Parametric analysis of Abrasives water jet machining of EN8 Material

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ABSTRACT

Abrasive water jet machine (AWJM) is a mechanical base non-conventional machining process. This is process of removal of materials by impact erosion of high pressure (1500-4000 bar), high velocity of water and entrained high velocity of grit abrasives on a work piece. Experimental investigations were conducted to assess the influence of abrasive water jet machining (AWJM) process parameters on response-Material removal rate (MRR) and Surface roughness (Ra) of EN8. The approach was based on Taguchi's method and analysis of variance (ANOVA) to optimize the AWJM process parameters for effective machining. Experiments are carried out using L25 Orthogonal array by varying traverse speed, abrasive flow rate and stand of distance (SOD) for EN8 material. In present study, Analysis found that varying parameters are affected in different way for different response.

***Keywords* –** AWJM, MRR, ANOVA, SN-Ratio, Mixing Ratio

I. INTRODUCTION

Abrasive water jet machine (AWJM) is a non-traditional machining process. Abrasive water jet machining has various distinct advantages over the other cutting technologies, such as no thermal distortion, high machining versatility, high flexibility and small cutting forces, and has been proven to be an effective technology for processing various engineering materials. The mechanism and rate of material removal during AWJ depends both on the type of abrasive and on a range of cutting parameters. Abrasive water jet machine can cut hard and brittle materials like Steels, Non-ferrous alloys Ti alloys, Ni- alloys ,Polymers, Metal Matrix Composite, Ceramic Matrix Composite, Concrete , Stone – Granite , Wood , Reinforced plastics, Metal Polymer Laminates, Glass Fiber Metal Laminates[1] .

II. EXPERIMENTAL PROCEDURE

2.1 Material specification

AWJM is capable of machining geometrically complex and/or hard material components, that are precise and difficult-to-machine such as heat treated tool steels, composites, super alloys, ceramics, carbides, heat resistant steels etc. I have selected the EN8 material because it is widely used for industrial application in metal forming; forging, squeeze casting and pressure die casting. Die and old are generally made up of EN8 materials [2]. In this research work EN8 selected as a specimen material. Material is tested before used for experiments in material testing laboratory at **DIVINE LABORATORY SERVICES, AHMEDABAD.** Chemical composition obtained is as per Table 1.

Table 1 Chemical composition of EN8

Chemical	Obtained Value	Required Value
%Carbon	0.430	0.35-0450
%Sulphur	0.030	0.00-0.050
%Phosphorous	0.048	0.00-0.050
%Silicon	0.200	0.00-0.350
%Manganese	0.600	0.60-1.000
%Chromium	0.097	-
%Nickel	0.075	-
%Moly	0.020	-

.2 Design of experiment based on Taguchi method

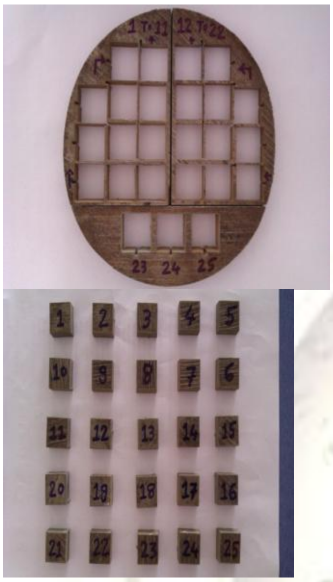
In this investigation carried out by varying three control factors traverse speed, abrasive mass flow rate and SOD on AWJM DWJ1525-FA at Yogesh Industries, Ahmadabad. A Orifice diameter 0.25 mm, Nozzle diameter 0.76 mm, abrasive size garnet 80 mesh,Water flow rate 3.1 ltr/min and Impact angle 90^0 ware used as a constant for every experimental work. Control factors along with their levels are listed in Table 2. Hence Taguchi based design of experiment method was implemented. In Taguchi method L25 Orthogonal array provides a set of well-balanced experiments, and Taguchi's signal-to-noise. (S/N) ratios, which are logarithmic functions of the desired output, serve as objective functions for optimization [3].

