TO STUDY THE PROCESS PARAMETERS OF NIMONIC80A ON SURFACE ROUGHNESS IN DRY MACHINING: BY ANOVA APPROACH

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Abstract: Dry Machining is a process of metal removal and it does not involve the use of cutting fluids. It has become more popular as a finishing process. In metal cutting process, the use of cutting fluids, cooling and easy chip removal causes long term effects of cutting fluids disposal into environment. Manufactures all over the world are trying to discover the new methods to eliminate the use of cutting fluids. Thus it is especially crucial to select the machining parameters to obtain the desired surface finish of machined component. This paper presents the experimental investigation and analysis of the machining parameters while turning the nimonic80a alloy using CBN cutting tool. The experiments were designed using Taguchi's experimental design. The parameters considered for the experiment are cutting speed, feed rate and depth of cut. The experimental results were analyzed statistically to study the influence of process parameters on surface roughness.

Keyword: Dry Machining, Surface Roughness.

1. INTRODUCTION

Machining hardened steels has become an important manufacturing process, particularly in the automotive and bearing industries. Abrasive process such as grinding have typically been required to machine hardened steels, but advances in machine tools and cutting materials have allowed hard turning on modern lathes to become a realistic replacement for many grinding applications[1]. Machining of hard materials has always remain as a challenging task to the researchers and industries. Machining does not simply imply cutting of metal, but it accounts surface integrity and cost effectiveness to evaluate the success of machining operation, which will depend on the machinability of a work material and suitability of a tool material for that particular purpose. As the hardness of the material increases, its machinability decreases as the cutting force required to cut the work piece increases, which in turn spoil the surface integrity of the surface generated. Other than aesthetic point of view, surface roughness is of vital importance because machined surface characteristics such as surface roughness and surface damage have significant influence on the surface sensitive properties such as fatigue strength, corrosion resistance and creep strength [2]. The situation now demands the best tool material for a particular work piece material with best suited cutting parameters so as to achieve best possible surface with minimum cost. The cost effectiveness of a tool for a particular work piece depend on tool material properties like toughness, hardness, wear resistance, coefficient of friction and initial cost. It is just because of this reason that the tools are now coated with different compound layers to improve its properties.

Thus finding the best tool and work piece material combinations is of prime importance.

2. LITERATURE SURVEY

M. V. R DURGA PRASAD: The purpose of this literature deals with the experimental investigations to study the process parameters of dry machining. Dry machining is crucial to select the machining parameters to obtain the desired surface roughness of machined component. In dry machining the speed , feed , depth of cut are studied as surface roughness as the output response variable. The experimental results were analyzed statistically to study the process parameters on surface roughness. The following conclusions are drawn from this paper. Concepts of dry machining and its importance in turning. Surface roughness values are increasing with increase in speed. Depth of cut is not influencing much on roughness values. Roughness values are varying non linearly with increase variation of feed.

MOHAMMED ALAZHARI: The purpose of this literature deals with the cutting parameters of mild steel in dry turning operation. The quality of machined surface is characterized by the accuracy of manufacture with respect to the dimensions specified by the designer. In the propose research work the cutting parameters have been optimized in dry turning operations of mild steel by high speed cutting tool in dry condition and as a result of that combination the factors was obtained to get the lowest surface roughness. ANOVA and signal to noise factor ratio were used to study the performance characteristics in this turning operation.

NEERAJ SHARMA, RENU SHARMA: The purpose of this literature deals with the process parameters of turning parts. The study aimed at evaluating the best process environment which could satisfy the requirements of both quality and productivity with special emphasis on reduction of cutting tool flank wear increases in tool life. From present research of ANOVA , it is found that depth of cut is most significant , spindle speed is significant and feed rate is least significant factor affecting surface roughness. Influences of turning process variables on surface roughness of mild steel have been studied in this research. Results shown that cutting speed and depth of cut were significant variables to the surface roughness of mild steel. Surface roughness decreases with increase in spindle speed. Surface roughness increases with depth of cut.

