Scientific Journal of Impact Factor(SJIF): 3.134

e-ISSN(O): 2348-4470
p-ISSN(P): 2348-6406

International Journal of Advance Engineering and Research Development

Volume 2,Issue 5, May -2015

AN INVESTIGATION OF TEMPERATURE, SURFACE ROUGHNESS AND MATERIAL REMOVAL RATE OF EN19 MATERIAL USING TUNGSTEN CARBIDE TOOL DURING HARD TURNING ON LATHE MACHINE

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Abstract —*The main aim of this Project work is to study experimentally the influence of depth of cut, cutting speed, and feed rate on the tool tip temperature, Material Removal Rate, Surface Roughness during turning process. The experiments will be obtained by varying one parameter while, the remaining two parameter were kept constant. So the influence of tool tip on different machining parameters is done in this research work. To increase the tool life, Taguchi Optimization method is used to optimization of machining parameters. Through this study, not only the optimal cutting parameters for turning operations are obtained, but also the main cutting parameters that affect the cutting performance in turning operations will be evaluated. Experimental results will be provided to confirm the effectiveness of this approach. It will give the best result for turning operation of EN19 Material.*

Keywords- *Optimization, Hard Turning, Surface roughness, MRR, Temperature*

I. INTRODUCTION

Turning is a very important machining process in which a single-point cutting tool removes material from the surface of a rotating cylindrical work-piece. The cutting tool is fed linearly in a direction parallel to the axis of rotation. The turning is carried out on a lathe that provides the power to turn the work-piece at a given rotational speed and to feed the cutting tool at a specified rate and depth of cut.

Therefore, three cutting parameters are listed below Cutting speed (v), Feed rate (f), Depth of cut (d).

It should be properly selected for performance evaluation criteria such as Surface finish, Lower Temperature at Cutting zone, Less Tool wear and Long Tool life etc.

Turning is the removal of metal from the outer diameter of a rotating cylindrical work piece to a specified dimension, and to produce a smooth finish on the work-piece. Often the work piece will be turned so that adjacent sections have different diameters.

A. TEMPERATURE

Heat phenomena that occur in the narrow and in the broad area of the cutting zone, are directly related to wear rate of tool, to the machinability rate of workpiece material, to the tool stability and related to many other characteristics of the machining process. Generated heat goes from the cutting zone into the chips, tool, workpiece and into the environment though thermal energy. The decrease of the hardness of tool's cutting elements, cutting wedge deformations, the loss of the tool cutting ability and its bluntness occur. Generated heat distribution in workpiece, in tool and in chips, that is, the temperature level at working elements of the tool, at processed surface and at chips depends on: workpiece material (its mechanical and chemical characteristics), cutting speed, feed rate, depth of cut, tool geometry, lubricants type and many other relevant parameters.

B. SURFACE ROUGHNESS

The surface quality is an important performance criterion to asses' machinability of any material with dimensional accuracy and surface finish. Surface roughness is used as the critical quality indicator for the machined surface. Formation of a rough surface is a complicated mechanism involving many parameters. The quality of the work piece (either roughness or dimension) are greatly influenced by the cutting conditions, tool geometry, tool material, machining process, chip formation, work piece material, tool wear and vibration during cutting. Every machining process leaves its impact on the machined surface in the form of finely spaced irregularities. Each cutting tool leaves its own individual pattern on the surface. Surface Roughness may be considered as being superposed on a wavy surface.

The maximum height (H_{max}) or the roughness form produced by a single point cutting tool is given by,

$$H_{max} = \frac{f^2}{8 \times R}$$

Where, f = feedrate,mm/min.
R= Nose Radius, mm

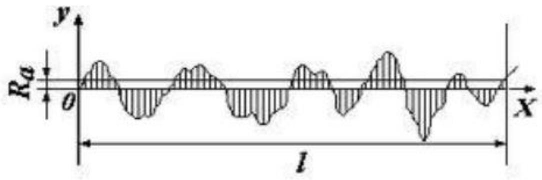

Figure 1: Average surfaces roughness[9]

The CLA or Centre Line Average value of surface roughness (Ra) is the arithmetical average of the departure of the whole of the profile both above and below its centerline throughout the prescribed meter cut-off in a plane substantially normal to the surface.

$$Ra = \left(\frac{1}{L}\right)\int_0^L |z(x)|dx$$

Where z(x) is the ordinate of the profile curve, x is the profile direction and L is the sampling length. The unit of Ra is μm.

