International Journal of Innovative Research in Advanced Engineering (IJIRAE) ISSN: 2349-2763
Issue 11, Volume 3 (November 2016) www.ijirae.com

Investigation of Metal Removal Rate and Surface Finish on Inconel 718 by Abrasive Water Jet Machining

Arun S*
Assistant Professor,
Dept of Mechanical Engineering,
Jeppiaar Institute of Technology.

Balaji N
Assistant Professor,
Dept of Mechanical Engineering,
Jeppiaar Institute of Technology.

Kannan S
Assistant Professor,
Dept of Mechanical Engineering,
Jeppiaar Institute of Technology.

Abstract* —Abrasive Waterjet (AWJ) cutting has proven to be an effective technology for material processing with the distinct advantages of no thermal distortion, high machining versatility, high flexibility and small cutting forces. In this paper, Taguchi robust design analysis is employed to determine optimal combination of process parameters. The Analysis of Variance (ANOVA) is also applied to identify the most significant factor. The process parameters such as pressure, transverse speed, stand of distance and abrasive flow rate are optimized to investigate their influence on Metal Removal Rate (MRR) and Surface Roughness (Ra) of Inconel. Experiments are carried out by L9 orthogonal array and the results are provided to verify this approach and credible tendencies of output parameters with respect to the input parameters are discussed, from which recommendations are made for process control and optimization.

***Keywords* - Abrasive Water Jet Machining, MRR, Surface roughness, Taguchi's method, ANOVA**

I. INTRODUCTION

Abrasive water jet machining makes use of the principles of both abrasive jet machining and water jet machining. In abrasive water jet machining a small stream of fine grained abrasive particles is mixed in suitable proportion, which is forced on a work piece surface through a nozzle. Material removal occurs due to erosion caused by the impact of abrasive particles on the work surface. AWJM is especially suitable for machining of brittle material like glass, ceramics and stones as well as for composite materials and ferrous and nonferrous material. The characteristics of surface produced by this technique depend on many factors like jet pressure, Stand-off distance of nozzle from the target. Abrasive flow rate, Traverse rate, works materials. Non-contact of the tool with work piece, no heat affected zone, low machining force on the work surface and ability to machine wide range of materials has increase the use of abrasive water jet machining over other machining processes.

Many researchers have been carried out on different parameters of AWJM, Neelesh K Jain etal [1] discussed about the optimization of process parameters of four mechanical type AMPs namely ultrasonic machining (USM), abrasive jet machining (AJM), water jet machining (WJM), and abrasive-water jet machining (AWJM) processes using genetic algorithms by giving the details of formulation of optimization models and solution methodology. AzlanMohd Zain etal [2] investigated the minimal surface roughness value by optimizing the parameters with an integrated Arificial Neural Network (ANN) and Simulated Annealing (SA) techniques on Al 7075-T6 wrought alloy. And also they verified the experimental results by integrating the soft computing techniques like Simulated Annealing (SA) and Genetic Algorithm (GA) to estimate optimal process parameters that lead to a minimum value of machining performance in AWJM [3]. Vinod B Patel [4], investigated the influence of AWJM process parameters on response MRR and Ra of EN8 material based on Taguchi's method and analysis of variance. They found that varying parameters are affected in different way for different response. The previous investigations [5-8] by the experimental data they analyzed that the effects of the four basic parameters, i.e., water pressure, abrasive mass flow rate, nozzle traverse speed and nozzle standoff distance on the depth of cut are in the similar approach as testified in preceding studies for other materials. The influence each of these parameters are premeditated while keeping the other parameters considered in this study as constant. In this paper the machining performances such as Metal Removal Rate (MRR) and Surface Roughness (Ra) are considered as the performance measure as in many industrial application it is the main constraint on the process applicability. The effect and optimization of machining parameters in terms of the output parameters will be investigated using Taguchi method and ANOVA.

II.EXPERIMENTAL WORK

A. Material:

In this investigation, the work material Inconel 718 was used. Inconel 718 is a gamma prime strengthened alloy with excellent mechanical properties at elevated temperatures, as well as cryogenic temperatures. Suitable for temperatures upto around 1300 F. It can be readily worked, age hardened and may be welded in fully aged condition, excellent oxidation resistance up to 1800 degrees F (980 degrees C). Typically sold in the solution annealed temper, but can be ordered aged, cold worked, or cold worked & aged. Inconel 718 tend to be used in the field of gas turbine components and cryogenic storage tanks. Jet engines, pump bodies and parts, rocket motors and thrust reversers, nuclear fuel element spacers, hot extrusion tooling.The dimension of the material are (50mm X 50mm X 20mm).

