An Investigation of Different Material on Abrasive Water jet Machine

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Abstract

Abrasive water jet machine (AWJM) is a nontraditional machining process. Abrasive water jet machining is a process of removal of material by impact erosion of high pressure (1500-4000 bar), high velocity of water and entrained high velocity of grit abrasives on a work piece. It's a non-conventional machining process. At here first works on theoretical work after it make some experimental work and then analyses both results. Theoretical MRR found equal to the experimental MRR. In this paper investigation for three different materials like en8, acrylic and aluminum is carried out using Taguchi design of experiment method. Experiments are carried out using L25 Orthogonal array by varying Material traverse speed and abrasive mass flow rate for each material respectively. Anova carried out for identifies significant parameters

Keywords: AWJM, ANOVA, SN-Ratio, MRR

1. Introduction

Abrasive water jet machine (AWJM) is a nontraditional machining process. Abrasive water jet machining is a process of removal of material by impact erosion of high pressure (1500-4000 bar), high velocity of water and entrained high velocity of grit abrasives on a work piece. [3]. It's a non-conventional machining process. Abrasive water jet machining is a relatively new machining technique in that it makes use of the impact of abrasive material to erode the work piece material. It relies on the water to accelerate the abrasive material and deliver the abrasive to the work piece. In addition the water afterwards carries both the spent abrasive and the eroded material solid tool to cut the material usually by a shearing process. [1].

In the early 60's O. Imanaka, University of Tokyo applied pure water for industrial machining. In the late 60's R. Franz of University of Michigan, examine the cutting of wood with high velocity jets. The first industrial application manufactured by McCartney Manufacturing Company and installed in Alto Boxboard in 1972. The invention of the abrasive water jet in 1980 and in 1983 the first commercial system with abrasive entrainment in the jet became available. The added abrasives increased the range of materials, which can be cut with a Watergate drastically. Higher traverse speeds, thicker materials and better edge quality could be achieved. [2]

2. Experimental Procedure

In this investigation used three different material en8, acrylic and aluminium and two varying parameters traverse speed and abrasive mass flow rate. Experiments are carried out using L25 Orthogonal array by varying Material traverse speed and abrasive mass flow rate for each material respectively. Anova carried out for identifies significant parameters.

2.1 Material specification: In this experiment use En8 (10mm thick), Acrylic (4mm thick) and Aluminium (1mm thick) three different material.
2.3 Design of experiment based on Taguchi method: In this investigation carried out by varying two control factors one is traverse speed and other is abrasive mass flow rate on AWJM DWJ1525-FA at A innovative

international ltd, Ahmadabad. A 0.25 mm nozzle diameter, 2mm stand of distance, 2700 bar pressure and 80 mesh abrasive size silica was used is constant for every experimental work. Control factors along with their levels are listed in Table 1. Full factorial design of experiments would require a large no. of runs; Hence Taguchi based design of experiment method was implemented. In Taguchi method 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. It helps to learn the whole parameter space with a minimum experimental runs. Taguchi replaces the full factorial experiments with a lean, less expensive, faster partial factorial experiment.

Table 1. Control parameters and their levels

Machining Process Parameter	**Level 1**	**Level 2**	**Level 3**	**Level 4**	**Level-5**
Traverse Speed mm/min	50	55	60	65	70
Abrasive mass flow rate kg/min	290	310	330	350	370

2.4 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 30 mm x 15 mm from Dia.170 mm EN8 material, 400X500 MM from Acrylic material and 400X500 MM from Aluminum material. Water pressure 2700 bar selected as constant. Specimen after machining for each abrasive level shown in figure 1, figure 2 and figure 3. Mass of material removal is calculated based on mass difference and theoretically based on kerf width. MRR is calculated based on it in mm^3/min.

