Available online: www.ijsrmes.com

International Journal for Scientific Research in Modern Engineering and Science

International Journal for Scientific Research in Modern Engineering and Science, 1(6): 8-15 (2020)

MULTIOBJECTIVE OPTIMIZATION OF TURNING OPERATIONS BASED ON THE RESPONSE SURFACE METHODOLOGY

Akash Sahu[1]*, Parag Shrivastava[2]

[1]*M. Tech. Scholar, Department of Mechanical Engineering, SSTC-SSGI, Bhilai (C. G.)*
[2]*Assistant Professor, Department of Mechanical Engineering, SSTC-SSGI, Bhilai (C. G.)*

Abstract

In this work, the response surface methodology is a powerful tool for designing quality optimization, which is used to determine the optimal cutting parameters for conducting operations. A reaction model and analysis of variance (ANOVA) are used to examine the harvesting characteristics of the INCONEL 718 bars, which use uncemented carbide cutting tools. In metal cutting operations, parameters are required that can withstand extreme conditions produced during machining. Common problems that all cutting parameters, e.g. Surface roughness, cutting force, power consumption, tool life, and material removal rate. Various methods are used to find the optimal parameters for the machining process. Design analysis was performed on an experimental matrix that is available in the literature and a central composite design is applied to find the optimal process parameters for the INCONEL 718 turning process. This process involves various parameters, such as speed. Spindle, feed and cut depth, etc. Using a factor, the minimum parameter can be obtained using the reaction surface method in Minitab 17.0. This work can demonstrate optimal machining parameters that give minimum surface roughness, maximum tool life, minimum cutting force, minimum energy consumption and maximum material removal rate.

Keywords: *Optimization, Turning Process, Machining Parameters, RSM.*

** Corresponding author*

1. Introduction

Machining costs more than 20% of the value of products manufactured in industrialized countries. Therefore, it is mandatory to investigate the machinability behavior of different materials by changing the machining parameters to obtain optimal results. The machinability of a material provides an indication of its adaptability for fabrication by a machining process. Good machinability is defined as an optimal combination of factors such as low cutting force, good surface finish, low tool tip temperature, and low power consumption. Modeling and process optimization are two important issues in product manufacturing. Selecting the optimal cutting parameters, such as depth of cutting, feed and speed, is a very important issue for each machining process. In shop practice, the cutting parameters are chosen from specialized manuals or machining databases, but the limits given in these sources are actually initial values and not optimal values. Optimization of machining parameters not only increases usability for machining economics, but also increases product quality to a great extent. In today's manufacturing environment, many industries have tried to introduce Flexible Manufacturing Systems (FMS) as a strategy suited to the ever-changing competitive market requirements. To ensure the quality of mechanized products to reduce machining costs and increase machining efficiency, it is very important to select the appropriate machining parameters when selecting machine tools for machining.

Turning is a very efficient machining method to remove excess material from the base metal with the help of a single cutting tool through a rotating cylindrical workpiece. The cutting tool has a direction of travel similar to the axis of rotation of the work. The turning operation is performed on a lathe machine that provides the necessary power to rotate the work at the desired rotational speed with respect to the depth of the cut and depth. Therefore, the three cutting elements are the depth of cut, feed rate, and cutting speed to optimize in a turning process. Turning operation is a major operation used for manufacturing machine elements in manufacturing industries, i.e., shipping, automotive and aerospace.

2. Methodology

In this analysis, the cutting parameters are analyzed for material INCONEL 718 metal having dimensions of 50mm diameter and 1000mm length. It is an important engineering material employed in manufacturing of components in auto and aerospace industries. This material is selected for Analysis as it has the property of high-speed dry machining and the present trend in the manufacturing industry is high speed dry machining.

Table 1. Factors (parameters) and levels for Design of Experiments

Factor	Code	Level 1	Level 2	Level 3
Speed (rpm)	A	18	33	45
Feed (mm/rev)	B	0.1	0.2	0.3
Depth of Cut (mm)	C	1.0	1.5	2.0

There are five objective functions such as reducing the surface roughness, the cutting force, power consumption, and maximizing the tool life and the material removal rate.

