Multi Objective Optimization Of parameter Of Turning on 17-4 PH Material by Grey Relational Method

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Abstract **-17-4 PH is the most widely used of all the precipitation-hardening stainless steels. Its valuable combination of properties gives designers opportunities to add reliability to their products while simplifying fabrication and often reducing costs. This valuable alloy is widely used in the aerospace, chemical, petrochemical, food processing, paper and general metalworking industries. This Research study refers to parametric optimization of turning process applying full factorial method in order to improve quality of manufacturing goods, and engineering development of designs for studying variation 17-4 PH is used as work-piece for carrying out experiment to optimize tool wear, temperature and surface roughness. There are three machining parameters i.e. spindle speed, feed rate, depth of cut. Different experiments are done by varying one parameter and keeping other two fixed so that optimized value of each parameter can be obtained. Full Factorial Method is designed with three levels of turning parameters with the help of software Minitab version 16.. It is predicted that Full Factorial Method is a good method for optimization of various machining parameters as it reduces number of experiments.**

***Keywords*-** **CNC Turning; ANOVA; Full factorial; Grey relational analysis; surface roughness; Temperature.**

I. INTRODUCTION

Recent advances in aerospace and automotive industries find demand of light rusting and pitting in all heat-treated conditions due to their favourable physical and mechanical properties such easy fabrication, high strength, relatively good ductility, and exceptional corrosion resistance in severeconditions, particularly in making components for marine constructions, oil and chemical industries and nuclear power plants Therefore, it is essential to analyse the machinability behaviour of these materials toreduce the material removal rate, surface roughness and minimize the Temperature. Literature in this field highlights various aspects of machining to studyprocess behaviour and parametric influence so that high quality finished parts interms of dimensional accuracy and surface finish can be produced Carbide cutting tools are widely used in metal cutting industry for the cutting of various hard materials such as, alloy steels, die steels, high speed steels, bearing steels, white cast iron and graphite cast iron. The past few decades have witnessed great advancements in the development of these cutting tools. Coating is also used on cutting tools to provide improved lubrication at the tool/chip and tool/workpiece interfaces and to reduce friction, and consequently reduce the temperatures at the cutting edge. The coating of tool or cryotreated tungsten carbide tool is essentially required to reduce the wear while machining hard materials.Turning is the removal of metal from the outer diameter of a rotating cylindrical work piece. Turning is used to reduce the diameter of the work piece, usually to a specified dimension, and to produce a smooth finish on the metal. Often the work piece will be turned so that adjacent sections have different diameters. Turning is the machining operation that produces cylindrical parts. In its basic form, it can be defined as the machining of an external surface:

- With the work piece rotating.
- With a single-point cutting tool, and
- With the cutting tool feeding parallel to the axis of the work piece and at a distance that will remove the outer surface of the work.

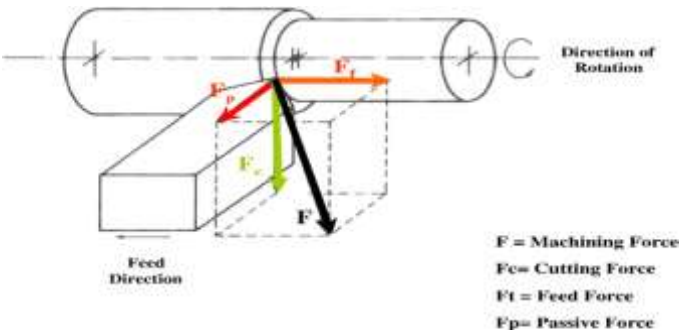

Fig 1: Schematic draw of the machining forces components in a turning operation

II. LITERATURE REVIEW

1. Ay Mustafa and at all carried out experiment on aluminum 7075 using diamond like carbon (DLC) coated cutting tool. It used to find that the surface roughness, cutting temperature and cutting forces in turning of above material and optimized the experimental results using Taguchi optimization method. The effect of each parameter on above response using ANOVA and showed that relationship between dependant and independent parameter was modeled with regression analysis. They were found the percentage of influence of various factors and their interaction on turning.[1]
2. Young huang and et all carried out experiment turning operation of hardened 52100 steel with use of CBN insert. They measured forces with vary depth of cut, feed rates (0.0762 and 1.778 mm/rev) without considering the Ploughing effects with shallow cuts with large negative rake angle and large nose radius. Comparison of experimental result and model prediction result give difference 15%.[2]
3. P.G. Benardos and et all conducted experiment on C45 steel as work piece and use of cutting insert VNMG160404 on turning of CNC lathe. He determines difference in part dimensions cause of elastic deflection of the work-piece due to cutting forces during machining. he mainly worked on analytical modeling equation of work piece and developed artificial neural network(ANN). In the case of analytical model requires the mechanical properties of the work-piece material, the geometry of the final part and the cutting force values, this numerical method can predict the elastic deflection to determine cutting force. In case of ANN had Five inputs were the depth of cut, feed per revolution, spindle speed, the L/D ratio (L being the length of the work-piece and D its diameter) and the Li/L ratio (Li being the distance of a work-piece point from the clamping point) and ANN model runs by MATLAB application. Comparing the two above model he found that, the analytical model is able to handle even the most complex geometries by approximating circular, conical and other profiles through cylindrical segments. In contrast, the ANN model must be re-trained with different input parameters and data in order to be applied to case of e the different geometries and different equipment but after evaluation He also measure that the ANN Model is better in most aspects. Its predictions are more accurate and more consistent than the analytical model and also ANN model applicable for production floor environment.[3]
4. Yusuf SahinAndRizaMotorcu had worked on 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 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.[4]

