International Journal of Innovation and Scientific Research
ISSN 2351-8014 Vol. 21 No. 2 Apr. 2016, pp. 293-300

http://www.ijisr.issr-journals.org/

Experimental Investigation and Optimization of Process Parameters in Abrasive Water Jet Drilling on AL6061

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ABSTRACT: Abrasive Water jet (AWJ) Machining is a recent non-traditional machining process. Major part of this technology is a very high-pressure beam of water and abrasives, which is used for machining. Abrasive water jet drilling of material involves the effect of a high velocity jet of water with entrained abrasive particles on to material to be drilled. This technology is widely used in industry for drilling, difficult to machine materials, milling slots, polishing hard materials, cleaning contaminated surfaces, etc. In the proposed work , the process parameters on surface roughness (Ra) which is an important drilling performance is measured in abrasive water jet drilling of AL6061 . Experiments will be conducted in varying, nozzle traverse speed, abrasive mass flow rate and standoff distance for drilling AL6061 alloy using abrasive water jet drilling process. The effects of these parameters on surface roughness will be studied based on the experimental results and useful recommendations will be given in order to select the suitable process parameters in abrasive water jet drilling of AL6061 alloy.

KEYWORDS: Abrasive water jet, Surface Roughness, drilling, nozzle.

1 INTRODUCTION

Abrasive Water jet (AWJ) Machining is a recent non-traditional machining process. Major part of this technology is a very high-pressure beam of water and abrasives, which is used for machining. Abrasive water jet cutting of material involves the effect of a high velocity jet of water with entrained abrasive particles on to material to be cut. This technology is widely used in industry for cutting difficult to machine materials, milling slots, polishing hard materials, cleaning contaminated surfaces, etc. AL6061 aluminium alloys have found application in automotive structures, as they offer an attractive combination of strength, formability and corrosion resistance, surface properties and good weld ability.

In the proposed work, the process parameters on surface roughness (Ra) which is an important cutting performance is measured in abrasive water jet cutting of AL6061 . Experiments will be conducted in varying water pressure , nozzle traverse speed, abrasive mass flow rate for cutting AL6061 alloy using abrasive water jet cutting process. The effects of these parameters on surface roughness will be studied based on the experimental results and useful recommendations will be given in order to select the suitable process parameters in abrasive water jet drilling of AL6061 alloy. Abrasive water jet machine is shown in fig.1.

Fig. 1. Abrasive Water Jet (AWJ) Machine

2 METHDOLOGY

2.1 MATERIAL SELECTION

T6 temper 6061 has an ultimate tensile strength of at least 42,000 psi (300 MPa) and yield strength of at least 35,000 psi (241 MPa). More typical values are 45,000 psi (310 MPa) and 40,000 psi (275 MPa), respectively. In thicknesses of 0.250 inch (6.35 mm) or less, it has elongation of 8% or more; in thicker sections, it has elongation of 10%.

2.2 DESIGNS OF EXPERIMENTS

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 levels, as shown in table1. In the Taguchi method, most all of the observed values are calculated based on „the smaller the better". Thus in this study, the observed values of SR is set to be at minimum condition. Experimental trial was performed with three simple replications at each set value. The optimisation of the observed values was determined by comparing the standard analysis and analysis of variance (ANOVA) which was based on the Taguchi method.

For each experiment, the machining parameters were set to the pre-defined levels according tothe orthogonal array. All machining procedures were done using a single pass cutting. The supply pressure, transverse speed and standoff distance is controlled through the controller in the operator control stand. The surface finish parameter employed to indicate the surface quality in this experiment was the arithmetic mean roughness (Ra). Work piece surface roughness Ra was measured by a surface roughness equipment model "TAYLOR HOBSON". Surface roughness was measured at the centre of the cut for each specimen.

3 INPUT PARAMETERS

3.1 LEVEL OF INPUT PARAMETERS

The experiments were carried out in full factorial method. The level of input parameter is given in Table 1. Each experiment were replicated three times in order to identify the variability associated with the experiment.