Figure.1 Specimen after Machining (En 8): Size - Dia.170mm and Thickness 10mm

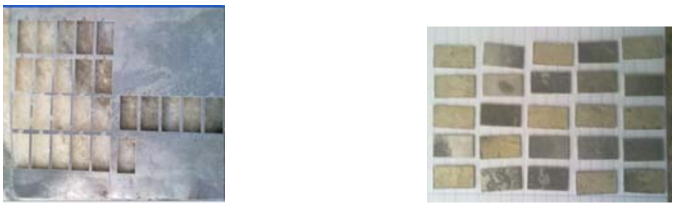

Figure.2 Specimen after Machining (Acrylic): Size –400X500mm and Thickness 1mm

Figure.3 Specimen after Machining (aluminium): Size –400X500mm and Thickness 4 mm

3. 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). The analysis carried out on MINITAB 15 software For EN8, ACRYLIC AND ALUMINIUM. Table 2. Shows the result with calculated Signal to Noise ratio.

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

Table 2. Taguchi Orthogonal L25 Array and result of MRR for En8, Acrylic and Aluminium

SR NO	Traverse speed mm/min	Abrasive mass flow rate gm/min	MRR in mm^3/min En8	SNRA1	MRR in mm^3/min Acrylic	SNRA1	MRR in mm^3/min Aluminium	SNRA1
1	50	290	400.00	52.0412	243.24	47.7207	41.47	32.3547
2	50	310	566.03	55.0568	246.57	47.8388	42.45	32.5576
3	50	330	580.64	55.2781	268.66	48.5841	43.30	32.7298
4	50	350	592.50	55.4538	297.52	49.4703	56.60	35.0563
5	50	370	620.68	55.8574	302.52	49.6151	58.06	35.2775
6	55	290	405.40	52.1577	246.58	47.8392	42.25	32.5165
7	55	310	573.24	55.1667	248.28	47.8988	42.85	32.6390
8	55	330	584.41	55.3344	272.73	48.7147	45.00	33.0643
9	55	350	600.00	55.5630	305.08	49.6883	57.32	35.1661
10	55	370	633.80	56.0390	307.69	49.7623	59.60	35.5049
11	60	290	409.09	52.2364	248.27	47.8985	43.26	32.7217
12	60	310	580.64	55.2781	251.75	48.0194	43.90	32.8493
13	60	330	592.10	55.4479	281.25	48.9819	56.96	35.1114
14	60	350	608.10	55.6795	313.04	49.9120	58.06	35.2775
15	60	370	642.85	56.1622	318.58	50.0644	60.00	35.5630
16	65	290	412.84	52.3156	253.52	48.0802	44.11	32.8907
17	65	310	588.23	55.3909	257.14	48.2034	45.00	33.0643
18	65	330	600.00	55.5630	290.32	49.2575	57.69	35.2220
19	65	350	620.68	55.8574	318.58	50.0644	59.60	35.5049
20	65	370	652.17	56.2872	324.32	50.2195	60.40	35.6207
21	70	290	418.60	52.4360	258.99	48.2657	44.77	33.0197
22	70	310	600.00	55.5630	262.77	48.3915	57.32	35.1661
23	70	330	612.24	55.7384	295.08	49.3988	59.21	35.4479
24	70	350	625.00	55.9176	330.27	50.3774	60.00	35.5630
25	70	370	676.69	56.6078	339.62	50.6199	62.06	35.8562

3.1 Analysis Of Variance (ANOVA): Analysis of Variance (ANOVA) is a powerful analyzing tool to identify which are the most significant factors. It calculates variations about mean ANOVA results for the each response. Based on F-value (Significance factor value) important parameters can be identified. Table 3, Table 4 and Table 5 ANOVA Table obtained by MiniTab15 software. ANOVA Table contains Degree of freedom (DF), Sum of Squares (SS), Mean squares (MS), Significant Factor ratio (F-Ratio) and Probability (P).

3.3 Result Discussion for EN8 Material:

Table 3. ANOVA for Material Removal Rate

Source	DF	Seq SS	Adj SS	Adj MS	F value	P
Traverse Speed mm/min	4	0.8018	0.8018	0.2005	64.96	0.000
abrasive mass flow rate kg/min	4	49.1859	49.1859	12.2965	3984.97	0.000
Residual Error	16	0.0494	0.0494	0.0031		
Total	24	50.0371				