Table 2 Control parameters and their levels

Factors	Level -1	Level - 2	Level - 3	Level - 4	Level - 5
Traverse speed	50	55	60	65	70
Abrasive flow rate	250	300	350	400	450
SOD	2	4	6	8	10

2.3 Specimen detail

L25 Orthogonal array obtain based on the control factors. Total 25 nos. of experiments has been carried out and then cut a piece of 20 mm x 20 mm from Dia.170 mm and 12mm thick size of EN8 material. Abrasive type, Abrasive size, water flow rate, orifice diameter and impact angle selected as constant parameter. Specimen after machining for each experiment shown in figure 1. Mass of material removal is calculated based on mass difference. Surface roughness measured precisely with help of Surface roughness tester Mitutoyo SJ-210[4].



Work piece after Machining (Size 170mm dia. and 12 thick) Cut piece after machining (Size 20 x 20 square pieces)

Figure 1 Machined specimen of EN8

III. RESULTS AND ANALYSIS

3.1 Calculation of Signal to Noise ratio:

SN ratio can be calculated based on response requirement. Material removal rate preferred always higher is better and roughness value lower is better. According to Taguchi technique MRR calculated based on Higher is better (Eq. 1) and surface roughness as smaller is better (Eq. 2). The analysis carried out on MINITAB 16 software [5]. Table 3 Show the taguchi Orthogonal L25 Array and result of MRR and Surface roughness. Table 4. Shows the result with calculated Signal to Noise ratio.

$$SN\ for\ Higher\ is\ better = -10\log_{10}\left[\frac{1}{n}\sum_{i=1}^{n}\frac{1}{y_1^2}\right] \text{----- (Eq. 1)}$$

$$SN\ for\ Lower\ is\ better = -10\log_{10}\left[\frac{1}{n}\sum_{i=1}^{n}y_1^2\right] \text{----- (Eq. 2)}$$

Table 3 Taguchi Orthogonal L25 Array and result of MRR and Surface roughness for En8

Exp. No	Process Parameter			MRR (gm/ min)	Surface Roughness (µm)
	Traverse Speed (mm/ min)	Abrasive flow rate(gm /min)	Stand of distance (mm)		
1	50	250	2	3.28	10.32
2	50	300	4	3.53	10.96
3	50	350	6	3.66	11.27
4	50	400	8	3.69	11.34
5	50	450	10	3.65	11.25
6	55	250	4	3.62	11.17
7	55	300	6	3.64	11.22
8	55	350	8	3.72	11.41
9	55	400	10	3.68	11.32
10	55	450	2	3.75	11.48
11	60	250	6	4.00	12.04
12	60	300	8	4.13	12.32
13	60	350	10	3.96	11.95
14	60	400	2	3.99	12.02
15	60	450	4	4.08	12.21
16	65	250	8	4.18	12.42
17	65	300	10	3.97	11.98
18	65	350	2	4.13	12.32
19	65	400	4	4.24	12.55
20	65	450	6	4.25	12.57
21	70	250	10	4.17	12.40
22	70	300	2	4.09	12.23
23	70	350	4	4.10	12.26
24	70	400	6	4.15	12.36
25	70	450	8	4.18	12.42

Table 4 SN Ratio for MRR and Surface roughness

Exp. No	MRR (gm/min)	SN Ratio For MRR	Surface Roughness (µm)	SN Ratio For Surface Roughness
1	3.28	10.32	2.78	-8.88
2	3.53	10.96	2.96	-9.43
3	3.66	11.27	3.23	-10.18
4	3.69	11.34	3.43	-10.71
5	3.65	11.25	3.73	-11.43
6	3.62	11.17	2.98	-9.48
7	3.64	11.22	3.4	-10.63
8	3.72	11.41	3.61	-11.15
9	3.68	11.32	3.6	-11.13
10	3.75	11.48	2.92	-9.31
11	4.00	12.04	3.29	-10.34

12	4.13	12.32	3.62	-11.17
13	3.96	11.95	3.77	-11.53
14	3.99	12.02	2.94	-9.37
15	4.08	12.21	3.11	-9.86
16	4.18	12.42	3.68	-11.32
17	3.97	11.98	3.84	-11.69
18	4.13	12.32	2.99	-9.51
19	4.24	12.55	3.23	-10.18
20	4.25	12.57	3.52	-10.93
21	4.17	12.40	3.84	-11.69
22	4.09	12.23	3.11	-9.86
23	4.10	12.26	3.2	-10.10
24	4.15	12.36	3.53	-10.96
25	4.18	12.42	3.74	-11.46

3.2 Analysis Of Variance (ANOVA):

Analysis of Variance (ANOVA) is a powerful analyzing tool to identify which are the most significant factors and it's (%) percentage contribution among all control factors for each of machining response. It calculates variations about mean ANOVA results for the each response. Based on F-value (Significance factor value) important parameters can be identified. Table 5 and Table 6 are ANOVA Table obtained by Minitab 16 software. ANOVA Table contain Degree of freedom (DF), Sum of Squares (SS), Mean squares (MS), Significant Factor ratio (F-Ratio), Probability (P) and calculated percentage contribution.