Table 1. Levels of Input Parameters

Factors	Level 1	Level 2	Level 3
Abrasive flow rate(gm/min)	100	200	300
Feed rate(mm/rev)	90	100	110
Stand of distance(mm)	2	3	4

3.2 ABRASIVE FLOW RATE

In abrasive flow machining, the abrasive fluid flows through the work piece, effectively performing erosion. Abrasive particles in the fluid contact raised features on the surface of the work piece and remove them. The fluid is forced through the work piece by a hydraulic ram, where it acts as a flexible file, or slug, molding itself precisely to the shape of the work piece. The highest amount of material removal occurs in areas where the flow of the fluid is restricted; according to Bernoulli's Principle, the flow speed and pressure of the fluid increase in these areas, facilitating a higher material removal rate

3.3 FEED RATE(Ƒ)

The rate at which the tool moves along the cutting path is known as feed rate. Feed rate is measured in mm/revolution. The formula for finding the feed rate is given below.

ƒ= Fn mm/min

Where, ƒ is the feed in mm/min, F is the feed in mm/rev and n is the rotations per minute (rpm).

3.4 STAND OF DISTANCE(MM)

Standoff distance is a security measure that focuses on preventing unscreened people and vehicles from approaching within a certain distance of a building, car, other shelter where a violent criminal is sheltered, hostages are under armed threat from kidnappers, where a bomb is believed to have been placed, or where other unspecified dangers may be lurking. It is a measure of distance informally used by agents handling the situation to protect their own persons from physical injury or death while the situation is resolved.

4 OUTPUT PARAMETERS

4.1 CIRCULARITY

A circularity ratio as a compactness measure of a shape. An assumption of ANOVAs with repeated-measures. It denotes the homogeneity of the variances of difference values between the conditions. It is often also called “sphericity”

Fig. 2. Video measuring system for circularity

4.2 SURFACE ROUGHNESS

Surface roughness is a measure of the technological quality of a product and a factor that greatly influences manufacturing cost. It describes the geometry and surface textures of the machined parts. There are several ways to describe surface roughness, such as roughness average (*R*a), root-mean-square (rms) roughness (*R*q) and maximum peak-to-valley roughness (*Ry* or *R*max), etc.

Fig. 3. Computer controlled surface roughness measurement

5 CONTROLABLE PARAMETERS

The possible controllable parameters of AWJM are water jet orifice size, water jet pressure, abrasive grit size, abrasive material, abrasive flow rate, traverse rate, standoff distance, angle of attack, composition of work piece. The table2 clearly shows the controllable parameters.

Table 2. Controllable parameters

Parameters	**Level 1**	**Level 2**	**Level 3**
Stand of distance(mm	**2**	**3**	**4**
Traverse rate(mm/min)	**90**	**100**	**110**
Abrasive flow rate(gm/min)	**100**	**200**	**300**

5.1 RESPONSE FOR INPUT PARAMETERS

From table 3, it can be seen that the highest value is obtained in the 7th row, which is related to optimal process parameters. The optimal parameters are abrasive flow rate 300g/min, feed rate110 mm/min, an standoff distance 2mm. At these parameters we observe optimum outputs as Surface Roughness 3.9 µm and Circularity 10.101 mm. Figure 4 and 5 clearly shows the test conducted for surface roughness for different input parameters.

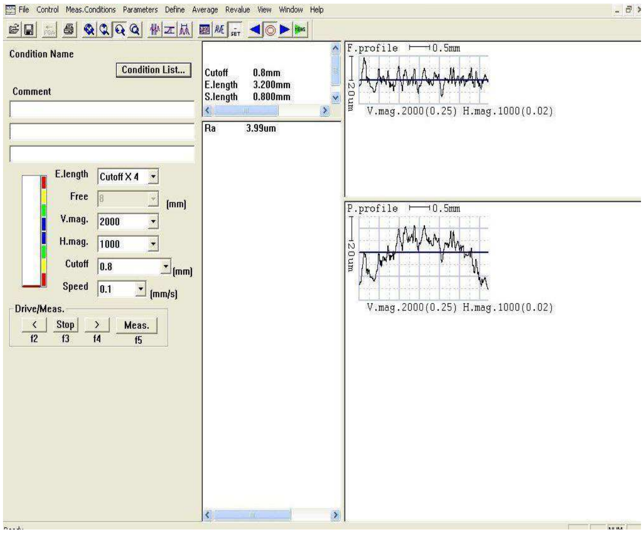

Fig. 4. Test conducted for Surface Roughness(Ra)