The abrasive material used was garnet 80 mesh. The mechanical properties and chemical composition of Inconel are described in table I and II.

TABLE I
MECHANICAL PROPERTIES OF INCONEL 718

Ultimate tensile strength	1275MPa
Yield strength	1304 MPa
Brinell hardness	331

TABLE II
CHEMICAL COMPOSITION OF 718

Ni	Fe	Mo	Mn	Si	Cr	C
55.0	Bal	3.30	0.35	0.35	21.0	0.8

B. Experimental Design:

The experimental layout for the machining parameters using the L9 orthogonal array was used in this study. This array consists of three control parameters and three level, as shown in table III. In the taguchi method, most all of the observed values are calculated based on ‘the larger the better’ and ‘the smaller the better’. Pressure is kept constant at 3500 bar. The optimization of the observed values was determined by analysis of variance (ANOVA) and SN ratio which was based on the taguchi method. Further the optimal equations for better results are obtained by regression analysis and experiments are conducted to verify the optimal output. The surface finish of the material are verified with the experimental setups and the metal removal rate is calculated by using the following formulae

$$MRR = \frac{weight\ before\ machining - weight\ after\ machining}{time\ taken\ for\ machining}$$

TABLE III
DESIGN STRUCTURE OF EXPERIMENT OF PARAMETERS AND LEVELS

Control Parameter	**Min**	**Inter**	**Max**	**Observed Values**
Standoff distance (mm)	0.5	1.5	2.5	i) MetalRemovalRate ii) SurfaceFinish
Abrasive flow rate (g/min)	100	150	200	
Transverse speed (mm/min)	30	40	50	

III.RESULTS AND DISCUSSIONS

The following discussion focuses on the different of process parameters to the observed values Metal Removal Rate, Surface Finish based on the Taguchi methodology. The results obtained from the experiments are discussed in table IV. The S/N ratio for the metal removal rate is considered with “Larger the Best” criteria and for surface finish “Smaller the Best” criteria is considered for optimization.Fig 1 & 2 shows the interaction plots of metal removal rate and surface roughness of each factor for various level conditions. Fig 3 & 4 explains the SN ratio of metal removal rate and surface finish with respect to the process parameters. It was observed that the abrasive flow rate, transverse speed and standoff distance have a considerable effect on the responses. Accuracy of the water jet cutting is mainly defined by the extent and form of time for machining and finishing of the final product. The optimum values were obtained abrasive flow rate at level 1, transverse speed at level 3, standoff distance at level 1 (i.e. abrasive flow rate 100 g/min, transverse speed 50 mm/min and standoff distance 0.5mm) for metal removal rate. And for surface roughness abrasive flow rate at level 3, transverse speed at level 2, standoff distance at level 1(i.e. abrasive flow rate 200 g/min, transverse speed 40 mm/min and standoff distance 0.5mm). It shows that the response table V&VI, SN ratios for MRR and Ra at different levels to select the beat levels for each factor.

Those best SN ratio values are highlighted.

TABLE IV
EXPERIMENTAL RESULTS

Trials	Standoff Distance (mm)	Abrasive flow rate (g/min)	Transverse Speed (mm/min)	Weight Before Machining (g)	Weight after Machining (g)	Time Take for Machining (sec)	Metal Removal Rate (g/s)	Surface Finish (µm)
1	0.5	100	30	0.395	0.282	187	0.604	2.68
2	0.5	150	40	0.39	0.272	139	0.849	3.72
3	0.5	200	50	0.395	0.28	117	0.983	4.19
4	1.5	100	40	0.395	0.284	133	0.835	3.03
5	1.5	150	50	0.39	0.278	122	0.918	2.59
6	1.5	200	30	0.39	0.274	185	0.627	3.9
7	2.5	100	50	0.385	0.268	126	0.929	3.03
8	2.5	150	30	0.385	0.272	177	0.638	3.42
9	2.5	200	40	0.385	0.27	140	0.821	3.62

