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Analysis of Process Parameters in AWJM on Aluminium 2219 using Taguchi Method

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Abstract: ***This paper investigates the effect of various process parameters of abrasive water jet machining (AWJM) on material removal rate, surface roughness and kerf width with Aluminium 2219 alloy. Taguchi method is used to find out the optimal process parameters as well as the most significant parameters affecting the machine performance. The input parameters chose for optimization are abrasive flow rate, stand off distance, water pressure and traverse speed.***

Keywords: AWJM, Taguchi method, Parameter Optimization, SN Ratio

1. Nomenclature

AFR Abrasive flow rate (gm/min)
SOD Stand off distance (mm)
WP Water pressure (MPa)
TS Traverse speed (mm/min)
MRR Material removal rate (gm/min)
SR Surface roughness (µm)
KW Kerf width (mm)

2. Introduction

Abrasive water jet machining is a nonconventional nontraditional machining process, in which abrasives are used along with pressurized water for machining of materials. Recent development has witnessed improvements in jet cutting technology by using abrasive water jets where water is used as carrier fluid. In Abrasive water jet machine water is used as a carrier fluid in place of gas. From two different sources, a water jet and a stream of abrasives are supplied and mixed in a chamber passes through the abrasive jet nozzle which impinges on the work piece and material removal takes place due to shear, erosion or failure under rapid changing localized stress fields. It is used for cutting, drilling and cleaning of hard materials. It is capable to cut ceramics, composites and rock metals.

K.S. Jai Aultrin et al., found that water pressure, abrasive flow, orifice diameter, nozzle diameter and standoff distance and along with their interactions have significant effect on the MRR and SR. B. Satyanarayana et al., optimized material removal rate and kerf width simultaneously using AWJM process on Inconel 718. The selected process parameters are abrasive flow rate, water pressure, and standoff distance. Taguchi and Grey Relational Analysis is opted because of multi response optimization. Thilak M et al., attempt to select the significant process parameters by Taguchi methodology while machining of Aluminium 6063 by AWJM. Different process parameters like pressure, feed rate, standoff distance and abrasive flow rate in three different levels are selected for optimization with two contravene responses, higher MRR and lower SR by a single parametric combination. C.R. Sanghani et al., investigated the effect of various process parameters on kerf taper, surface roughness and power consumption which are important performance measures in abrasive water jet machining. The variable process parameters considered here include water pressure, traverse speed, stand-off distance and abrasive flow rate. Experiments were conducted by varying these parameters for cutting AISI 304 austenitic stainless steel using abrasive water jet machining process. The result showed that kerf taper and surface roughness increases while power consumption decreases with increase in traverse speed, stand-off distance and abrasive flow rate as well as reduction in water pressure. Harsh A Chaudhari et al., used Al Oxide and garnet as abrasive particles. Experiment was performed based on traverse speed, abrasive flow rate and stand of distance. This work includes that creation and analyzing of response surface. Moreover, statistical analysis was carried out using taguchi & optimization parameters were identified with the application of genetic algorithm. Hence this paper made an attempt to analyse the process parameters of AWJM on various output responses with Aluminium 2219 alloy.

3. Experimentation

The work material was acquired as a rectangular piece of aluminium 2219 whose estimated measurements were 50 mm in width 10 mm thickness and of length 1800 mm. The specimens were produced with this piece using same wt 2515 AWJ machine which were approximately closer to the minimum possible dimensions which can be set on the machine. All the experiments were done on same wt 2515 AWJ machine (Figure 1).

Figure 1: AWJM Machine

After the experimentation, the MRR, surface roughness and kerf width is calculated. L9 orthogonal array is used for the experimental design. Process parameters and their levels for the work are shown in the Table 1.

Table 1: Process Parameters and Level

Parameter	Levels		
	1	2	3
AFR	200	250	300
SOD	3	4.5	6
WP	260	310	360
TS	15	25	35

The designed matrix of input parameters and the output parameters are shown in the Table 2.

