Experimental Parametric Studies And Optimization of Abrasive Water Jet Machining On Inconel-825

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Abstract : Abrasive water jet machining process plays a crucial task to many manufacturing process, as it eliminates the heat generated in the machined part and formation of chip during machining were eliminated. It uses combination of abrasives and water as the medium for material removal action. It does not comprise a cutting tool as the removal work is attained through the mechanism of eroding the work material. Moreover, formation of chips during the material removal will be in the order of micron level. The proper selection of process parameters is essential towards superior performance in the area of abrasive waterjet machining process. The research work experiments were carried by taguchi design further multi response optimization for machining on Inconel-825 was conducted through Grey relational analysis The performance characteristics considered are, the hole taperness and kerf angle. The optimization results also suggest that stand off distance abrasive flow rate, and traverse speed provide the most promising variables on reducing the hole taperness and kerf angle in Inconel-825.

***IndexTerms* – Inconel-825, Hole Taperness, Grey Relational Analysis, Kerf width, Optimization.**

I. INTRODUCTION

Abrasive Waterjet Machining (AWJM) is the widely used mechanical energy based non-conventional machining process which was introduced in the late 1935s. AWJ is a machining process the material machining takes placed by means of eroding the work piece. Water is pressurized by means of a pump with an intensifier and abrasive particles are mixed in the mixing chamber and forced through a nozzle. In AWJM both conducting materials and non-conducting materials are machined. Without any cutting tool material removal is obtained as shown in Fig.1 No heat affected zone is created by AWJM. Researchers in the area of material science are developing materials having higher strength and diverse properties Provides good surface finish, faster in operation, simple in design changes, no secondary finish required to make all sorts of shapes with only one tool, properties of the material will not be lost. Complex profiles can easily be machined, vibration induced in the machine is less, leaves a smooth finish thus reducing secondary operations and conducting and non – conducting materials can be machined. to increase the performance of AWJM machining, investigations are made to obtain higher material removal rates along with accuracy and surface finish.