C. *MATERIAL REMOVAL RATE*

The Investigation presents the use of Taguchi method for optimizing the material removal rate in turning medium EN19 which is extensively used as a main engineering material in various industries such as Rollers, Supporting shafts, and Structural column etc. These materials are considered as easy to machining and possess superior machinability. Taguchi's orthogonal arrays are highly fractional designs, used to estimate main effects using only few experimental runs. These designs are not only applicable to two level factorial experiments, but also can investigate main effects when factors have more than two levels.

II. LITERATURE REVIEW ON HARD TURNING

[1] Effect of cutting parameters on cutting force and surface roughness during finish hard turning AISI52100 grade steel, Gaurav Bartarya[1], S.K.Choudhury[2], Procedia CIRP 1 (2012) 651 – 656.

In this paper researcher had worked on effect of cutting parameters on cutting force and surface roughness during finish hard turning AISI52100 grade steel. The present work is an attempt to develop a force prediction model during finish machining of EN19 steel (equivalent to AISI 52100 steel) hardened to 60±2 HRC using hone edge uncoated CBN tool and to analyze the combination of the machining parameters for better performance within a selected range of machining parameters. A full factorial design of experiments procedure was used to develop the force and surface roughness regression models, within the range of parameters selected. The regression models developed show that the dependence of the cutting forces i.e. cutting, radial and axial forces and surface roughness on machining parameters are significant; hence they could be used for making predictions for the forces and surface roughness. The predictions from the developed models were compared with the measured force and surface roughness values. To test the quality of fit of data, the ANOVA analysis was undertaken. The favorable range of the machining parameter values is proposed for energy efficient machining [1].

[2] Analysis of surface roughness and cutting force components in hard turning with CBN tool: Prediction model and cutting conditions optimization, HamdiAouici[1], Mohamed AthmaneYallese[2], KamelChaoui[3], TarekMabrouki[4], Jean-François Rigal[5], Measurement 45 (2012) 344–353.

This paper is related to analysis of surface roughness and cutting force components in hard turning with CBN tool: prediction model and cutting conditions optimization. In this study, the effects of cutting speed, feed rate, work piece hardness and depth of cut on surface roughness and cutting force components in the hard turning were experimentally investigated. AISI H11 steel was hardened to (40; 45 and 50) HRC, machined using cubic boron nitride (CBN 7020 from Sandvik Company) which is essentially made of 57% CBN and 35% TiCN. Four-factor (cutting speed, feed rate, hardness and depth of cut) and three-level fractional experiment designs completed with a statistical analysis of variance (ANOVA) were performed. Mathematical models for surface roughness and cutting force components were developed using the response surface methodology (RSM). Results show that the cutting force components are influenced principally by the depth of cut and work piece hardness. [2].

[3] The effects of cutting tool geometry and processing parameters on the surface roughness of AISI 1030 steel, HasanGo¨kkaya[1] ,MuammerNalbant[2], Materials and Design 28 (2007) 717–721.

The researcher had worked on the effects of cutting tool geometry and processing parameters on the surface roughness of AISI 1030 steel. In this study, we have investigated the effects of different insert radii of cutting tools, different depths of cut and, different feed rates on the surface quality of the work pieces depending on various processing parameters. Properly, the AISI 1030 steel is processed at a digitally controlled computerized numerical control(CNC) turning lathe without using cooling water with three different insert radii (0.4, 0.8, and 1.2 mm) of cemented carbide cutting tools, coated with three layer coating materials (outermost is TiN) applied by the chemical vapour deposition CVD technique. The effects of five different depths of cut (0.5, 1, 1.5, 2, 2.5 mm) and five different feed rates/advancing steps (0.15, 0.2, 0.25, 0.30, 0.35 mm/rev) on the surface roughness values have been investigated by a turning process while from the cutting parameters the cutting speed is kept constant at (300 m/min). It is seen that the insert radius, feed rate, and depth of cut have different effects on the surface roughness. In the experiments, the minimum average surface roughness has been obtained using the cutting tools of maximum insert radius (1.2 mm). The surface roughness has been improved by 293% when the insert radius (0.4 mm) was increased by 200% (1.2 mm). When the feed rate (0.35 mm/rev) was reduced by 133% (0.15 mm/rev), the surface roughness have been improved by 313%, and by reducing the depth of cut (0.5 mm) by 400% (0.25 mm), an amelioration of 23% has been obtained on the surface roughness[3].