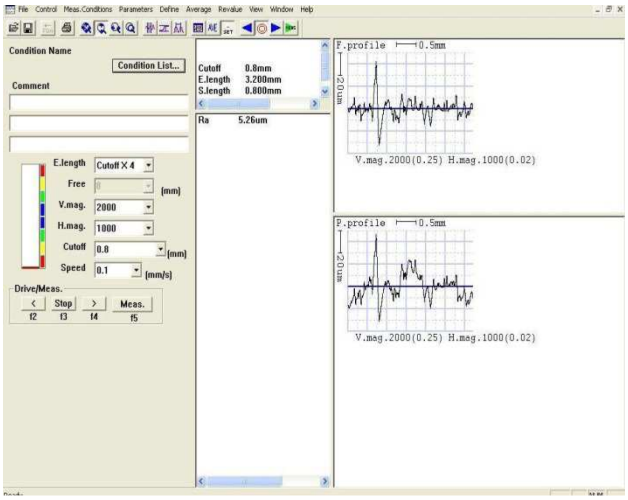

Fig. 5. Test conducted for Surface Roughness(Ra)

Table 3. Response for input parameters

S.No	Stand Of Distance(mm)	Traverse Rate(mm/Min)	Abrasive Flow Rate(Gm/Min)	Surface Roughness - Ra (µm)	Circularity (Mm)
1	2	90	100	6.03	10.033
2	2	90	100	4.49	10.028
3	2	90	100	6.34	10.101
4	2	100	200	5.26	10.064
5	2	100	200	5.69	10.084
6	2	100	200	5.39	10.005
7	2	110	300	3.99	10.101
8	2	110	300	3.23	10.107
9	2	110	300	5.28	10.019
10	3	90	200	2.87	10.119
11	3	90	200	6.18	10.004
12	3	90	200	5.86	10.039
13	3	100	300	4.36	10.074
14	3	100	300	7.13	10.078
15	3	100	300	4.3	10.139
16	3	110	100	5.75	10.14
17	3	110	100	6.6	10.09
18	3	110	100	5.24	10.005
19	4	90	300	6.33	10
20	4	90	300	5.29	10.184
21	4	90	300	5.38	10.229
22	4	100	100	5.02	10.09
23	4	100	100	4.24	10.193
24	4	100	100	5.01	10.167
25	4	110	200	6.69	10.21
26	4	110	200	5.41	10.074
27	4	110	200	4.68	10.193