P. S. SREEJITH: This paper presents the recent developments in the dry machining operation. Dry machining requires suitable measures to compensate for the absence of coolants. This paper gives a state of art and recent advancements. Dry machining is only possible when all the operations can be done dry. Technology has to be further improved if dry cutting is to be fully employed in industries.

3. EXPERIMENTAL DETAILS

3.1 Work Material and Cutting Tool

Nickel based super alloys pose a real threat to industries when it comes to machining, due to their strength and hardness. Despite of this disadvantage, they are high in demand just because of their excellent performance at high temperature. Nimonic80a is one of such alloys which exhibits all the essential properties of a super alloy and has a hardness less than inconel718 [3].super alloys are such among hard material which due to their exceptional properties – excellent mechanical strength an creep resistance at high temperatures, good surface stability and corrosion and oxidation resistance – are in heavy demand these days and are the subject to be focused on because of their extensive applications in gas turbines, space vehicles, submarines, nuclear reactors, military electric motors, chemical processing vehicles and heat exchanger tubing. Nickel based alloys are part of these family of super alloys which has nickel as its major component in its composition (more than 50%) [4]. Nimonic80a is a nickel based super alloy. It is a wrought, age hardened alloy and strengthened by additives like titanium, aluminum and carbon. The chemical composition of nimonic80a is shown in table1.

Table-1 chemical composition of nimonic80a material

Factors	Level 1	Level 2	Level 3
Speed (m/min)	100	175	250
Feed rate (mm/rev)	0.02	0.03	0.04
Depth of cut (mm)	0.100	0.125	0.150

The tools used in dry machining have to suit some specific requirements such as:

Coating of the tool should withstand with high temperature and it should provide with lubricant effect to reduce friction. The material of the tool should be ultra hard. The machining of hard work piece materials requires significantly harder cutting tools. Cubic Boron Nitride (CBN) is the second hardest tool next to diamond. It is very expensive and only available in the form of simply shaped inserts. It has high hardness, high thermal stability, chemical resistance and longer tool life [5].

3.2 SELECTION OF PROCESS PARAMETERS

Performance of CBN cutting tools is highly dependent on the cutting conditions i.e., cutting speed, feed rate and depth of cut. Especially cutting speed and depth of cut significantly influence tool life. Increased cutting speed and depth of cut result in increased temperatures at the cutting zone [6]. Since CBN is a ceramic material, at elevated temperatures chemical wear becomes a leading wear mechanism and often accelerates weakening of cutting edge, premature in resulting tool failure(chipping), namely edge breaking of the cutting tool.

Based on extensive literature review, process parameters considered for the present study are cutting speed, feed rate and depth of cut. These parameters plays a vital role in obtaining a finished surface.Table2 shows the details of the process variables and their levels considered.

Material	Ni	Cr	Al	Fe	Co
Nimonic80a	60	18-21	1-1.8	3	2

Table2 process parameters

4. EXPERIMENTAL INVESTIGATION

A three factor-three level factorial design comprising of cutting speed, feed rate and depth of cut was adopted for optimization. The levels of the cutting speed, feed rate and depth of cut were chosen, such that they cover the full applicable range of cutting for the whisker reinforced ceramic insert tool material for turning the nimonic80a material l[4]. A dry machining environment was adopted for the conduct of the turning trails. Taguchi's method was adopted to select the levels of the control factors(cutting speed, feed rate and depth of cut).

Taguchi design of experiment with a standard L27 orthogonal array was selected to conduct the turning experiments. Design of experiment concept was used for planning the necessary experimentation. The details of experimental layout are shown in table-3.