3.3 Result Discussion for Material Removal Rate (MRR)

Analysis of Variance tables 5 shows the effect of parameter on MRR. The significant parameters can be easily identified .Traverse speed is a most significance factor for MRR and it has p-value<0.05. Abrasive flow rate and Stand of distance has less effect on MRR. Percentage contribution of residual error is 6.09 %. It strengthens the analysis as it is on minimum side. Maximum % percentage contribution of Traverse speed has 87.10%.

Table 5 ANOVA for Material Removal Rate

Source	DF	Seq SS	Adj SS	Adj MS	F val	P	% Con.
Traverse speed	4	7.6373	7.6373	1.90932	42.86	0.000	87.10
Abrasive flow	4	0.3249	0.3249	0.08122	1.82	0.189	3.71
Stand of distance	4	0.2715	0.2715	0.06787	1.52	0.257	3.10
Residual Error	12	0.5346	0.5346	0.04455			6.09
Total	24	8.7683					

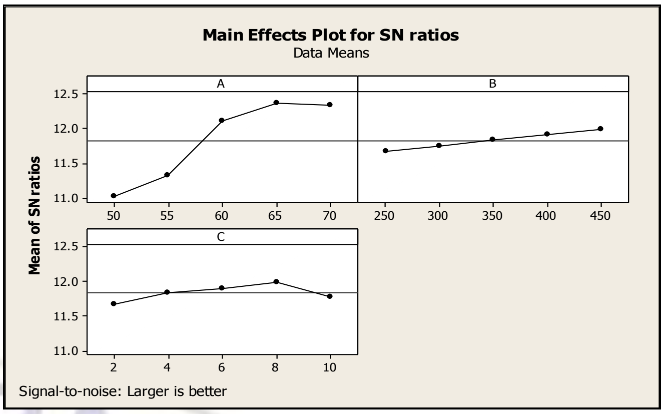


Figure 2 Main Effect plot for SN Ratio (MRR) V/s Factors

Figure 2 shows the main effect plot of MRR at different parameters like Traverse speed, Abrasive flow rate and Stand of distance in Abrasive water jet machining process of EN8.From the figure, it can be seen that maximum MRR obtained is at Traverse speed of 65 mm/min, Abrasive flow rate of 450 gm/min and Stand of distance of 8mm.

3.3 Result Discussion for Surface Roughness (Ra)

Analysis of Variance table 6 shows the significance parameter effect on Surface roughness. The significant parameters can be easily identified. Traverse speed and Stand of distance has p-value almost <0.05. Hence for Surface roughness these parameters are much significant. Abrasive flow rate does not much affect the surface roughness. Percentage contribution of residual error is 1.24%. Stand of Distance has maximum percentage contribution (88.80 %) and % percentage contribution of Traverse speed has 8.89 %.

Table 6 ANOVA for Surface Roughness

Source	DF	Seq SS	Adj SS	Adj MS	F val	P	% Con.
Traverse speed	4	1.5780	1.5780	0.39451	21.43	0.000	8.89
Abrasive flow	4	0.1893	0.1893	0.04732	2.57	0.092	1.07
Stand of distance	4	15.7575	15.7575	3.93938	213.99	0.000	88.80
Residual Error	12	0.2209	0.2209	0.01841			1.24
Total	24	17.7458					