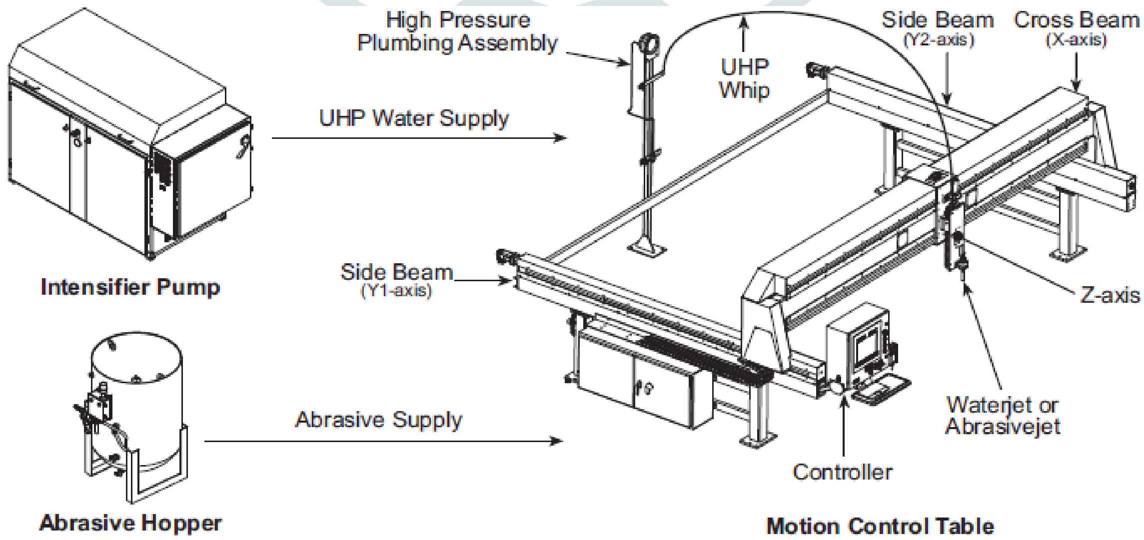

Fig.1. Schematic representation of Abrasive water jet machining set up

Vishal gupta et.al, investigated the kerf taper angle minimization, nozzle transverse speed shows affect on the kerf taper angle and at low levels of water pressure and nozzle transfer speed minimum kerf angle is obtained [1].Fritz et al., stated abrasive machining is utilized in production for removing material from aerospace alloys and composites[2]. Valicek et al., experienced the TS plays a significant role in reducing the surface roughness value[3].Fowler et al., observed by high impingement angle primarly lower MRR is occurred[4]. Akkurt studied the surface roughness defects by varying thickness and he observed abrasive water jet energy is lossed after it makes contact with the work piece, due to its friction of abrasive particles gets increased surface of the upper region was good as compared with the lower region [5].Jankovi et.al, identified that due to increase in abrasive flow rate, a high number of abrasive particels involved in mixing, increases the probability of particle collision decreases the impacting particles of average diameter [6]. Zhang et.al, studied the striation marks created on glass due to vibration of jet and the cutting depth increases, the kinetic jet energy decreases[7]. Tousen et.al, discovered that increase in water pressure increses the surface roughness linearly due to higher pressure requires more energy to be spent on the area bombarded by the jet and also causes irregular energy diffusion in the jet zone[8].Halvac et.al, proposed a mathematical model and the experimental values are used in selecting the tilting cutting angle of the jet and transverse speed required to reduce the stirations[9].Orbanic and Junkar calculated the situations developed in machining change in topography of the cutting groove guides the flow of jet and results in striation developed[10]. Ma & Deam defined the kerf geometry with simple empirical correlation shows kerfwidth opens outs at low cutting speeds[11]. Alberdi et.al, studied the taper rate decreases by increase the material thickness, optimum traverse speed in reducing the surface roughness and kerf angle without compromising the machinability index[12]. Hlavac et.al, conducted experiments and developed a model to determine the curvature of the jet, the declination angle and the optimum traverse speed to reduce the kerf angle were predicated [13]. Massive amount of research studies had been performed over the years on various process parameters such as feed rate, water pressure, standoff- distance, jet angle and abrasive flow rate etc., with the aim of minimizing the responses of surface roughness (Ra), kerf angle, and to increase the MRR and Depth of cut. However the entire operation of this method is not fully understood. This is due to the difficult in nature of the process and more number of parameters is concerned in it. It was found that in AWJM large number of process parameters are involved on deciding the responses. Single process variable cannot decide on the responses selected. In this research paper, the influence of abrasive flow rate, traverse speed, standoff-distance is examined on reducing kerf width and kerf angle.

II. EXPERIMENTAL SETUP

The experiments were performed using an Abrasive waterjet machine of type Water jet S3015 at Water jet Germany limited, located at SIDCO INDUSTRIAL ESTATE, Thirumazhisai, Chennai., India. The specifications of the AWJM are enclosed in Table1.

Fig.2. AWJM set up at Excel Water jet

Table 1 Chemical Composition of Inconel-825

Constituent	Fe	Ni	Cr	Mb	Cu	Ti	Mn	Si	Al
% Concentration	22.0	38.0	19.5	2.5	1.5	1.2	1.0	0.5	0.2

Table 2 Specifications of AWJM

S.NO	Feature	Specification
1	Model type	WATER JET S3015
2	CONTROL SYSTEM	SIEMENS 810 D
3	CUTTING TABLE AREA	3200 MM × 1700 MM
4	MOVEMENT ON X,Y,Z	3010 MM, 1510 MM, 250 MM
5	MINIMUM DISTANCE BETWEEN THE NOZZLE	150 MM
6	MAXIMUM DISTANCE BETWEEN THE NOZZLE	750 MM
7	MAXIMUM FLOW OF HIGH PRESSURE WATER	0.0034 M3 /MIN

The type of abrasive particles used for the experimental work is Al_2o_3. The size of the garnet preferred is in the order 80 mesh. 80 mesh size is used for moderate finish. Abrasives along with water provide erosion on the work piece thereby machining is performed. The speed at which the nozzle moves at a work piece determines the feed rate. Standoff determines the gap between nozzle tip and the work piece. More standoff distance makes the jet to expand and thereby reducing the number of impact of the abrasives. This results in producing a rough finish on the machined surface.