Table-3 Experimental Layout and Output Response

#	Speed (m/min)	Feed (mm/rev)	Depth of cut(mm)	Surface Roughness
1	100	0.02	0.100	0.80
2	100	0.02	0.100	0.86
3	100	0.02	0.100	0.46
4	100	0.03	0.125	0.40
5	100	0.03	0.125	0.16
6	100	0.03	0.125	0.38
7	100	0.04	0.150	0.30
8	100	0.04	0.150	0.66

9	100	0.04	0.150	0.74
10	175	0.02	0.125	0.66
11	175	0.02	0.125	0.58
12	175	0.02	0.125	0.30
13	175	0.03	0.150	0.56
14	175	0.03	0.150	1.00
15	175	0.03	0.150	0.46
16	175	0.04	0.100	0.30
17	175	0.04	0.100	0.80
18	175	0.04	0.100	1.14
19	250	0.02	0.150	1.88
20	250	0.02	0.150	1.08
21	250	0.02	0.150	0.58
22	250	0.03	0.100	1.18
23	250	0.03	0.100	1.16
24	250	0.03	0.100	1.16
25	250	0.04	0.125	0.50
26	250	0.04	0.125	1.02
27	250	0.04	0.125	0.76

All the work pieces were machined and the roughness values for all the twenty seven samples were measured, the corresponding surface roughness values are shown in the table 3.

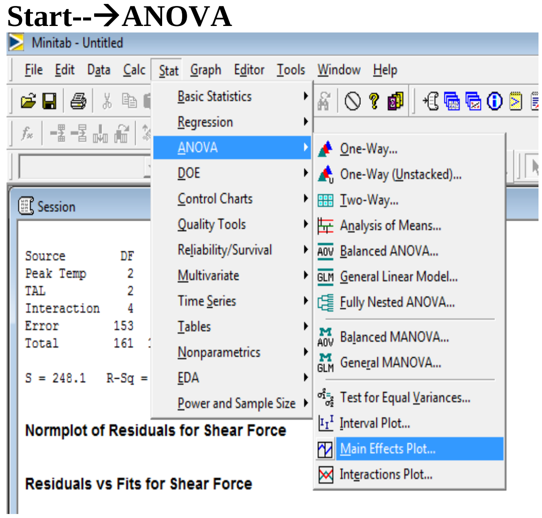
5. EXPERIMENTAL ANALYSIS

The factors effecting the surface roughness values are known by ANOVA using Minitab software.

By using plan of tests to study the influence of input parameters i.e. cutting speed, feed rate and depth of cut on output parameter i.e. surface roughness of Nimonic80A can be acknowledged. Analysis can be conducted using a statistical tool with aid of various plots like main effect plots, interaction plots and surface plots which are discussed in this chapter.

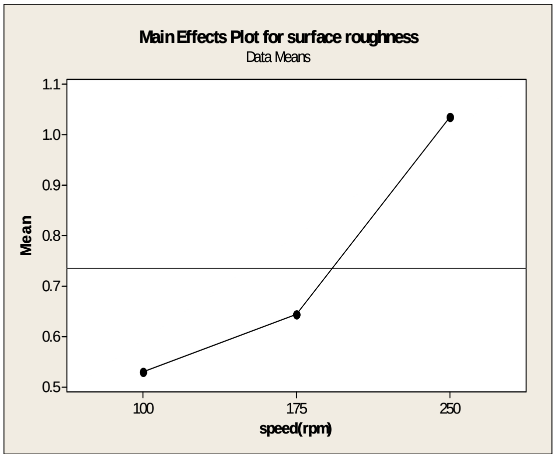
5.1 INTERPRETING ANOVA RESULTS

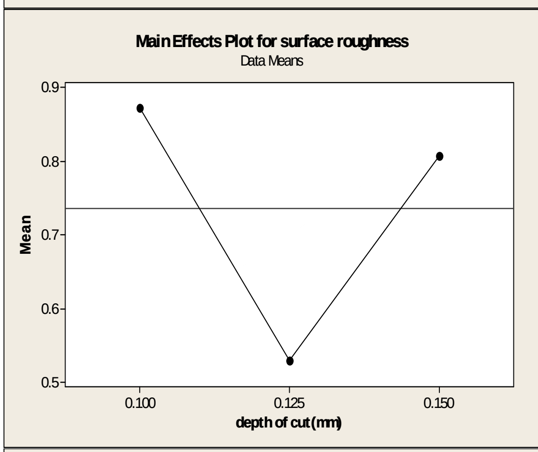
Assume there were significant factors; the **Main Factor Plot** can be obtained by clicking **Start--→ANOVA**