III. METHODOLOGY

Full factorial design

Full factorial design is used for simultaneous study of several factor effects on the process. By varying levels of factors simultaneously we can find optimal solution. Responses are measured at all combinations of the experimental factor levels. The combination of the factor levels represent the conditions at which responses will be measured. Each experiment condition is a run. The response measurement is an observation. The entire set of run is a design of experiment. It is used to find out the variables which are the most influence on the response and their interactions between two or more factors on responses.

Process Parameter and Their Levels

The three primary factors in turning operation are speed, feed, and depth of cut. Other factors such as kind of material, environment and type of tool have a large influence, sothese three are the ones the operator can change by adjusting the controls, right at the machine.

Table 1– Proposed Range of process parameter & selected level

Control factor	Unit	level 1	level2	Level 3
Feed (f)	mm/rev	0.05	0.1	0.15
Cutting speed (v)	m/min	50	65	80
Depth of cut	Mm	0.50	0.75	1

GREY RELATIONAL METHODOLOGY.

Through the grey relational analysis, a grey relational grade can be obtained to evaluate the multiple performance characteristic. As a result, optimization of the complicated multiple performance characteristic can be converted into the optimization of a single grey relation grade. For multiple performance characteristic optimizations using GRA, following steps are followed:

1. Conduction of experiments at different settings of parameters based on OA.
2. Normalization of experimental result for all performance characteristics.
3. Performance of grey relational generating and calculation of grey relational coefficient (GRC).
4. Calculation of grey relation grade (GRG) using, weighing factor for performance characteristics.
5. Analysis of experimental results using GRG and statistical analysis of variance (ANOVA).
6. Selection of optimal levels of process parameters.
7. Conducting confirmation experiment to verify optimal process parameter settings.

IV. EXPERIMENTAL RESULTS AND DISCUSSION

Table 2 Experimental Readings

Sr no.	Feed [mm/rev]	Speed [m/min]	DOC [mm]	Surface Roughness [µm]	Temperature [^{0}C]
1	0.05	50	0.50	1.45	53
2	0.05	50	0.75	1.62	55
3	0.05	50	1.00	1.69	58
4	0.05	65	0.50	1.34	54
5	0.05	65	0.75	1.39	55
6	0.05	65	1.00	1.49	59
7	0.05	80	0.50	1.31	57
8	0.05	80	0.75	1.37	60
9	0.05	80	1.00	1.45	64
10	0.10	50	0.50	1.69	55
11	0.10	50	0.75	1.79	56
12	0.10	50	1.00	1.85	56
13	0.10	65	0.50	1.58	59
14	0.10	65	0.75	1.62	60
15	0.10	65	1.00	1.73	62
16	0.10	80	0.50	1.49	63
17	0.10	80	0.75	1.57	66
18	0.10	80	1.00	1.67	70
19	0.15	50	0.50	1.87	60
20	0.15	50	0.75	1.93	63
21	0.15	50	1.00	2.01	64
22	0.15	65	0.50	1.68	63
23	0.15	65	0.75	1.73	67
24	0.15	65	1.00	1.83	71
25	0.15	80	0.50	1.59	64
26	0.15	80	0.75	1.69	67
27	0.15	80	1.00	1.87	75

Main Effects Plot for Surface Roughness

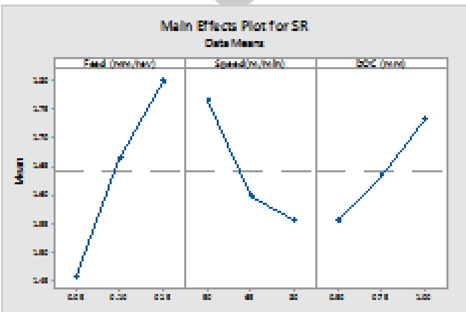

Fig 2- Effect of control factor on Surface Roughness

.From the figure.2, it has been conclude that the optimum combination of each process parameter for lower Surface Roughness is meeting at low feed [A1], highSpeed [B3] and low Depth of cut[C1]

