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PREDICTION AND MODELLING OF MACHINING PARAMETERS THROUGH WATER JET MACHINING OF SUPER ALLOY

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ABSTRACT

Abrasive water jet machining is renowned over other technologies due to the absence of heat generation in the work piece during the process. Moreover, scarce research has been carried out over Ni-Cr alloy which is therefore considering the current study. Our experimental observations made during water jet machining of Ni-Cr alloy are: super surface finish is attained on considerably lower transverse speed and jet pressure while stand-of-distance has no effect; higher material removal rate is achieved at higher transverse speed while jet pressure and stand-of-distance has negligible effect. A mathematical model is developed successfully using regression analysis a prediction accuracy of 92.31% and 92.61% is attained for surface roughness and material removal rate respectively. In addition ANOVA analysis revealed optimal machining conditions for response variable surface roughness and material removal rate.

I. INTRODUCTION

A super alloy, or high-performance alloy, is an alloy that exhibits several key characteristics: excellent mechanical strength, resistance to thermal creep deformation, good surface stability and resistance to corrosion or oxidation. Nickel-based alloys generally have better high-temperature strength than alloy steels. Nickel is the base metal. The principal alloying elements are chromium and cobalt; lesser elements include aluminum, titanium, molybdenum, niobium (Nb), and iron. Some familiar names in this group include Inconel, Nimonic, Hastelloy, and Rene 41.

In this research work NIMONIC C263 super alloy is used as work piece material. In the recent years researchers are carried out on the NIMONIC C 263 alloy on various Non Conventional machining processes like Die sinking[1-3] to evaluate the Material Removal rate, Surface roughness and Tool Wear rate.

II. EXPERIMENTAL SETUP

2.1. Material:

The work piece used is Nimonic C-263 super alloy having a chemical composition as shown in Table 1. The dimensions considered are a flat plate of 30mm X 15 mm with a thickness of 3 mm.

Table .1: Chemical composition (weight %) of Nimonic C-263

Constituents	Ni	Cr	Co	Mo	Ti	Al	Fe	Cu	C
Weight %	49.0	19.0-21.0	19.0-21.0	5.6-6.1	1.9-2.4	< 0.6	0.7 max	0.2 max	0.04-0.08

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Fig .1&2 : Nimonic c-263

2.2. Equipment used:

Water jet machine widely used for cutting plastic, cloth, rubber, paper and leather, because of the lack of heat it produces kerf very narrow, and if set up correctly produce very smooth edges no scraps or burrs Water jet machine is a very clean job with no dust or noise, door and very little, in fact, the health and safety and environmental impact is minimal, almost.

The water jet cutting machine uses a stream of water and abrasive particles, such as garnet, to perform the cutting operation. The water jet cutter takes city water (typically 80 psi), and through the use of an intensifier-type pump, pressurizes the water to 55,000 psi. When the abrasive jet cutting head is enabled, the water flows through a 0.010-inch diameter orifice into a mixing chamber. As the water jet stream enters the mixing chamber, it creates a partial vacuum that draws the flow of abrasive particles through the abrasive delivery line. The abrasive particles combine with the water jet stream to create the high energy abrasive jet cutting stream. This stream exits the cutting head at a velocity of up to 3,000 feet per second. Today's water jet cutting machines are CNC controlled for accuracy, repeatability and ease of setup.

Fig .3&4: Water jet machining

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Fig.5: Display monitor

2.3. Surface Roughness Tester:
Surface roughness, for purposes of this forum, is the result of some machining process and its effect on the material surface in question.

Skid type surface roughness testers are common instruments used on the shop floor. A diamond stylus is traversed across the specimen and a piezoelectric pickup records all vertical movement. Peaks and valleys are recorded and converted into a known value of a given parameter.

Parameters differ in how they approach looking at peaks and valleys. The most popular parameter is "Ra". Ra is commonly defined as the arithmetic average roughness. While the Ra parameter is easy and efficient, there are other parameters that can be more specific and useful depending on the application requirements. It is the parameters that enable us to define surface roughness.