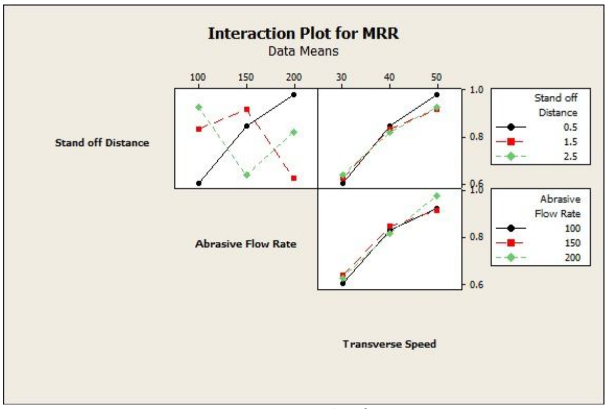

Fig 1: Interaction plot for MRR

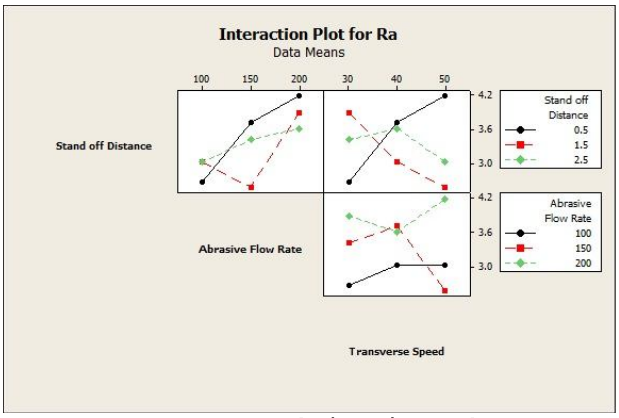

Fig 2: Interaction plot for Surface Finish

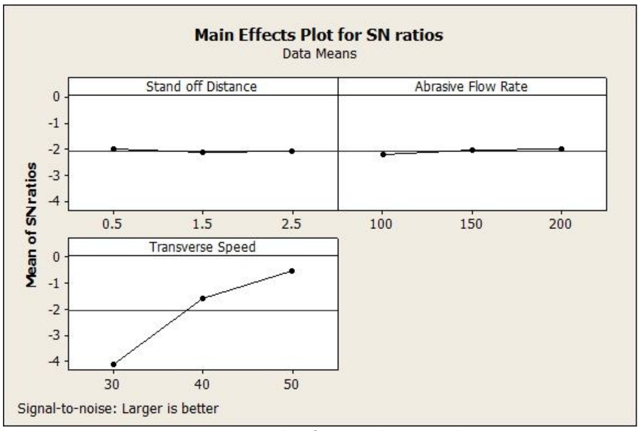

Fig 3: SN ratio plot for metal removal rate

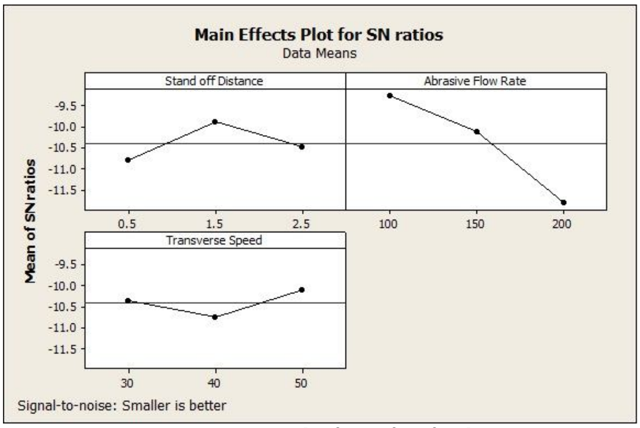

Fig 4: SN ratio plot for surface finish

The regression equation calculated for the metal removal rate and surface finish are as follows,
MRR = 0.141 - 0.0079 Standoff Distance + 0.000213 Abrasive Flow Rate + 0.0160 Transverse Speed
Ra = 2.13 - 0.087 Standoff Distance + 0.00990 Abrasive Flow Rate- 0.0032 Transverse Speed

