20
19	0.7832249	6
20	0.7937331	5
21	0.6705672	13
22	0.8550465	2
23	0.7673066	8
24	0.8165977	3
25	0.558654	18
26	0.6770798	11
27	0.6901119	9

The mean response for each factor and the ranks are determined from the loss function as shown in Table 8.

TABLE VIII
GREY RELATION GRADE RESPONSE

Level	Vc	F	Dc	R
1	0.5298439	0.6583191	0.6826088	0.6562664
2	0.6767645	0.6930752	0.6488234	0.6830271
3	0.7347024	0.5899165	0.6098787	0.6020173
Delta	0.2048585	0.1031587	0.0727301	0.0810099
Rank	1	2	4	3

The effect from response table is plotted in Figure 4

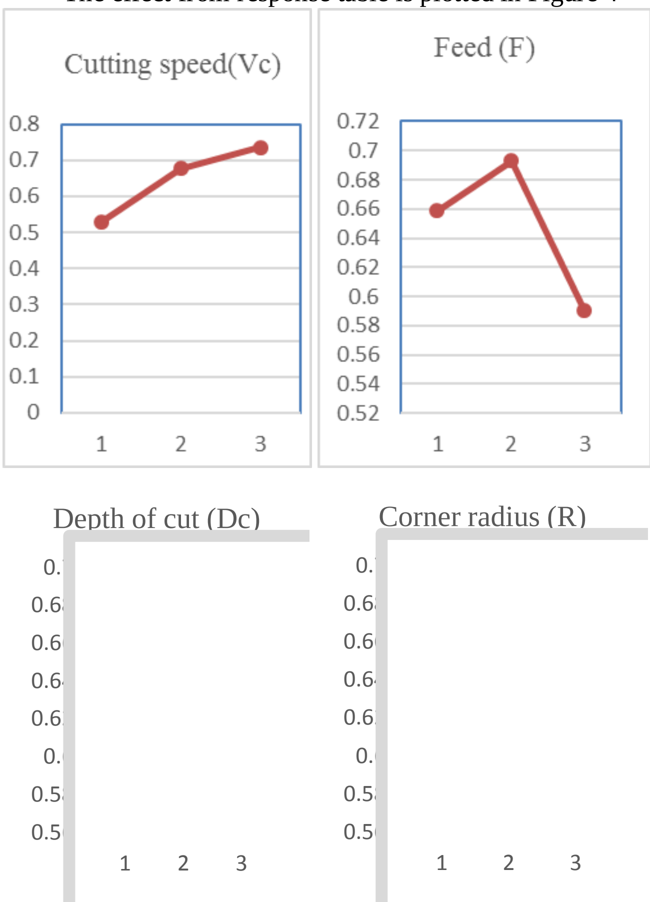

Fig. 4: Grey relational grade response graph

In order to understand contribution of the cutting parameters depth of cut, cutting speed, feed, and corner radius on the experimental result of variance were carried out. The result of ANOVA for grey relation grade are shown in Table 9

TABLE IX
ANOVA FOR GREY RELATIONAL GRADE

Parameters	DOF	Sum of square	Mean square	F value	% contribution
Cutting speed (Vc)	2	0.20072	0.10036	11.8718	40.719814
Feed (F)	2	0.04958	0.02479	2.93269	10.059005
Depth of cut (Dc)	2	0.05979	0.02989	3.53676	12.130912
Corner radius (R)	2	0.03066	0.01533	1.81365	6.2207345
Error	18	0.15217	0.00845		30.869535
Total	26	0.49295	0.17884		100

Here, Table 9 gives the results of the analysis of variance (ANOVA) for the Flank wear (VB) and the Surface roughness (Ra) using the calculated values from the Grey relational grade of Table 7 and the response table of Table 8. According to Table 9, the Cutting Speed with 40% of contribution, is the most significant controlled parameters for the turning operation; the Depth of cut is with 12% contribution, the Feed with 10%, and the corner radius with 6% of contribution if the minimizing surface roughness and flank wear are simultaneously considered.

B. Confirmation test

After identifying the most influential parameters, the final phase is to verify the VB and Ra by conducting the confirmation experiments. The Vc3F2Dc1R2 is an optimal parameter combination of the turning process via the Grey relational analysis. Therefore, the condition Vc3F2Dc1R2 of the optimal parameter combination of the turning process was treated as a confirmation test. If the optimal setting with a cutting speed 325 m/min, a feed of 0.1 mm/rev, a depth of cut of 0.25 mm, and corner radius of 0.8 mm is used, the final work piece gives the Flank wear (i.e., VB) of 0.12mm, the Surface roughness(i.e., Ra) of 0.5888 µm.