Fig.6 & 7: Surface roughness tester

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Fig.8: Weighing Balance

III. DESIGN PLAN

Table.2: L27 orthogonal array

S .No	Jet Pressure	Transverse Speed	Stand-off Distance(SOD)
1	240	10	1
2	240	10	2
3	240	10	3
4	240	20	1
5	240	20	2
6	240	20	3
7	240	30	1
8	240	30	2
9	240	30	3
10	210	10	1
11	210	10	2
12	210	10	3
13	210	20	1
14	210	20	2
15	210	20	3
16	210	30	1
17	210	30	2
18	210	30	3
19	180	10	1
20	180	10	2
21	180	10	3
22	180	20	1
23	180	20	2
24	180	20	3
25	180	30	1
26	180	30	2
27	180	30	3

3.1. Material Removal Rate:

The Material Removal Rate (MRR) was calculated using the formula given below

$$\text{MRR} = \frac{\text{Material lost per each slot (gm/sec)}}{\text{Time taken per each slot}}$$

$$\text{Material lost per each slot} = \frac{\text{Before cutting weight-after cutting weight (gm/sec)}}{\text{Number of slots}}$$

The Regression equation is

MRR = - 0.00263 + 0.000011 JP + 0.00104 TS + 0.000252 SOD

Table.3:

Predictor	Coef	SE Coef	T	P
CONSTANT	-0.002629	0.002085	-1.26	0.220
JET SPEED	0.00001089	0.00000915	1.19	0.246
TRASVERSE SPEED	0.00103683	0.00002745	37.77	0.000
STAND OF DISTANCE	0.0002522	0.0002745	0.92	0.368

S = 0.00116475 R-Sq = 98.4% R-Sq(adj) = 98.2%

Table.4: ANOVA Analysis for Material Removal Rate

SOURCE	DOF	SEQSS	ADJ SS	Adj Ms	F	P	%Contribution
JP	2	0.0000019	0.0000019	0.0000010	0.65	0.531	0.0964
PS	2	0.0019351	0.0019351	0.0009675	658.53	0.000	98.26
SOD	2	0.0000030	0.0000030	0.0000015	1.00	0.384	0.152
ERROR	20	0.0000294	0.0000294	0.0000015			1.4
TOTAL	26	0.0019693					

3.2. Conclusion:

For Material removal rate, Transverse speed is the most prominent factor with a percentage contribution of 98.26 followed by stand of distance with percentage contribution of 0.152. Jet pressure has negligible influence on Material removal rate as illustrated by fig.6.

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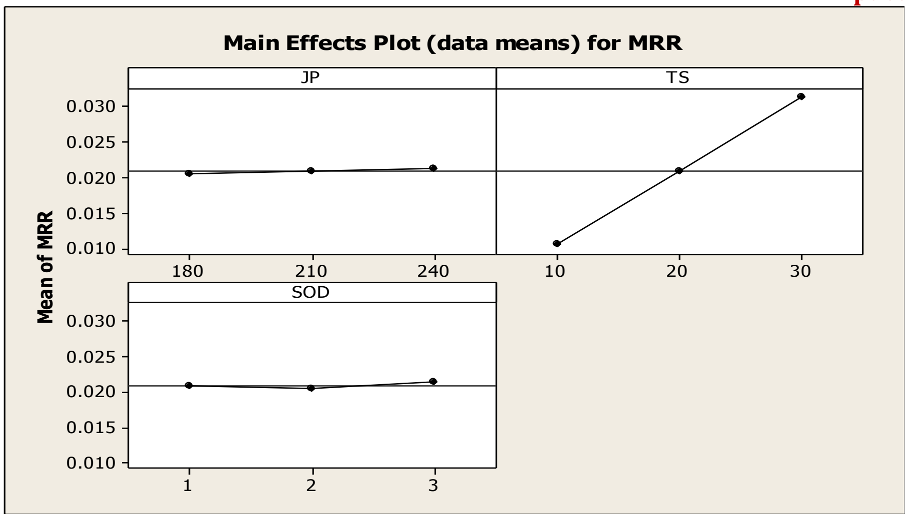

Fig.9: Main effects plot for MRR

3.3. Surface Roughness:

The regression equation is

SR = 1.90 + 0.00400 JP + 0.0589 TS + 0.0312 SOD

Table .6:

Predictor	Coef	SE Coef	T	P
CONSTANT	1.9025	0.7063	2.69	0.013
JET PRESSURE	0.003996	0.003100	1.29	0.210
TRANSVERSE SPEED	0.058889	0.009301	6.33	0.000
STAND OF DISTANCE	0.03117	0.09301	0.34	0.741