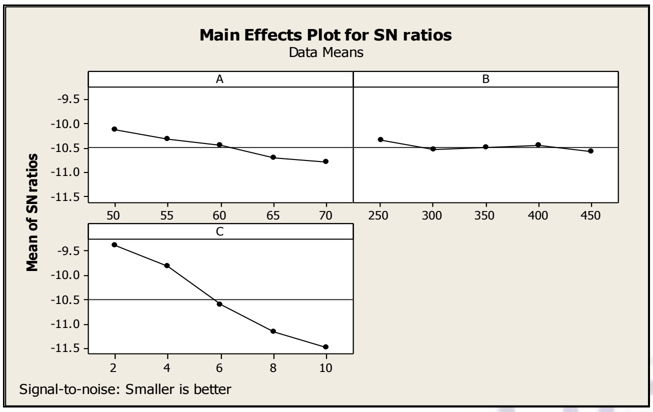


Figure 3 Main Effect plot for SN Ratio (Ra) V/s Factors

Figure 3 shows the main effect plot of Surface Roughness at different parameters like Traverse speed, Abrasive flow rate and Stand of distance in Abrasive water jet machining process of EN8.From the figure, it can be seen that less Surface roughness obtained is at Traverse speed of 50 mm/min, Abrasive flow rate of 250 gm/min and Stand of Distance of 2 mm.

3.4 Effect of Mixing Ratio for MRR and Surface Roughness

The Effect plot of Mixing Ratio v/s MRR and Mixing Ratio v/s Surface Roughness at Traverse speed 50 mm/min are shown in figure 4 and figure 5 respectively. Mixing Ratio is defined as the ratio mass flow rate of Abrasive Material to mass flow rate of water in AWJM.

$$\text{Mixing ratio} = \frac{\text{Mass flow rate of abrasive(gm/min)}}{\text{Mass flow rate of water (gm/min)}}$$

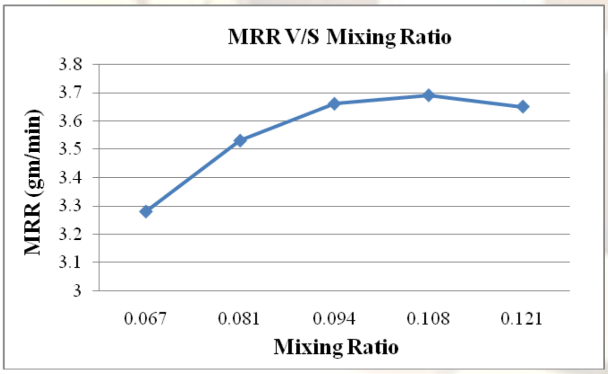


Figure 4 Effect of Mixing Ratio v/s MRR

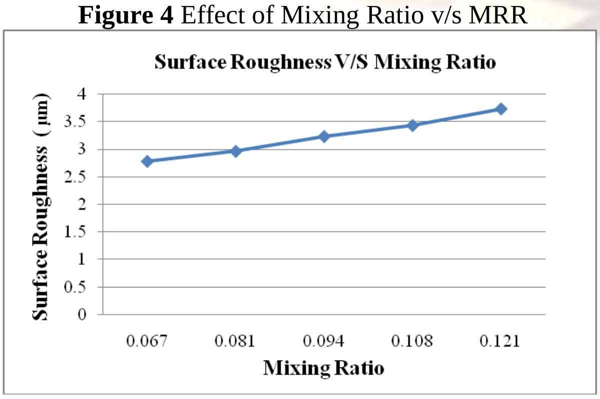


Figure 5 Effect of Mixing Ratio v/s Surface Roughness

When Mixing Ratio increase, the MRR increase up to certain limit and further increase in Mixing Ratio beyond the limit results in decrease of MRR.Surface Roughness value which is measured in Ra increase with increase in Mixing Ratio.

IV. Conclusion

This paper presents analysis of various process parameters and drawn following conclusions from the experimental study:

- Process parameters affect different response in different ways. Hence need to set parameter based on requirement.
- MRR increases with the increase in Traverse speed (50 to 65 mm/min) and also Surface Roughness increase with increase in Traverse speed.
- Higher Abrasive flow rate give increase MRR and less influence on Surface Roughness. Abrasive flow rate is less significant control factor for MRR.
- MRR increases with the increase in SOD (2 to 8 mm) up to certain limit and further increase in SOD beyond the limit results in decrease of MRR and Surface Roughness increase with increase in SOD.
- Traverse speed is a most significant control factor for MRR and Abrasive flow rate and SOD are equally significant control factor for MRR. SOD is the most significant control factor on Surface Roughness.
- Mixing ratio is a most significant control factor for MRR and Surface Roughness.

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