[4] Determination of optimum cutting parameters during machining of AISI 304 austenitic stainless steel, IhsanKorkut[1], Mustafa Kasap[2], Ibrahim Ciftci[3], UlviSeker[4], Materials and Design 25 (2004) 303–305.

This paper determination of optimum cutting parameters during machining of AISI304 austenitic stainless steel. High strength, low thermal conductivity, high ductility and high work hardening tendency of austenitic stainless steels are the main factors that make their machinability difficult. The optimum cutting speed has been aimed when turning an AISI 304 austenitic stainless steel using cemented carbide cutting tools. The influence of cutting speed on tool wear and surface roughness was investigated. A decrease in tool wear was observed with increasing the cutting speed up to 180 m/min. Surface roughness (Ra) was also decreased with increasing the cutting speed. Correlation was made between the tool wear/surface roughness and the chips obtained at the three cutting speeds of 120, 150 and 180 m/min [4].

[5] Effect of spindle speed and feed rate on surface roughness of Carbon Steels in CNC turning, N. Satheesh Kumar[1], Ajay Shetty[2], AshayShetty[3], Ananth K, HarshaShetty[4] , Procedia Engineering 38 (2012) 691– 697.

The Researcher had worked on effect of spindle speed and feed rate on surface roughness of carbon steels in cnc turning. The effect of process parameters in turning of Carbon Alloy Steels in a CNC lathe. The parameters namely the spindle speed and feed rate are varied to study their effect on surface roughness. The experiments are conducted using one factor at a time approach. The five different carbon alloy steels used for turning are SAE8620, EN8, EN19, EN24 and EN47. The study reveals that the surface roughness is directly influenced by the spindle speed and feed rate. It is observed that the surface roughness increases with increased feed rate and is higher at lower speeds and vice versa for all feed rates [5].

III. S/N RATIO CALCULATION FOR MATERIAL REMOVAL RATE, SURFACE ROUGHNESS, TEMPERATURE

In this the observe value of Temperature, material removal rate, surface roughness are transform in S/N ratio values to find out the optimum combination of parameters for response variable. In Temperature and surface roughness response “smaller is better” is objective characteristics, where as in material removal rate response should be “higher is the better”.

A. *Main Effects Plot of Material Removal Rate*

The main effects plot for S/N ratio of material removal rate versus feed, speed and DOC are shown in fig.

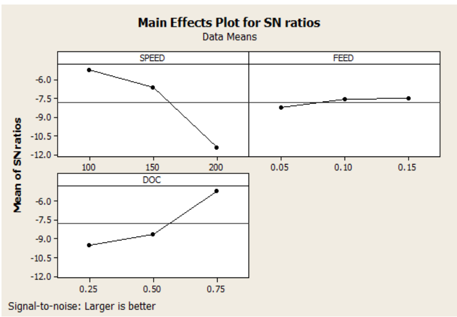

Figure 2 Effect of control factor on material removal rate

Fig.2 shows that higher material removal rate will meet at feed 0.15 mm/rev, speed 100 RPM and depth of cut 0.75 mm. The graph generate by use of minitab-16 statistical software for material removal rate.

It has been conclude that the optimum combination of each process parameter for higher material removal rate is meeting at high Feed [B3], low speed [A1] and high DOC [C3].

B. Main Effects Plot of Surface Roughness

Fig.3 shows that lower Surface roughness will meet at cutting speed 200 RPM, feed 0.15 mm/rev and depth of cut 0.50 mm.

It has been conclude that the optimum combination of each process parameter for lower Surface Roughness is meeting at high Feed [B3], low Speed [A3] and nominal DOC [C2].