S = 0.394591 R-Sq = 64.5% R-Sq(adj) = 59.9%

Table.7: ANOVA Analysis for SURFACE ROUGHNESS

SOURCE	DOF	SEQSS	ADJ SS	Adj MS	F	P	%Contribution
JET PRESSURE	2	0.8128	0.8128	0.4064	2.89	0.079	8.04
TRANSVERSE SPEED	2	6.4510	6.4510	3.2255	22.91	0.000	63.87
STAND OF DISTANCE	2	0.0197	0.0197	0.0099	0.07	0.933	0.2
ERROR	20	2.8160	2.8160	0.1408			27.88
TOTAL	26	10.0996					

3.4. Conclusion:

In surface roughness Transverse speed is the most prominent factor with a percentage contribution of 63.87 followed by jet pressure with percentage contribution of 8.04. Stand of distance has negligible influence on Surface roughness.

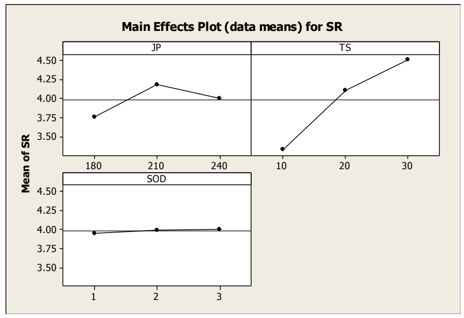

Fig.10: Main effects plot for SR

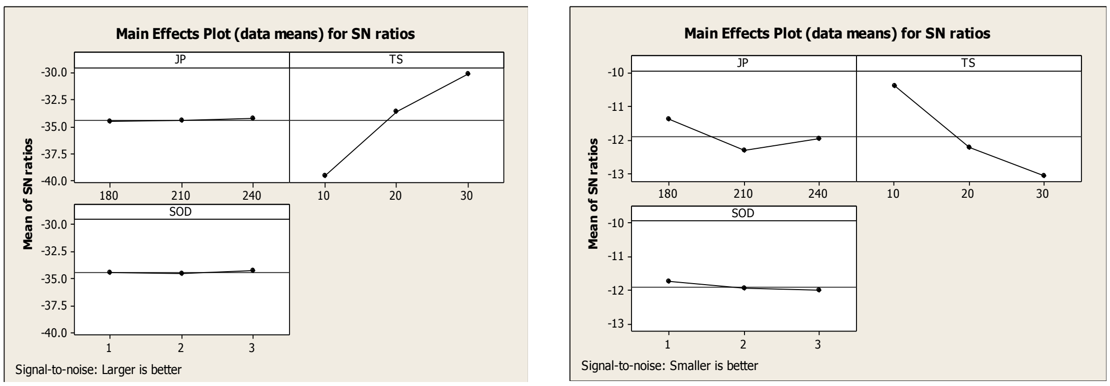

Fig.11&12: Signal to Noise ratio plot for (a) MRR, (b) SR

Table.8: Validation of Performance Results

PARAMETER	OPTIMUM CONDITION
MRR	JET PRESSURE- 240 TRANSVERSE SPEED-30 STAND OF DISTANCE- 3
SR	JET PRESSURE- 180 TRANSVERSE SPEED- 10 STAND OF DISTANCE- 1

IV. CONCLUSION

The machining was carried out on nimonic alloy work piece for full factorial design of 27 values using on abrasive water jet machining in order to predict material removal rate and surface finish. Based on analysis conclusions are drawn.

V. MATERIAL REMOVAL RATE

- Regression analysis was successfully applied to predict the material removal rate in water jet machining.
- It has been observed from plot of material removal rate that Material removal rate is going to have slight increase with increase in jet pressure and stand of distance.
- Material removal rate increases drastically with increase of transverse speed.

VI. SURFACE FINISH

- Regression analysis was successfully applied to predict surface roughness in water jet machining.
- It has observed from plots of surface roughness that surface roughness increases to some extent and decreases linearly with increase of jet pressure.
- Material removal rate increases drastically with increase in transverse speed.
- Finally material removal rate shows minimum variations with increase in stand of distance.

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