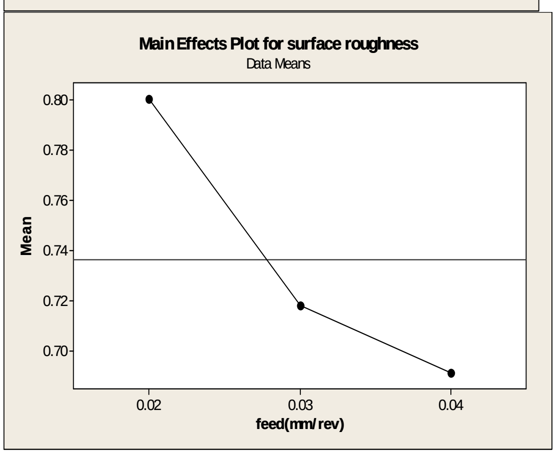


5.2 MAIN EFFECT PLOTS FOR MEANS

The main effect plots are used to plot data means when there are multiple factors. The points in the plot are the means of the response variable at the various levels of each factor, with a reference line drawn at the grand mean of the response data. The main effect plots are used for comparing magnitudes of main effects.







It is observed from the above figure that as the cutting speed increases from 100 m/min to 175m/min the surface roughness gradually decreases. Further increase in the cutting speed to 250m/min also decreases the surface roughness. The above trend of decreasing the surface roughness with an increase in cutting speed is because of thermal softening effect that prevails in machining of nimonic80A. As the nimonic80a has low thermal diffusity, the rate of heat transferred to the surroundings from the machining region is very less. As a result, more heat gets accumulated in the machining zone.

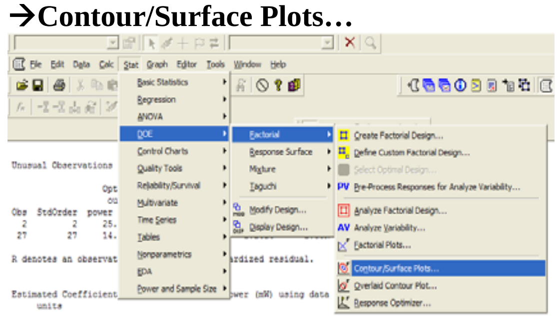
It is observed from the above fig. that as the feed rate decreases from 0.02mm/rev to 0.03mm/rev, the surface roughness decreases gradually. Further decrease in the feed rate to 0.04mm/rev causes decrease in the surface roughness. At higher feed rate, the friction between tool and work piece will be higher due to large cross sectional area in the deformed zone.

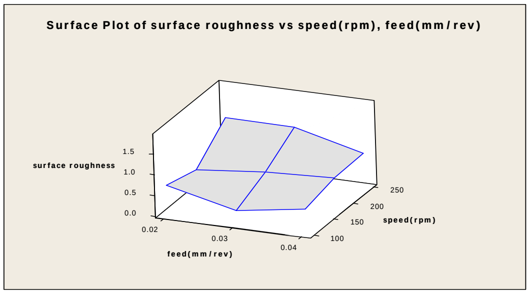
It is observed from the above fig. that as the depth of cut decreases from 0.100 mm to 0.125mm, the surface roughness increases. However further increase in the depth of cut to 0.150mm causes reduction in surface roughness. This can be attributed to the fact that, with an increase in depth of cut more amount of material in deforming volume leads to severe plastic deformation and therefore the machined surfaces show high surface roughness. However further increase in depth of cut causes increase in temperature on account of increase in frictional heat due to more contact between tool and work material. Therefore from the fig. it is found that machining at 250 m/min with 0.02mm/rev feed rate and 0.150 depth of cut produces lower surface finish.

5.3 SURFACE PLOTS

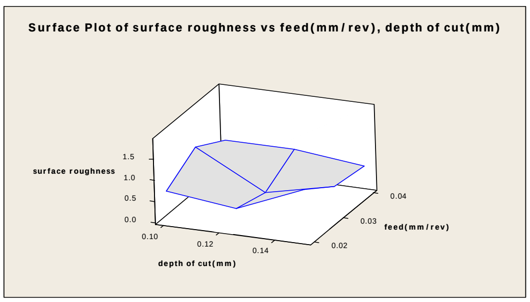
The 3D surface plots are used to evaluate the relationship between three variables at once. These plots use interpolation to produce a continuous surface i.e. surface plot or grid.