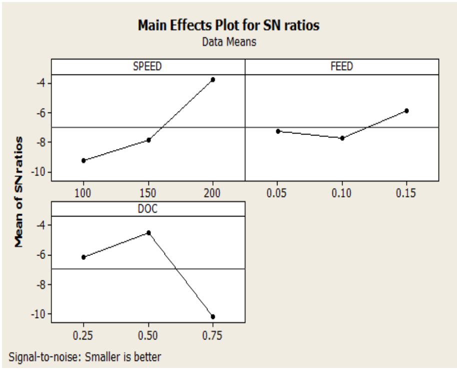

Figure 3: Effect of control factor on Surface roughness

C. Main Effects Plot of Temperature

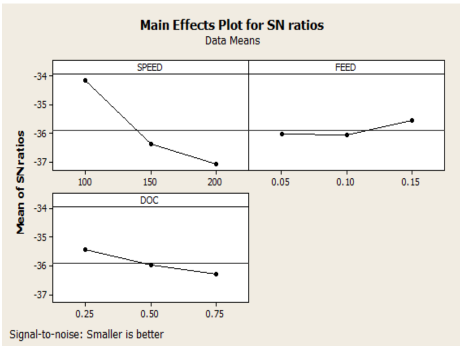

Figure 4: Effect of control factor on Temperature

Fig.4 shows that lower Temperature will meet at cutting speed 100 RPM, feed 0.15 mm/rev and depth of cut 0.25 mm. The optimum combination of each process parameter for lower Temperature is meeting at high Feed [B3], low Speed [A1] and low DOC [C1].

IV. ANALYSIS OF VARIANCE

Analysis of variance (ANOVA) is a statistical model which can be used for find out effect of independent parameter on single dependent parameter and also it can be use full to find out the significant machining parameters and the percentage contribution of each parameter. This table concludes all information of analysis of variance and case statistics for further interpretation.

A. Analysis of Variance for Material Removal Rate

According to the analysis done by the MINITAB16 software, if the values of probability are less than 0.05, it indicated that the factors are significant to the response parameters. Comparing the p-value to a commonly used - level = 0.05, it is found that if the p- value is less than or equal to α, it can be concluded that the effect is significant, otherwise it is not significant.

TABLE 1: ANOVA TABLE OF MATERIAL REMOVAL RATE

Analysis of Variance for Material Removal Rate, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
SPEED	2	0.44241	0.44241	0.22120	9.31	0.001
FEED	2	0.00501	0.00501	0.00250	0.11	0.900
DOC	2	0.33437	0.33437	0.16719	7.04	0.005
Error	20	0.47507	0.47507	0.02375		
Total	26	1.25686				

S = 0.154122 R-Sq = 82.20% R-Sq(adj) = 80.86%

From ANOVA result it is observed that the speed and depth of cut are influencing parameter for Surface roughness, while the value of p for feed is 0.900 which is greater than 0.05 p values. So, it is not influencing parameter for MRR.

B. Analysis of variance for Surface Roughness

TABLE 2: ANOVA TABLE FOR SURFACE ROUGHNESS

Analysis of Variance for Surface Roughness, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
SPEED	2	9.4013	9.4013	4.7006	19.18	0.000
FEED	2	0.9260	0.9260	0.4630	1.89	0.177
DOC	2	11.9647	11.9647	5.9824	24.41	0.000
Error	20	4.9009	4.9009	0.2450		
Total	26	27.1929				

S = 0.495019 R-Sq = 81.98% R-Sq(adj) = 76.57%

From ANOVA result it is observed that the speed and depth of cut are influencing parameter for Surface roughness, while the value of p for feed is 0.177 which is greater than 0.05 p values. So, it is not influencing parameter for Surface roughness.

C. Analysis of variance for Temperature

TABLE 3: ANOVA TABLE FOR TEMPERATURE

Analysis of Variance for Temperature, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
SPEED	2	2040.52	2040.52	1020.26	43.45	0.000
FEED	2	115.63	115.63	57.81	2.46	0.111
DOC	2	165.63	165.63	82.81	3.53	0.049
Error	20	469.63	469.63	23.48		
Total	26	2791.41				

S = 4.84577 R-Sq = 83.18% R-Sq(adj) = 78.13%

From ANOVA result it is observed that the speed and depth of cut are influencing parameter for Temperature, while the value of p for feed is 0.111 which is greater than 0.05 p values. So, it is not influencing parameter for Surface roughness

V. REGRESSION MODEL

The Regression model for predicting the response parameters in turning can be derived using methods like Regression analysis. Regression analysis is often used to: Determine how the response variable changes as particular predictor variable changes. Predict the value of the response variable for any value of the predictor variable, or combination of values of the predictor variables.