Main Effects Plot for Temperature

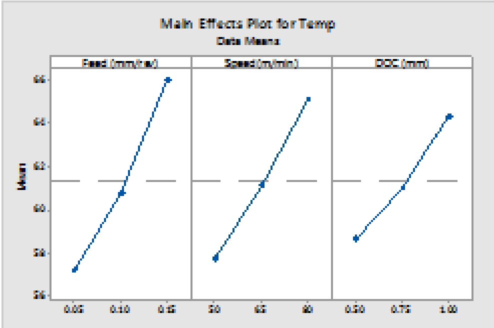

Fig.3- Effect of control factor on Temperature

. From the figure.3, it has been conclude that the optimum combination of each process parameter for lower temperature is meeting at feed [A1], Speed [B1] and Depth of cut[C1].

Analysis of Variance for Surface Roughness

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 α- 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. From ANOVA result it is observed that the feed, Speed and Depth of cut influencing parameter for Surface Roughness, because the value of p for all process parameters are 0.000 so they are influencing parameter for Surface Roughness.

Table 3 - ANOVA table of Surface Roughness

Source	DF	Seq SS	Adj SS	Adj MS	F	P	Contibution (%)
Speed time	2	0.53876	0.53876	0.26938	314.32	0.000	58.62
Speed	2	0.22210	0.22210	0.11105	129.57	0.000	24.16
No of passes	2	0.14099	0.14099	0.07049	82.25	0.000	15.34
Error	20	0.01714	0.01714	0.00086			
Total	26	0.91899					
R-Sq = 98.13%				R-Sq(adj) = 97.58%			

Analysis of variance for Temperature

From ANOVA result it is observed that the feed, Speed and Depth of cut are influencing parameter for Temperature, while the value of p for feed, Speed and depth of cutis less than 0.05 p values. So, all process parameter influencing parameter for material removal rate.

Table 4 – ANOVA Table for Temperature

Source	DF	Seq SS	Adj SS	Adj MS	F	P	Contibution (%)
Speed time	2	350.89	350.89	175.44	44.73	0.000	42.89
Speed	2	242.67	242.67	121.33	30.93	0.000	29.66
DOC	2	146.00	146.00	73.00	18.61	0.000	48.78
Error	20	78.44	78.44	3.92			17.84
Total	26	818.00					
R-Sq = 90.41%				R-Sq(adj) = 87.53%			

V Multi-Response Optimization of Process Parameter

Table 5 *Normalization, Grey relational coefficient and grey relational grade of experimental data*

No.	Normalized S/N ratios		GRC		GRG
	RA	Temp	RA	Temp	

1	0.8	1	0.7143	1	0.85715
2	0.5571	0.9091	0.5303	0.8462	0.68825
3	0.4571	0.7727	0.4795	0.6875	0.5835
4	0.9571	0.9545	0.9211	0.9167	0.9189
5	0.8857	0.9091	0.814	0.8462	0.8301
6	0.7429	0.7273	0.6604	0.6471	0.65375
7	1	0.8182	1	0.7333	0.86665
8	0.9143	0.6818	0.8537	0.6111	0.7324
9	0.8	0.5	0.7143	0.5	0.60715
10	0.4571	0.9091	0.4795	0.8462	0.66285
11	0.3143	0.8636	0.4217	0.7857	0.6037
12	0.2286	0.8636	0.3933	0.7857	0.5895
13	0.6143	0.7273	0.5645	0.6471	0.6058
14	0.5571	0.6818	0.5303	0.6111	0.5707
15	0.4	0.5909	0.4545	0.55	0.50225
16	0.7429	0.5455	0.6604	0.5238	0.5921
17	0.6286	0.4091	0.5738	0.4583	0.51605
18	0.4857	0.2273	0.493	0.3929	0.44295
19	0.2	0.6818	0.3846	0.6111	0.49785
20	0.1143	0.5455	0.3608	0.5238	0.4423
21	0	0.5	0.3333	0.5	0.41665
22	0.4714	0.5455	0.4861	0.5238	0.50495
23	0.4	0.3636	0.4545	0.44	0.44725
24	0.2571	0.1818	0.4023	0.3793	0.3908
25	0.6	0.5	0.5556	0.5	0.5278
26	0.4571	0.3636	0.4795	0.44	0.45975
27	0.2	0	0.3846	0.3333	0.35895

The higher grey relational grade reveals that the corresponding experimental result is closer to the ideally normalized value. Experiment 4 has the best multiple performance characteristic among 27 experiments, because it has the highest grey relational grade shown in table 5. The higher the value of the grey relational grade, the closer the corresponding factor combination is, to optimal.