Table 2. Output response based on L_{27} orthogonal array achieved from artificial neural network tool

S. No.	A	B	C	Ra (µm)	F (N)	P (kW)	T (min)	MRR (mm^3/min)
1	18	0.1	1	1.419	444.84	1.442	24.99	2794.16
2	18	0.2	1	1.296	407.46	1.601	22.67	2585.19
3	18	0.3	1	1.162	369.84	1.756	20.26	2375.34

4	18	0.1	1.5	1.030	513.36	0.966	21.15	3516.37
5	18	0.2	1.5	0.841	467.17	1.096	17.80	3246.19
6	18	0.3	1.5	0.650	421.62	1.231	14.47	2984.92
7	18	0.1	2	0.778	665.53	0.894	16.42	4845.59
8	18	0.2	2	0.475	603.62	0.889	12.33	4412.31
9	18	0.3	2	0.175	540.70	0.915	7.96	4012.66
10	33	0.1	1	1.149	522.96	1.001	22.95	3531.65
11	33	0.2	1	0.977	479.69	1.136	19.84	3278.81
12	33	0.3	1	0.803	437.00	1.275	16.75	3033.08
13	33	0.1	1.5	0.894	672.84	0.922	18.42	4855.59
14	33	0.2	1.5	0.609	613.87	0.925	14.57	4436.06
15	33	0.3	1.5	0.328	553.84	0.957	10.45	4048.93
16	33	0.1	2	1.052	852.30	1.409	8.74	6988.83
17	33	0.2	2	0.714	817.18	1.280	5.71	6603.20
18	33	0.3	2	0.353	770.20	1.156	2.39	6149.44
19	45	0.1	1	1.013	624.13	0.884	21.41	4366.55
20	45	0.2	1	0.775	570.87	0.942	17.73	4019.16
21	45	0.3	1	0.542	518.32	1.020	13.95	3698.68
22	45	0.1	1.5	1.055	819.51	1.279	12.72	6475.33
23	45	0.2	1.5	0.722	774.79	1.173	9.82	6019.52
24	45	0.3	1.5	0.378	719.01	1.083	6.49	5524.22
25	45	0.1	2	1.221	901.79	1.685	3.81	7846.46
26	45	0.2	2	0.940	888.03	1.577	0.74	7664.29
27	45	0.3	2	0.636	868.36	1.444	2.38	7429.59

3. Results and Discussion

Validation for optimization work is done in this section. This work has been done in Minitab 17.0 response surface analysis. Figure 1 – Figure 3 shows the residual graph of surface roughness, cutting force, power consumption, tool life and material removal rate.