The regression equation takes the form of:

$$\text{Response} = \text{constant} + \text{coefficient (predictor)} + \ldots + \text{coefficient (predictor)}$$

OR

$$Y = b_0 + b_1x_1 + b_2x_2 + \ldots + b_kx$$

Where;

Response (Y) is the value of the response.

Constant (b_0) is the value of the response variable when the predictor variable(s) is zero. The constant is also called the intercept because it determines where the regression line intercepts (meets) the Y-axis.

Predictor (X) is the value of the predictor variable.

Coefficients (b_1, b_2… b_k) represent the estimated change in mean response for each unit change in predictor value. In other words, it is the change in Y that occurs when X increase by one unit. The mathematical model using regression analysis is derived with the help of MINITAB software.

A. Regression Equation for Material Removal Rate

The regression equation is
MATERIAL REMOVAL RATE = 0.630 - 0.00301 SPEED + 0.324 FEED + 0.495 DOC

Table 4: REGRESSION COEFFICIENT FOR MATERIAL REMOVAL RATE

Predictor	Coefficient	SE Coef	T	P
Constant	0.6299	0.1559	4.04	0.001
Speed	-0.0030080	0.0007420	-4.05	0.000
Feed	0.3243	0.7420	0.44	0.666
Doc	0.4946	0.1484	3.33	0.003

S = 0.157394   R-Sq = 84.7%   R-Sq(adj) = 88.6%

As shown in above table 4, the p value of factors, feed rates is 0.666 which is higher than 0.05, therefore these factor are not significant. R-Sq is 88.6 %, which is quiet high; therefore model is suitable for result prediction.

B. Regression Equation for Surface Roughness

The regression equation is
SURFACE ROUGHNESS = 3.60 - 0.0136 SPEED - 3.34 FEED + 2.44 DOC

TABLE 5: REGRESSION COEFFICIENT FOR SURFACE ROUGHNESS

Predictor	Coefficient	SE Coef	T	P
Constant	3.5993	0.7072	5.09	0.000
Speed	-0.013571	0.003365	-4.03	0.001
Feed	-3.339	3.365	-0.99	0.331
Doc	2.4373	0.6730	3.62	0.001

S = 0.713845   R-Sq = 86.9%   R-Sq(adj) = 91.3%

C. Regression Equation for Temperature

The regression equation is
TEMPERATURE = 30.6 + 0.207 SPEED - 44.4 FEED + 12.0 DOC

TABLE 6: REGRESSION COEFFICIENT FOR TEMPERATURE

Predictor	Coefficient	SE Coef	T	P
Constant	30.593	5.138	5.95	0.000
Speed	0.20667	0.02445	8.45	0.000
Feed	-44.44	24.45	-1.82	0.082
Doc	12.000	4.889	2.45	0.022

S = 5.18576 R-Sq = 77.8% R-Sq(adj) = 85.0%

The p value of factors, feed rates is 0.082 which is higher than 0.05, therefore these factor are not significant. The co-efficient of determination (R-Sq) indicates the goodness of fit for model. The R-Sq value is 85.0 % which is indicates that model is fit for prediction.

The p value of factors, feed rates is 0.331 which is higher than 0.05, therefore these factor are not significant.. The R-Sq value is 91.30 % which is indicates that model is fit for prediction with high accuracy.

VI. GREY RELATIONAL ANALYSIS CALCULATION

The higher grey relational grade reveals that the corresponding experimental result is closer to the ideally normalized value. Experiment 14 has the best multiple performance characteristic among 27 experiments, because it has the highest grey relational grade shown in table 5.5. The higher the value of the grey relational grade, the closer the corresponding factor combination is, to optimal. A higher grey relational grade implies better product quality, therefore, on the basis of the grey relational grade, the factor effect can be estimated and the optimal level for each controllable factor can also be determined.