Table 3 Varying Process variables and their values

Parameter	Units	Levels				
		1	2	3	4	5
Transverse Speed	mm/min	40	50	60	70	80
Abrasive Flow Rate	gm/min	50	100	150	200	250
Stand- off Distance	mm	1.0	2.0	3.0	4.0	5.0

2.1Design of Experiments

Dr.Taguchi invented the method based on the theoretical calculations Orthogonal Array experiments a computer programming was developed, which gives a significantly reduced variance for the experiment with optimal settings for the control parameters.Taguchi proposed a 8 step procedure for optimizing any process. In this research paper for 3 parameters and 5 levels OA L_{25} is consider for experimentation and it is listed in Table 3.

Table 4 Variations in process parameters and process variables

S.No	Transverse speed (mm/min)	Abrasive flowrate (gm/min)	Standoff Distance (mm)	Kerf width-mm	Taperness-radians
1	40	50	1	1.17	0.125
2	40	100	2	1.20	0.5
3	40	150	3	1.23	0.575
4	40	200	4	1.3	0.05
5	40	250	5	1.28	0.55
6	50	50	2	1.15	0.275
7	50	100	3	1.11	0.775
8	50	150	4	1.14	0.5
9	50	200	5	1.20	1.2075
10	50	250	1	1.11	0.6675
11	60	50	3	0.97	1.375
12	60	100	4	1.07	0.1
13	60	150	5	1.13	0.45

14	60	200	1	1.10	0.05
15	60	250	2	1.12	0.15
16	70	50	4	1.1	0.15
17	70	100	5	1.12	1.45
18	70	150	1	1.06	0.875
19	70	200	2	1.17	0.975
20	70	250	3	1.17	1.55
21	80	50	5	1.06	3.05
22	80	100	1	1.04	2.35
23	80	150	2	1.11	0.7
24	80	200	3	1.13	0.275
25	80	250	4	1.16	0.15

III. RESULTS AND DISCUSSIONS

AWJM experiments were performed on Inconel-825 with different combinations of abrasive flow rate, Transverse speed and standoff-distance. The experimental results of the kerf width and taperness have been dealt. AWJM performed on the materials with Al_2O_3 as abrasive particle and jet impact angle of 90 degree for all the readings. The surface roughness values are measured 3 times in different places on the machined surfaces and the average values is considered for the study. Similarly, kerf angle is measured at the top and bottom of the machined work part by using tool makers microscope and the values are recorded.

3.1 Steps used for Optimization of Experimental Results

3.1.1 Normalize the S/N values using the fallowing formulae

The steps used the weight assignment for the process parameters for converting the multi-responses into single response..

For normalizing Kerf Width and taperness 'Lower-the-better' is to be selected in (equ.3.1)

$$X_j(v)=\frac{\max y_j(v)-y_j(v)}{\max y_j(v)-\min y_j(v)} \qquad (3.1)$$

Where, $X_j(v)$= value after normalizing data/ Grey relations generation value,

Min $y_j(v)$=smallest value of $y_j(v)$

Max $y_j(v)$=Largest value of $y_j(v)$

3.1.2 Calculate the grey relational coefficient for the S/N Values

$$\varepsilon_j(v)=\frac{\Delta_{\min}+\phi\Delta_{\max}}{\Delta_{oj}(v)+\phi\Delta_{\max}} \qquad (3.2)$$

Where, Δ_{min}= minimum value of $y_j(v)$, Δ_{max}= maximum value of $y_j(v)$

ε is the distinguishing coefficient, which is defined in the range $0 \le \zeta \le 1$ (the value may be adjusted based on the practical needs of the system).