VII. CONCLUSION

The following conclusions can be drawn based on the results of experimental study:

- The machining parameters namely cutting speed, feed rate, depth of cut, corner radius is optimized to meet the objectives. The results reveal that the primary factor affecting the surface roughness and flank wear is speed subsequently followed by depth of cut, feed and corner radius.
- The cutting speed is most significant factor which minimizing surface roughness and improving tool life is 40.72% subsequently followed by depth of cut which contributes 12.13%, feed rate 10.05% and corner radius has least significant factor contributes 6.22%.
- The optimized factor for great surface finish and low flank wear is cutting speed Vc3=325m/min, feed F2= 0.1 mm/rev, depth of cut Dc1=0.25 mm, and corner radius R2=0.8 mm.
- It is shown that performance characteristics of the CNC turning process such as VB and Ra are improved together by using grey taguchi method.

The research demonstrates how to use Grey Taguchi parameter design for optimizing machining performance with minimum cost and time to industrial readers. The research can be extended by considering more factors (e.g., lubricants, materials, etc.) to see how the factors would affect surface roughness and flank wear.

ACKNOWLEDGMENT

Every orientation work has imprint of many people and this work is not different. This work gives me an opportunity to express deep gratitude for the same. First and foremost I thank Dr. A. G. Thakur, Head of the Mechanical Engineering Department and Prof. S.P. Palekar for giving me the opportunity to prepare this work and his indispensable support, great suggestions and valuable time. I wish to thank my friends and family for being supportive to me.

REFERENCES

[1] Davis R., Madhukar J., Rana V., Singh P., "Optimization of Cutting Parameters in Dry Turning Operation of EN24 Steel", International Journal of Emerging Technology and Advanced Engineering, 2(10), pp. 559-563, 2012.

[2] Debnath S., Reddy M.M., Yi Q. S., "Influence of cutting fluid conditions and cutting parameters on surface roughness and tool wear in turning process using Taguchi method", Measurement, 78, pp.111–119, 2015.

[3] Gaur G., Singh H., "Application of Taguchi Method in the Optimization of the Cutting Forces in Turning Operation of 20MnCr5 Alloy Steel", Journal of Material Science and Mechanical Engineering, 2(9), pp. 58-61, 2015.

[4] Kajal S., Yadav S., "Optimization of CNC Turning Parameters for Surface Roughness on EN 354 Steel using Taguchi Method", Journal of Material Science and Mechanical Engineering, 2(10), pp. 54-57, 2015.

[5] Khoshdarregi M. R., Altintas Y., "Generalized modeling of chip geometry and cutting forces in multi-point thread turning", International Journal of Machine Tools & Manufacture, 98, pp. 21–32, 2015.

[6] Krishankant, Taneja J., Bector M., Kumar R., "Application of Taguchi Method for Optimizing Turning Process by the effects of Machining Parameters", International Journal of Engineering and Advanced Technology, 2(1), pp.263-274, 2012.

[7] Makadia A.J., Nanavati J.I., "Optimization of machining parameters for turning operations based on response surface methodology", Measurement, 46, pp. 1521–1529, 2013

[8] Motorcu A. R., "The Optimization of Machining Parameters Using the Taguchi Method for Surface Roughness of AISI 8660 Hardened Alloy Steel", Strojniski vestnik - Journal of Mechanical Engineering, 56, pp.391-401, 2010.

[9] Nalbant M., Gokkaya H., Sur G., "Application of Taguchi Method in the Optimization of Cutting Parameters for Surface Roughness in Turning", Materials and Design, 28, pp. 1379–1385, 2007.

[10] Ramya R., Kannan T., Giridharan S., Baskaran R., Madhan J., "Optimization of Turning Parameters of En-8 Steel Cylindrical Rods Using Taguchi Methodology", International Journal of Advances in Engineering & Technology, pp. 360-366, 2014.

[11] Sahin Y., Motorcu A. R., "Surface Roughness Model for Machining Mild Steel with Coated Carbide Tool", Journal of science direct, pp. 21–26, 2005.

[12] Verma J., Agrawal P., Bajpai L., "Turning Parameter Optimization for Surface Roughness of Astm A242 Type-1 Alloys Steel by Taguchi Method", International Journal of Advances in Engineering & Technology, pp. 255-261, 2012.

[13] Vikas, Roy A.K., Kumar K., "Effect and Optimization of various Machine Process Parameters on the Surface Roughness in EDM for an EN41 Material using Grey- Taguchi", 3rd International Conference on Materials Processing and Characterisation, 6, pp.383-390, 2014.