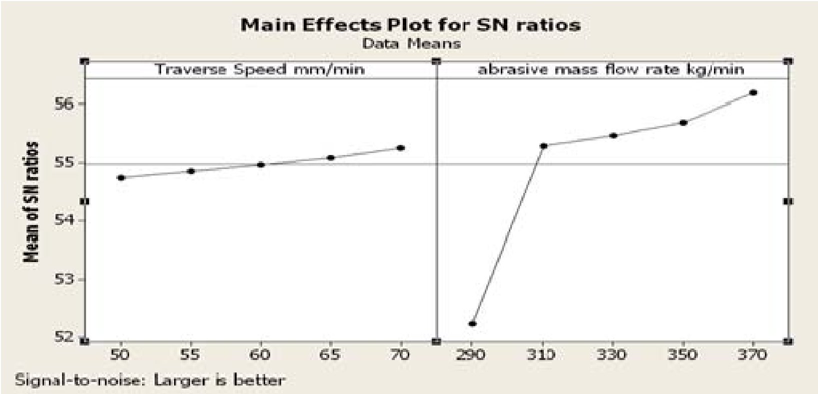

Figure 4. Plot for Mean of SN Ratio (MRR) v/s Factor for En8 material.

- Figure 4. Shows that MRR increases with increasing of abrasive mass flow rate and Traverse Speed ANOVA analyses calculate F-ratio (table 3) for abrasive mass flow rate 3984.97 and for Traverse Speed 64.96 for En8. P-value is <0.05 (α level), Hence both parameters are significant.

3.4 Result Discussion for Acrylic Material:

Table 4. ANOVA for Material Removal Rate

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Source	DF	Seq SS	Adj SS	Adj MS	F value	P
Traverse Speed mm/min	4	1.8497	1.8497	0.46243	57.14	0.000
Abrasive mass flow rate kg/min	4	19.3705	19.3705	4.84263	598.33	0.000
Residual Error	16	0.1295	0.1295	0.00809		
Total	24	21.3498				

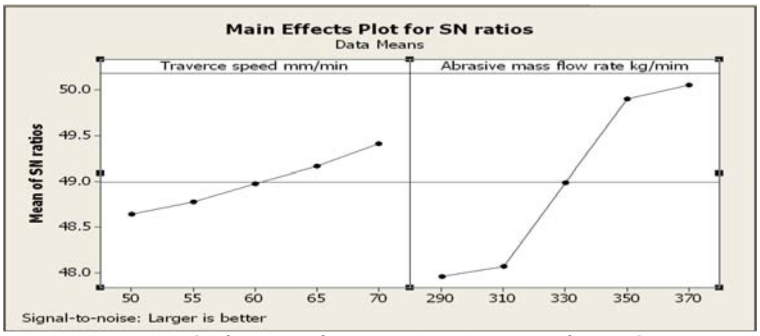

Figure 5. Plot for Mean of SN Ratio (MRR) v/s Facto for Acrylic

- Figure 5. Shows that MRR increases with increasing of abrasive mass flow rate and Traverse Speed. ANOVA analyses calculate F-ratio (Table 4) for abrasive mass flow rate 598.33 and for Traverse Speed 57.14. . P-value is <0.05 (α level), Hence both parameters are significant.

3.5 Result Discussion for Aluminium Material:

Table 5. ANOVA for Material Removal Rate

Source	DF	Seq SS	Adj SS	Adj MS	F value	P
Traverse Speed mm/min	4	6.376	6.376	1.5940	4.39	0.014
abrasive mass flow rate kg/min	4	19.3705	31.256	7.8140	21.50	0.000
Residual Error	16	5.815	5.815	0.3634		
Total	24	43.447				