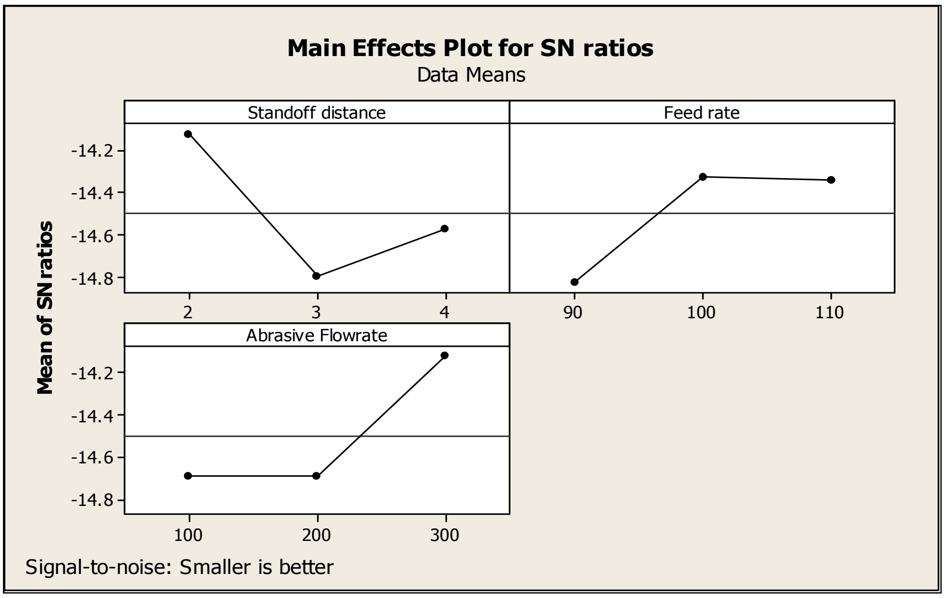

Fig. 6. Main effects plot for SN ratio

Figure 6 clearly shows the main effects plot for SN ratio for input parameters of 2mm standoff distance feedrate and abrasive flow rate of 110mm/min and 300 g/min respectively. Among 27 different parameters are tested, from that the optimal parameter is obtained are shown in table 4.

Table 4. Optimal parameters for surface roughness and Circularity

Sl no	Optimal Input parameters	Corresponding output parameters
1	**Standoff distance: 2mm** **Feed rate: 110mm/min** **Abrasive flow rate: 300g/min**	**Surface roughness: 3.99µm** **Circularity: 10.101mm**

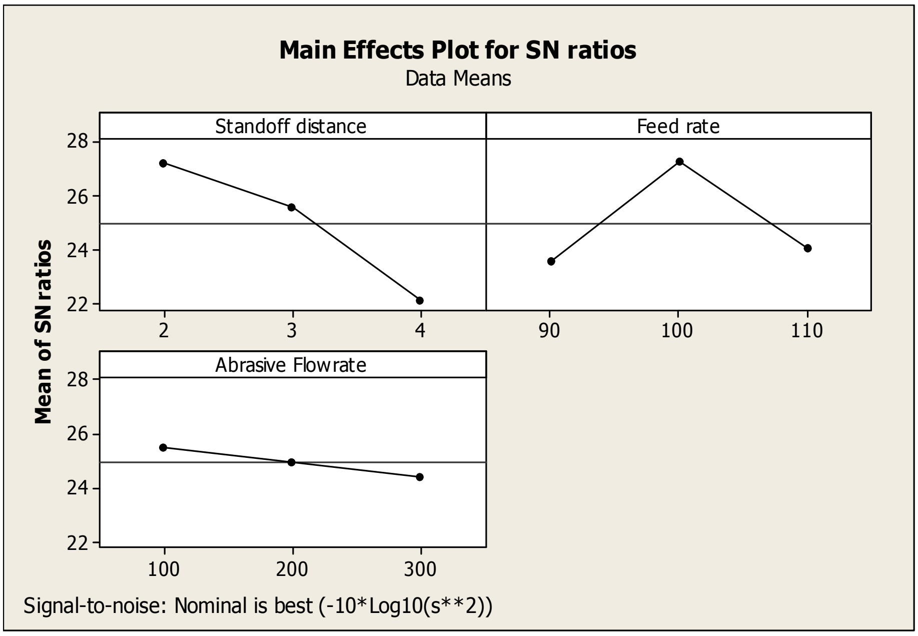

Fig. 7. Main effects plot for SN ratio

Figure 7 clearly shows the main effects plot for SN ratio for input parameters of 2mm standoff distance feedrate and abrasive flow rate of 100mm/min and 200 g/min respectively. Among 27 different parameters are tested, from that the optimal parameter is obtained are shown in table 5.

Table 5. Optimal parameters for surface roughness and Circularity

Sl no	Optimal Input parameters	Corresponding output parameters
1	**Standoff distance: 2mm** **Feed rate: 100mm/min** **Abrasive flow rate: 200g/min**	**Surface roughness: 5.26µm** **Circularity: 10.064mm**

6 CONCLUSION

The optimal parameter values with respect to surface roughness are abrasive flow rate at 200gm/min, Feed rate at 110mm/min and standoff distance at 2mm. At these parameters the values of Surface roughness and circularity are 3.99µm and 10.101mm respectively. The optimal parameter values with respect to circularity are abrasive flow rate at 200gm/min, Feed rate at 100mm/min and standoff distance at 2mm. At these parameters the values of Surface roughness and circularity are 5.26µm and 10.064mm respectively.

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