Table 5.7 Normalization experimental data, Grey relational coefficient and grey relational grade of experimental data

Sr. No.	Normalized S/N Ratios			GRC			GRG
	MRR	Ra	Temp.	MRR	Ra	Temp.	
1	0.8561	0.9050	0.2460	0.7765	0.8403	0.3987	0.6719
2	0.5079	0.6303	0.1098	0.5040	0.5749	0.3597	0.4795
3	0.5242	0.6670	0.0000	0.5124	0.6002	0.3333	0.4820
4	0.9507	0.9517	0.2784	0.9102	0.9119	0.4093	0.7438
5	0.6294	0.5654	0.2129	0.5743	0.5350	0.3885	0.4993
6	0.6305	0.6140	0.1098	0.5750	0.5643	0.3597	0.4997
7	1.0000	1.0000	0.5176	1.0000	1.0000	0.5089	0.8363
8	0.6294	0.5771	0.3414	0.5743	0.5418	0.4316	0.5159
9	0.7582	0.6489	0.1449	0.6740	0.5875	0.3690	0.5435
10	0.8150	0.9730	0.7758	0.7299	0.9488	0.6904	0.7897
11	0.7865	0.5972	0.7024	0.7008	0.5538	0.6269	0.6272
12	0.7922	0.7302	0.6256	0.7064	0.6495	0.5718	0.6426
13	0.8051	0.9953	0.7272	0.7195	0.9907	0.6470	0.7857
14	0.2606	0.6619	0.7024	0.4034	0.5966	0.6269	0.5423
15	0.3442	0.7114	0.5992	0.4326	0.6340	0.5551	0.5406
16	0.8793	0.8110	0.5452	0.8055	0.7257	0.5237	0.6850
17	0.6632	0.0716	0.6256	0.5975	0.3500	0.5718	0.5065
18	0.4164	0.0654	0.5724	0.4614	0.3485	0.5390	0.4497
19	0.3636	0.5473	1.0000	0.4400	0.5248	1.0000	0.6549
20	0.3140	0.0000	0.9358	0.4216	0.3333	0.8862	0.5470
21	0.0000	0.1419	0.8462	0.3333	0.3682	0.7648	0.4888
22	0.5814	0.5624	0.9575	0.5443	0.5333	0.9216	0.6664
23	0.6158	0.0176	0.9358	0.5655	0.3373	0.8862	0.5963
24	0.4618	0.4403	0.7758	0.4816	0.4718	0.6904	0.5480
25	0.2647	0.4848	0.6256	0.4047	0.4925	0.5718	0.4897
26	0.3459	0.1638	0.5452	0.4332	0.3742	0.5237	0.4437
27	0.3638	0.4170	0.4894	0.4401	0.4617	0.4948	0.4655

A. Main Effect of Factors on Grey Relational Grade (GRG)

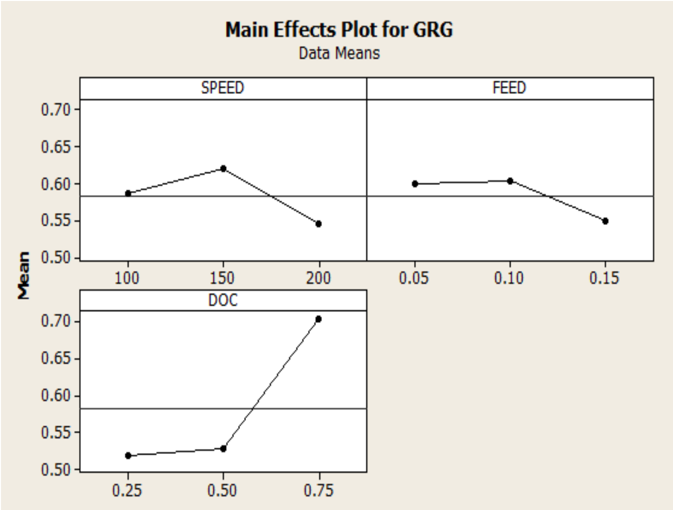

Figure 5 : *Main Effect of Factors on Grey Relational Grade (GRG)*

For the combined response maximization or minimization, fig.5.5 gives optimum value of each control factor. It interprets that level A2, B2, and C3 gives optimum result. The mean of grey relational grade for each level of the other machining parameters can be computed in similar manner. The mean of grey relational grade for each level of the machining parameters is summarized and shown in following table

Table 7: Main effect of factors on Grey Relational Grade

Symbol	Control Factor	Level-1	Level-2	Level-3
A	**Speed**	0.585767	**0.618811**	0.544478
B	**Feed**	0.598178	**0.602456**	0.548422
C	**DOC**	**0.682867**	0.528633	0.517822

higher grey relational grade value will give optimum value of MRR, surface roughness and Temperature. So from above table 5.6, it is concluded that level-2 is higher for cutting speed and level-2 is higher for feed and leve-1 for depth of cut. Thus it is revealed that response will be optimum at cutting speed 150 RPM, feed 0.10 mm/rev and depth of cut 0.75 mm.