Main Effect of Factors on Grey Relational Grade (GRG)

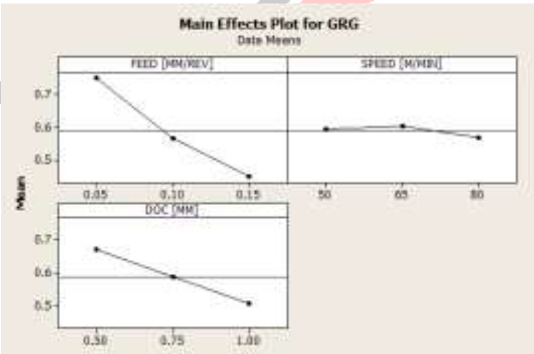

Fig. 4 Effect of control factors plot of GRG

For the combined response maximization or minimization, figure 4 gives optimum value of each control factor. It interprets that level A1, B2, and C1 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 6 Main effect of factors on Grey Relational Grade

Symbol	Control Factor	Level-1	Level-2	Level-3
A	Feed	**0.74865**	0.5651	0.449589
B	Speed	0.593528	**0.602722**	0.567089
C	DOC	**0.67045**	0.587833	0.505056

As we know that higher grey relational grade value will give optimum value of cutting forces, feed forces and surface roughness. So from above table 5.6, it is concluded that level-3 is higher for cutting speed and level-1 is higher than for feed and as well as depth of cut. Thus it is revealed that response will be optimum at feed 0.05 mm/rev, cutting speed 65 m/min, and depth of cut 0.50 mm.

VI. Experimental Validation

For experimental validation, there is L_9 Taguchi method used and nine combination generate as per based on Taguchi approach. In this method, combination of feed, speed and depth of cut are higher than to combination of which are used in research study array approach. For this concern feed are range of 0.15, 0.25 and 0.30 mm/rev, speed are range of 60, 90 and 120 m/min and depth of cut are range of 0.60, 0.80 and 1.20 mm are used.

Table 7 *L_9 Taguchi method*

sr no.	Feed [mm/rev]	Speed [m/min]	Doc [mm]	Surface roughness [µm]	Temperature[°C]	Predicted Surface roughness [µm]	Predicted Temperature [°C]
1	0.15	60	0.60	2.0119	55.9168	1.97	56
2	0.15	90	0.80	2.0753	58.4102	2.10	59
3	0.15	120	1.20	2.2093	63.1636	2.22	67
4	0.25	60	0.60	2.3549	64.6968	2.39	64
5	0.25	90	0.80	2.4183	67.1902	2.43	68
6	0.25	120	1.20	2.5523	71.9436	2.59	70
7	0.30	60	0.60	2.5264	69.0868	2.51	72
8	0.30	90	0.80	2.5898	71.5802	2.56	73
9	0.30	120	1.20	2.7238	76.3336	2.64	75

From table, it has been observed that value of R-Sq is 98.6% which described the proportion of variation in the observed response values that is explained by the predictor(s). In this study value of R-sq is high, so predicted result is approximately nearby actual result.

VI. Conclusion

The 17-4 PH has been turned with WC tool bit. The conclusions relevant to this investigation are outlined below:

1. The surface roughness increase with increase feed from 0.05 to 0.15 mm/rev, when the other two parameter are kept constant as well as surface roguhness increase with increase depth of cut 0.50 to 1.00 mm, but reversely in case of cutting speed and vice versa.
2. The temperature increase with increase feed from 0.05 to 0.15 mm/rev, when the other two parameter are kept constant as well as temperaratue increase with increase depth of cut 0.50 to 1.00 mm, as well same effect of cutting speed on temperature.
3. The optimum condition for machining to reduce surface roughness would be A1 B3 C1. The cutting speed kept at 1500 RPM, the feed kept at 0.05mm/rev and the depth of cut kept at 0.5 mm.
4. While studying the effect of the cutting parameters on the Temperature, it was observed that both the cutting speed and the feed rate play equally important roles in the effect on the temperature. The role of the depth of cut given is not crucial to the same extent. The optimum condition for machining to reduce temperature would be A1 B1 C1 i.e., the speed kept at 600 RPM, the feed kept at 0.05 mm/rev and the depth of cut kept at 0.50 mm.
5. Through use of regression equation, engineer can manipulate range of cutting speed, feed and depth of cut for this particular work- material and tool material combination. Also it has been find out and predicted surface roughness, material removal rate and temperature at any combination of process parameter.
6. From grey relational analysis it is concluded that response will be optimum at feed 0.05 mm/rev, cutting speed 1500 RPM, and depth of cut 0.50 mm

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