3.1.3 Generate the grey relational grade

$$\gamma_j=\frac{1}{n}\sum_{v=1}^{n}\varepsilon j(k) \qquad (3.3)$$

Where, n = number of process responses

$\varepsilon_j(v)$ = Grey relational coefficient

3.2 Optimum Response values as pet Grey Taguchi Technique

Table 5 Response Table for Grey Relational Grade

Level	Transvers Speed (A)	Abrasive Flow Rate (B)	Stand Off Distance (C)
1	0.5167*	0.5500	0.6080
2	0.5240	0.5493*	0.5799
3	0.6144	0.6030	0.6148
4	0.6092	0.5896	0.5600*
5	0.6672	0.6396	0.5688
Delta	0.1505	0.0903	0.0548
Rank	1	2	3

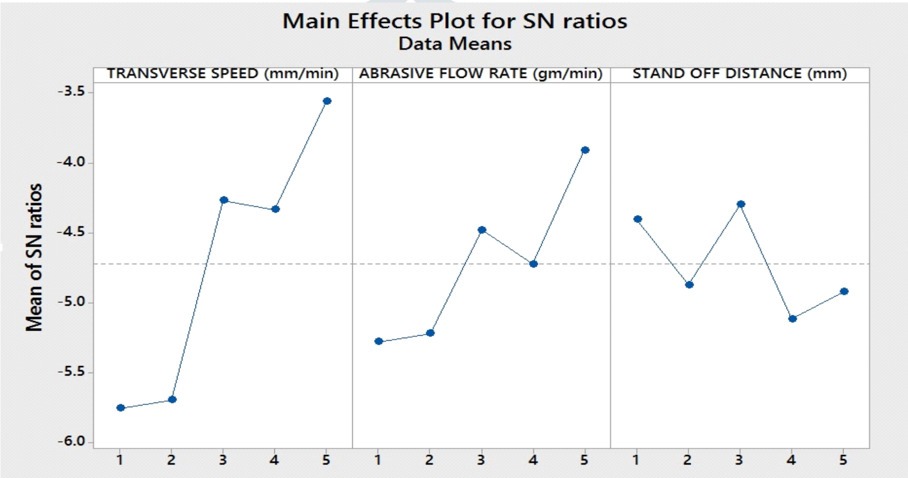

FIG.3. S/N RATIO MEAN EFFECTIVE PLOT FOR GREY RELATIONAL GRADE

From the below Response table the optimal condition for maximizing Metal Removal Rate, minimum Kerf Width and Surface roughness simultaneously in AWJM process, is found to be A1 B2 C4 i.e. Transverse speed is 40 mm/min, Abrasive Flow Rate is 100 gm/min and Stand Off Distance is 3 mm. For this optimal setting A1 B2 C4 conducted experimentation for validating results.

Table 6 Optimum Parameters Control

S.No	Process response	Optimal setting	Actual Value	Experimental Value	% of Error
1	Taperness	A_1B_2 C_4	0.05	0.0479	0.042
2	KERF WIDTH		1.16	1.17	0.08

From the confirmation experiments, the error percentage of process responses from the predicted responses is less than 5% is acceptable.

CONCLUSIONS

In this present analysis of various parameters and on the basis of experimental results, Grey relational analysis the conclusions are drawn for effective machining of INCONEL-825 by AWJM process as follows:

1. Traverse Speed (TS) is the most significant factor on kerfwidth during AWJM. Meanwhile Abrasive Flow Rate and Standoff distance is substationial influencing factor.
2. In case of taperness Abrasive Flow Rate is most significant control factor.
3. In case of kerfwidth and taperness, Transverse speed & Abrasive Flow Rate are most significant control factors.
4. The optimal condition for minimum Kerf Width and taperness simultaneously in Abrasive Water Jet Machining (AWJM) process, is located at A1 B2 C4 i.e. Transverse speed is 40 mm/min, Abrasive Flow Rate is 100 gm/min and Stand Off Distance is 4 mm.

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