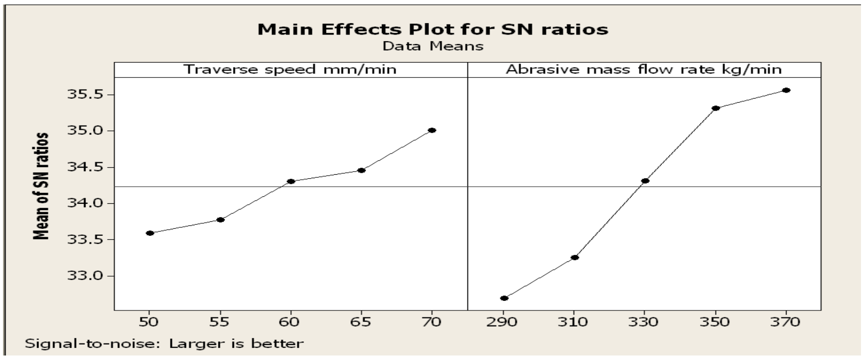

Figure 6. Plot for Mean of SN Ratio (MRR) v/s Factor for aluminium

- Figure.6 shows that MRR increases with increasing of abrasive mass flow rate and Traverse Speed. ANOVA analyses calculate F-ratio (Table 5) for abrasive mass flow rate 21.50 and for Traverse Speed 4.39. . P-value is <0.05 (α level), Hence both parameters are significant

3.6 theoretical Material removal rates for Material: For finding the theoretical MRR follow this equation for material removal rate for different materials.

The equation is

$$MRR = h_t \, w \, v_f \quad \text{………………………………………}\textit{eq (3)}$$

Where,

h_t = depth of penetration

w = width of the kerf

$= (w_{top} + w_{bottom}) / 2$

$\approx d_i$, the diameter of the focusing tube or nozzle or the insert

v_f = traverse speed of the AWJ or cutting speed

And for the measuring the Value of (h_t) depth of penetration by this equation is

$$h_t = \frac{\pi}{4} d_o^2 R \left(\frac{1}{1+R} \right)^2 \frac{p^{\frac{3}{2}}}{\mu_{job} d_i v_f} \sqrt{\frac{2}{q_w}} \quad \text{…………………………………………….….}\textit{eq(4)}$$

Where,

- d_o = orifice diameter in mm
- d_i = insert diameter in mm
- R = mass flow rate of abrasive ($m_{abr)}$ / mass flow rate of water (m_w)
- ρ_w = density of water
- μ_{job} = specific energy of material j/mm^3
- P = pressure in bar (psi)
- $\mathbf{v_f}$ **=** traverse speed mm/min. [1]

Now with the help of this equation find the MRR at different traverse speed of 50, 55, 60, 65, 70 mm/min and abrasive mass flow rate 290, 310, 330, 350, 370 kg/min for Taguchi array L25 in Table 4.

Table 6. Taguchi Array L25 and result of MRR for En8, Acrylic and Aluminium

Sr no	Traverse speed in mm/min	Abrasive mass flow in gm/min	MRR in mm^3/min En8	MRR in mm^3/min Acrylic	MRR in mm^3/min Aluminium
1	50	290	484.50	243.20	44.08
2	50	310	513.00	246.24	44.84
3	50	330	487.16	267.14	48.64
4	50	350	574.56	296.40	52.06
5	50	370	611.42	303.24	55.11
6	55	290	486.97	243.28	44.31
7	55	310	496.58	246.20	44.46
8	55	330	536.71	267.52	48.91
9	55	350	575.17	285.49	52.25
10	55	370	611.95	303.47	55.18
11	60	290	487.00	243.50	44.23
12	60	310	492.93	245.79	44.69
13	60	330	521.20	266.76	48.79
14	60	350	571.36	285.00	51.98
15	60	370	606.93	302.78	54.72
16	65	290	487.08	243.54	43.97
17	65	310	493.01	246.51	44.95
18	65	330	515.24	267.75	48.41
19	65	350	571.06	285.53	51.87
20	65	370	607.12	303.81	55.33
21	70	290	486.78	243.66	44.16
22	70	310	492.63	246.32	45.22
23	70	330	534.66	267.06	48.41
24	70	350	570.30	285.15	51.60
25	70	370	606.98	303.94	55.43

3.6 Confirmation Test: In reading no 25 where the set parameter level is maximum (70; 370) MRR obtain experimentally is maximum for all material, which confirms the analysis carried out in this research. Also the experimental MRR is almost nearer to theoretical MRR.

4. Conclusions

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

- MRR increase By increasing abrasive mass flow rate (290 to 370 gm/min).
- MRR increase for En8 - 484.50 to 606.98 mm^3/min, Acrylic - 243.20 to 303.94 and Aluminium - 44.08 to 55.43
- Increasing speed (50 to 70) is also increase MRR.
- Full factorial design help for analysis as no separate combination needs for confirmation test.

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