TABLE 5
RESPONSE TABLE FOR METAL REMOVAL RATE

Metal Removal Rate: Larger is better			
Level	**Abrasive Flow Rate (g/min)**	**Transverse Speed (mm/min)**	**Standoff Distance (mm)**
1	-1.9826	-4.1091	-1.9826
2	-2.1226	-1.5673	-2.1226
3	-2.0834	-0.5121	-2.0834
Delta	0.1400	0.2256	0.1400
Rank	1	2	3

TABLE 6
RESPONSE TABLE FOR SURFACE FINISH

Surface roughness: Smaller is better			
Level	**Abrasive Flow Rate (g/min)**	**Transverse Speed (mm/min)**	**Standoff Distance (mm)**
1	-9.273	-10.355	-10.806
2	-10.119	-10.738	-9.905
3	-11.813	-10.113	-10.495
Delta	2.540	0.625	0.901
Rank	1	3	2

Finally, we conclude that the optimum level of control factors at the end of the analysis of variance. Optimum levels of control factors are shown in the table VII.The confirmation experiment is a crucial step and is highly recommended by Taguchi to verify the experimental conclusions obtained from regression analysis. A confirmation experiment is not as critical as there is no confounding present and less opportunity for misinterpretation; however, a confirmation experiment is still required as large sample size used to evaluate that particular combination. These confirmation experiments were used to predict and verify the improvement in the quality characteristics for machining of Inconel 718.

TABLE 7
CONFIRMATION EXPERIMENT OF OPTIMUM LEVEL

Parameters	Optimum Factors (MRR)	Optimum Factors (Ra)	Response
Abrasive Flow Rate (g/min)	100	100	MRR 0.9383 g/s SF 2.8295µm
Transverse Speed (mm/min)	50	50	
Standoff Distance (mm)	0.5	1.5	

IV. CONCLUSIONS

This paper presents analysis of various parameters and on the basis of experimental results, analysis of variance (ANOVA) and SN Ratio the following conclusions can be drawn for effective machining of Inconel 718 by AWJM process as follows: Traverse Speed (S) is the most significant factor on MRR and surface finish during AWJM. Meanwhile Abrasive Flow Rate and Standoff distance are sub significant in influencing. The recommended parametric combination for optimum material removal rate is abrasive flow rate 100 g/min, transverse speed 50 mm/min and standoff distance 0.5mm; for surface roughness abrasive flow rate 200 g/min, transverse speed 40 mm/min and standoff distance 0.5mm.

REFERENCES

[1] Neelesh K Jain, V.K.Jain, &Kalyanmoy Deb (2007), "*Optimization of process parameters of mechanical type advanced machining processes using genetic algorithms*", International Journal of Machine Tools & Manufacture, 47, pp 900-919.
[2] AzlanMohd Zain, HabibollahHaron, &Safian Sharif (2011), "*Estimation of the minimum machining performance in the abrasive waterjet machining using integrated ANN-SA*", International Journal of Expert Systems with Applications, pp 8316-8326.
[3] AzlanMohd Zain, HabibollahHaron, &Safian Sharif (2011), "*Optimization of process parameters in the abrasive waterjet machining using integrated SA-GA*", International Journal of Applied Soft Computing, pp 5350-5359.
[4] Vinod B Patel &Prof.V.A.Patel (2012), "*Parametric analysis of abrasives water jet machining of EN8 material*", International Journal of Engineering Research and applications, 2, pp 3029-3032.
[5] M.ChithiraiPonselvan, & Dr. N. MohanaSundara Raju (2011) "*An Experimental investigation on depth of cut in abrasive waterjet cutting of aluminium*". International Journal of Engineering Science and Technology, 3: pp 2950-2954.
[6] Wang J, Kuriyagawa T & Huang C Z (2003), "*An experimental study to enhance the cutting performance in abrasive water jet machining*", Machining Science & Technology, 7: pp 191-207.
[7] Wang J & Xu S (2005), "*Enhancing the AWJ cutting performance by multi pass machining with controlled oscillation*", Key Engineering Materials, 291-292.
[8] Shanmugam D. K. & Masood S. H. (2009), "*An investigation on kerf characteristics in abrasive waterjet cutting of layered compo-sites*". Journal of Materials Processing Technology, 209: pp 3887- 3893.