A. Analysis of Variance of Grey Relational Grade

Analysis of variance is applied to analyze grey relational grade for find out effect of each parameter on multi objective optimization. By use of MINITAB16 statistical software used to analyze the ANOVA analysis for multi objective optimization is shown.

Table 8: ANOVA of Grey Relational Grade

Analysis of Variance for GRG, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Speed	2	0.0249	0.0249	0.0124	2.59	0.100
Feed	2	0.0162	0.0162	0.0081	1.68	0.211
DOC	2	0.1935	0.1935	0.0967	20.07	0.000
Error	20	0.0964	0.0964	0.0048		
Total	26	0.3312				
S= 0.0694520		R-Sq = 70.88%		R-Sq = 62.14%		

From ANOVA result it is observed that the feed rate and cutting speed are influencing parameter for multi objective optimization, while the value of p for Speed and Feed is 0.100 and 0.211 respectively, which is greater than 0.05 p values and . So, it is not influencing parameter for multi objective optimization.

VII. CONFIRMATION TEST

The confirmation test is the final step of this experimentation. The purpose of conformation test is to validate the conclusion drawn during the analysis phase. In addition, the conformation test needs to be carried out in order to ensure that the theoretical predicted model for optimum results using the software is accepted and in order to verify adequacy of the models that are developed.

In our research study, material removal rate, surface roughness and temperature has optimal combination are A1, B3, C3 and A3, B3, C2 and A1, B1, C1 respectively. All responses optimal combination is match in orthogonal array. So there are not required to confirmation for material removal rate, surface roughness and temperature.

VIII. CONCLUSION

As per review of research papers, we can see that researcher work on material AISI52100 grade steel, EN19, AISI 304 austenitic SS, AISI 1030 steel, MDN250 steel, SAE8620, EN8, EN24 and EN47 and various composite materials which possess high hardness. As per selecting the machining parameter there is increase the surface roughness and decrease the MRR, the aim of the paper is decided on approach of performance measurement of high material removal rate (MRR), low surface roughness (Ra) and low tool tip temperature during hard turning of EN19 material.

The EN-19 has been turned with tungsten carbide tool bit. The conclusions relevant to this investigation are outlined below: The material removal rate increase with increase feed from 0.05 to 0.15 mm/rev, when the other two parameter are kept constant as well as material removal rate increase with increase depth of cut 0.25 to 0.75 mm, but reversely in case of cutting speed and vice versa.

While studying the effect of the cutting parameters on the material removal rate, it was observed that the effect of the cutting speed far outweighs the effect of the feed and the depth of cut, which are again roughly equal. The optimum condition for machining to reduce material removal rate would be A1 B3 C3. The cutting speed kept at 100 m/min, the feed kept at 0.15mm/rev and the depth of cut kept at 0.75 mm.

The surface roughness increase with increase feed from 0.05 to 0.10 mm/rev, but after 0.10 mm/rev it will be decrease till 0.15 mm/rev. when the other two parameter are kept constant as well as surface roughness increase with increase depth of cut 0.50 to 1.00 mm, but reversely in case of cutting speed and vice versa.

While studying the effect of the cutting parameters on the surface roughness, it was observed that both the cutting speed and the depth of cut play equally important roles in the effect on the surface roughness. The role of the feed rate given is not crucial to the same extent. The optimum condition for machining to reduce surface roughness would be A3 B3 C2 i.e., the speed kept at 200 m/min, the feed kept at 0.15 mm/rev and the depth of cut kept at 0.50 mm.

The effect of change in the feed from 0.05 to 0.75 mm/rev on average surface roughness is slightly raised.

The temperature increase with increase speed from 100 to 150 m/min, when the other two parameter are kept constant as well as temperature increase with increase depth of cut 0.50 to 1.00 mm, but reversely in case of feed and vice versa.

From grey relational analysis, we came to know that the all this Reponses maximum material removal rate, minimum surface roughness and minimum temperature will obtain at optimum at cutting speed 150 RPM, feed 0.10 mm/rev and depth of cut 0.75 mm.

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