Click **Start---→DOE--→Factorial--→Contour/Surface Plots…**

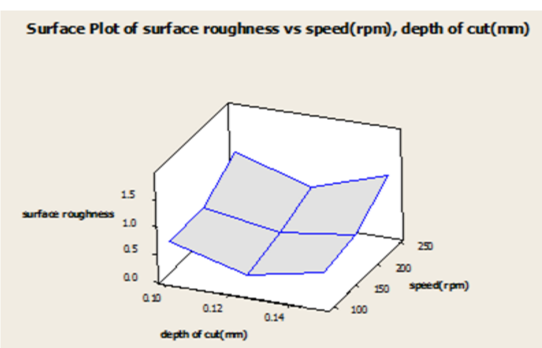




From the figure it is observed that minimum surface roughness is produced when the feed rate is in the range of 0.02mm/rev and 0.03mm/rev and cutting speed is in the range of 100m/min to 150m/min. but when the feed rate increases from 0.03mm/rev to 0.04mm/rev and when the cutting Speed changes from 150 m/min to 200 m/min, the surface roughness increases.



From the figure it is observed that minimum surface roughness is produced when depth of cut is 0.14mm and feed rate is in the range of 0.02mm/rev to 0.03mm/rev but when feed rate increases from 0.03mm/rev to 0.04mm/rev, surface roughness increases.



From the figure it is observed that the surface roughness is increased when the depth of Cut is in the range of 0.10mm to 0.14mm and cutting speed is in the range of 100m/min to 150 m/min. but it is found to be decreased when the depth of cut changes from 0.12mm to 0.14mm and cutting speed from 150m/min to 250 m/min.

SUMMARY:

From the above analysis the optimum conditions: 250m/min cutting speed, 0.04mm/rev feed rate and 0.12mm depth of cut are obtained.

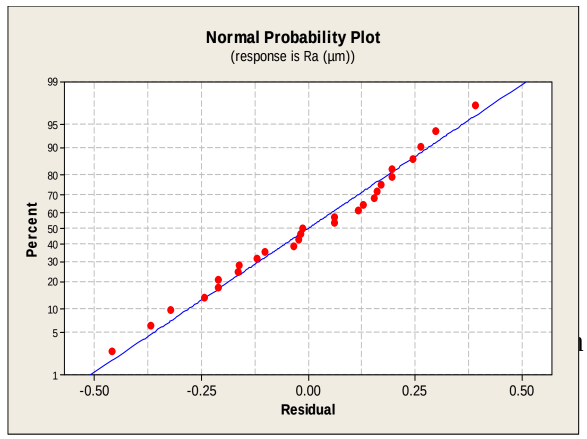
6. RESULTS AND DISCUSSIONS

VALIDATING ANOVA RESULTS

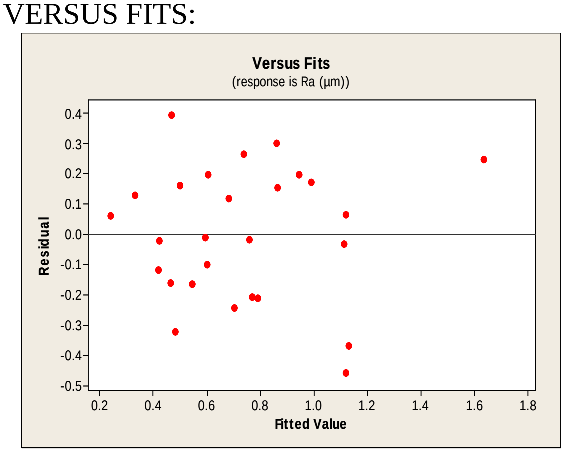
Choose Start ➤ DOE ➤Factorial ➤ Analyze Factorial Design.

It is necessary to check the assumptions of ANOVA before draw conclusions. There are three assumptions in ANOVA analysis: normality, constant variance, and independence.