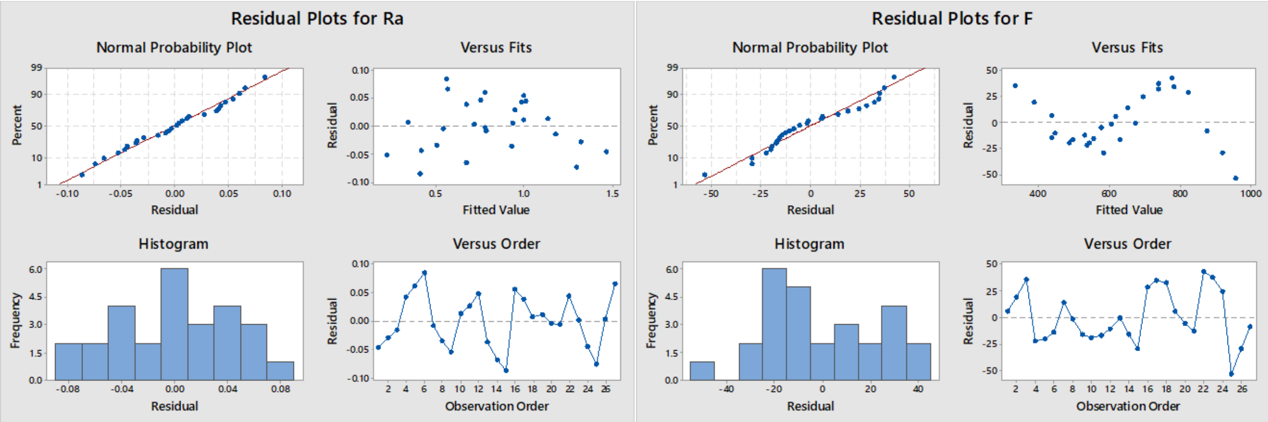

Figure 1. Residual plot for surface roughness (Ra) and cutting force (F)

Figure 0.1 Residual plot for

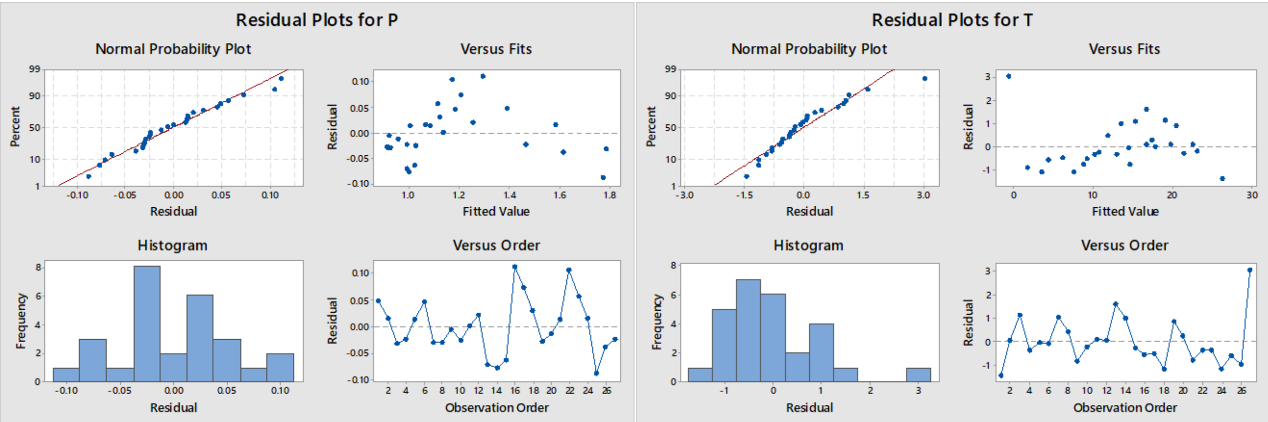

Figure 2. Residual plot for power consumption (P) and tool life (T)

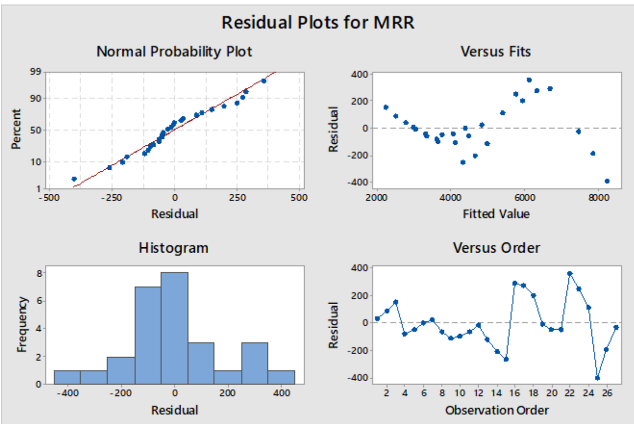

Figure 3. Residual plot for material removal rate (MRR)

The obtained parameter is comparing with the literature [18] and present investigation, which are found in Minitab 17.0.