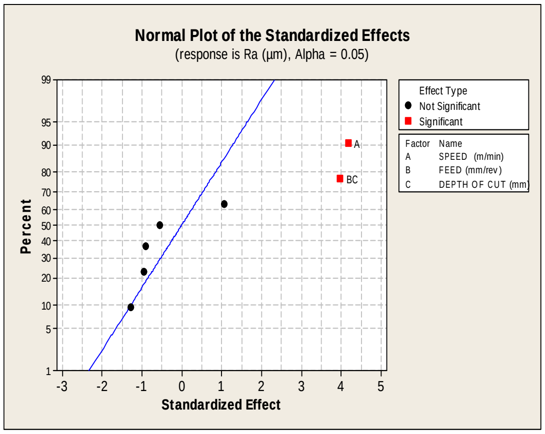
NORMALITY:

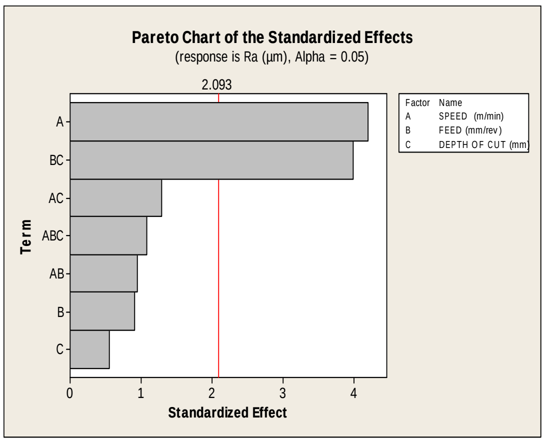


VERSUS FITS:



This plot should show a random pattern of residuals on both sides of 0, and should not show any recognizable patterns. A common pattern is that the residuals increase as the fitted values increase.





The results show that both normality and constant variance assumptions were met. According to the following normal plot of standardized effects, factors A and BC have significant effect on the response.

Pareto chart also shows the same results. It is clearly shown that the Factors A and BC crosses the significance line. So the factors speed and combination of feed and depth of cut are significant and effects the surface roughness.

7. REGRESSION ANALYSIS

A statistical measure that attempts to determine the strength of the relationship between one dependent variable (usually denoted by Y) and a series of other changing variables (known as independent variables) is called Regression Analysis.

The regression equation obtained is

Ra =0.475+0.00338(speed)-5.44(feed)-1.33(depth of cut.

This equation gives the expected value of surface roughness Ra for any combination of factor levels.

8. CONFIRMATION TESTS

To verify the fitness of the model developed, three confirmation run experiments shown in the table 5.2 are performed. The test conditions are within the range of levels defined before in the table 4. The percentage error is calculated based on the difference between the predicted values and the actual experimental values. The percentage error between the actual and predicted value for Ra is shown in the table 5

Table 4 Confirmation Runs

Test no.	Speed (m/min)	Feed rate (mm/rev)	Depth of cut (mm)
1	100	0.02	0.100
2	100	0.03	0.100
3	100	0.04	0.100

Table 5 Confirmation Results

Test no.	Experimental values	Predicted values
1	0.67	0.57
2	0.66	0.51
3	0.60	0.45

The Analysis of Variance is conducted and the most significant factor affecting the output parameter, surface roughness is determined. It is found that cutting speed has most significant impact on surface roughness. Also a mathematical model is developed using multiple linear regression. It is observed that the mathematical model is practically accurate.

9. CONCLUSIONS

The following conclusions can be drawn based on the analysis of the experimental study on dry turning Nimonic80A with CBN 10 tool insert

- It is observed that speed and combination of feed and depth of cut has the most significant effect on surface roughness Ra.
- It is found that machining at 250m/min cutting speed with 0.04mm rev feed rate and 0.12mm depth of cut produced lower surface roughness in dry machining.
- Therefore, the present work reveals that desired quality surfaces can be obtained with dry machining turning

and the analysis of results will provide in-depth knowledge of how the process variables are influencing the surface finish

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