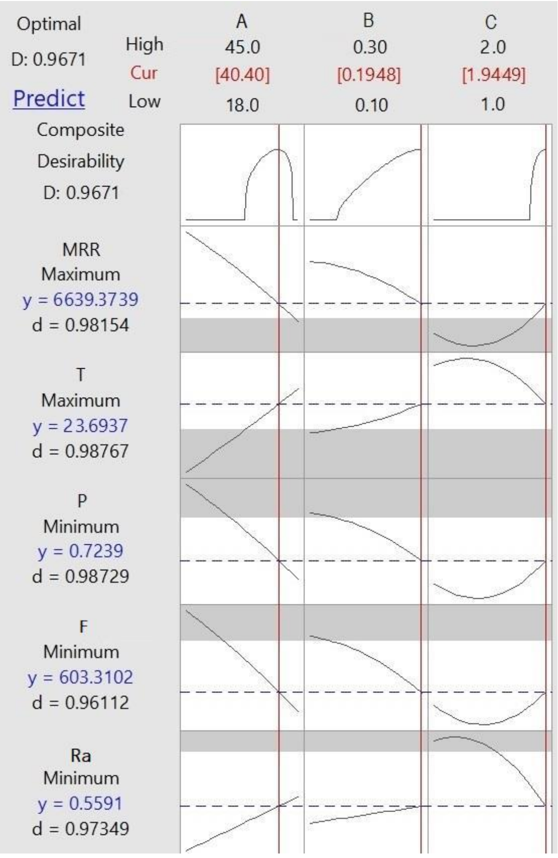

Figure 4. Optimization plot

Table 3. Comparison of optimized result

Parameter	Thirumalai and Kumar [18]	Present Work	% Difference
Surface Roughness (µm)	0.99	0.5591	44%
Cutting Force (N)	616	603.3	2%
Power Consumption	0.85	0.72	15%
Tool life (min)	22	23.6	7%
Material Removal Rate (mm3)	4221	6639.3	57%

From the Table 3, indicates that the comparison between Thirumalai and Kumar [18] and present work. The percentage difference in surface roughness, cutting force and power consumption in Thirumalai and Kumar [18] and present work is 44%, 2% and 15% decreased. Also, percentage difference tool life and MRR in Thirumalai and Kumar [18] and present work is 7% and 57% increased.

4. Conclusion and Future Work

- The result obtained from the data analysis indicated that the surface roughness, cutting force, and power consumption.

- The response surface model fits the analysis data of surface roughness, cutting force, and power consumption well with coefficient of correlation, R-sq (adjusted) and R-sq (predicted) is more than 90%.
- In literature [18], Thirumalai and Kumar find the output parameters from experimental and multi objective techniques by using cutting speed 41.98 m/min, feed 0.1 mm/rev and depth of cut 1.0 mm which gives minimum surface roughness (0.99μm), maximum Tool life (22 min), minimum cutting force (616 N), minimum power consumption (0.85) and maximum material removal rate (4221 mm3).
- The optimized results indicated that minimum surface roughness, cutting force and power consumption are 0.9591μm, 613N and 0.82 respectively and maximum tool life and material removal rate is 23.6 min and 4693.5mm3 by operating at 40 m/min speed, 0.1 mm/rev feed and 1.0mm depth of cut and the confidence level is 0.9167 (91.67%) indicated the model is fit.
- From above literature [18] and present investigation, which is clearly shown that the Response surface methodology is gives the best and optimal results.
- The percentage difference in surface roughness, cutting force and power consumption in Thirumalai and Kumar [18] and present work is 44%, 2% and 15% decreased. Also, percentage difference tool life and MRR in Thirumalai and Kumar [18] and present work is 7% and 57% increased.
- It has also been concluded that the Taguchi technique is generally used only in linear interactions, but RSM can help to visualize the effect of parameters on the response during a specified range. The Taguchi technique gives the average value of a response at a certain level of parameters, but the RSM is a promising analytical tool to predict the response that fits the range of parameters.
- In Future the work can try to find the optimal machining parameters using other methods or using single optimization techniques so that multiple variables can be optimized using the same experimental test.

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