Table 2: The Designed Matrix

S. No.	AFR	SOD	WP	TS	MRR	SR	KW
1	200	3	260	150	2.077	2.42	1.10
					1.977	2.45	1.10
					1.880	2.49	1.10
2	200	4.5	310	250	4.460	3.93	1.48
					4.738	4.02	1.52
					4.539	4.02	1.50
3	200	6	360	350	9.712	5.98	2.00
					10.015	5.86	1.95
					10.210	5.93	1.95
4	250	3	310	350	4.969	3.11	1.16
					5.504	3.20	1.20
					5.838	3.43	1.10
5	250	4.5	360	150	3.186	3.78	1.50
					3.322	3.88	1.48
					3.336	3.88	1.55
6	250	6	260	250	6.843	5.41	1.88
					6.920	5.48	1.84
					6.790	5.62	1.86
7	300	3	360	250	4.095	2.94	1.20
					4.114	2.94	1.10
					4.239	3.11	1.16
8	300	4.5	260	350	7.355	4.08	1.52
					7.088	4.26	1.54
					7.101	4.38	1.56
9	300	6	310	150	4.983	4.98	1.90
					4.879	5.12	1.86
					4.805	5.12	1.88

4. Results and Discussions

4.1 Effect of Input Parameter on MRR

It is found that the material removal rate is most influenced by pulse traverse speed then, stand off distance, abrasive flow rate and water pressure (Table 3). The optimized parameter settings for material removal rate are abrasive flow rate 300gm/min, stand off distance 6mm, water pressure 360MPa and traverse speed 350mm/min (Figure 2).

Table 3: Effect on Material Removal Rate

Level	AFR	SOD	WP	TS
1	13.03	10.97	13.25	10.00
2	13.89	13.55	13.88	14.09
3	14.42	16.82	14.22	17.25
Delta	1.39	5.85	0.97	7.25
Rank	3	2	4	1

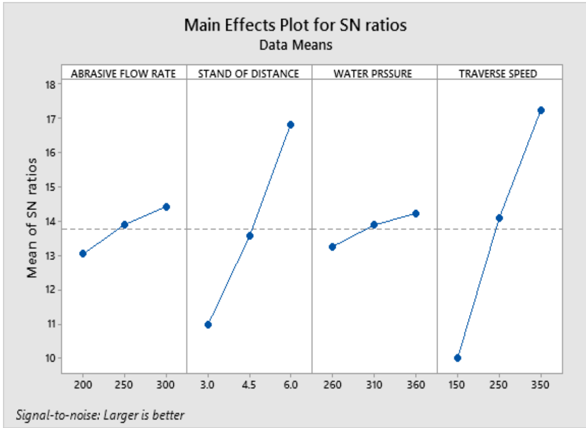

Figure 2: Mean Effects Plot of MRR

MRR = -6.08 - 0.00105 abrasive flow rate + 1.1284 stand off distance + 0.00466 water pressure + 0.02075 traverse speed (1)

MRR for optimum input combinations is 9.3155 gm/min.

4.2 Effect of Input Parameters on Surface Roughness

Surface roughness is affected mostly by stand off distance, then traverse speed, water pressure and abrasive flow rate (Table 4). The optimized parameter settings for surface roughness are abrasive flow rate 200gm/min, stand off distance 3mm, water pressure 260MPa and traverse speed 150mm/min (Figure 3).

Table 4: Effect on Surface Roughness

Level	AFR	SOD	WP	TS
1	-11.766	-9.203	-11.728	-11.213
2	-12.257	-12.096	-12.129	-12.127
3	-12.070	-14.794	-12.236	-12.752
Delta	0.492	5.590	0.508	1.539
Rank	4	1	3	2

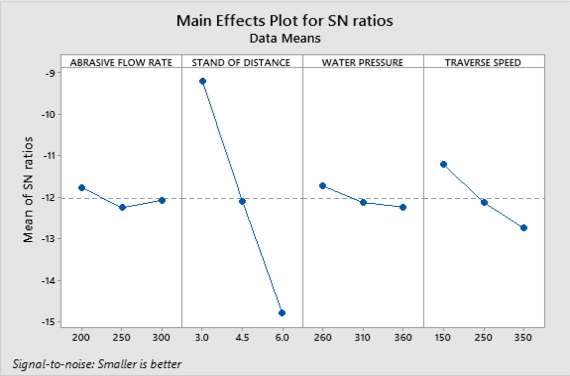

Figure 3: Mean Effects Plot of Surface Roughness

Surface roughness = -1.140– 0.000200 AFR+ 0.8661 SOD+0.001903 WP+ 0.003386 TS (2)
Surface roughness for optimum input combinations is 2.42098µm.

4.3 Effect of Input Parameters on Kerf Width

Kerf width is mostly influenced by stand off distance, then traverse speed, water pressure and abrasive flow rate (Table 5). The optimized parameter settings are abrasive flow rate 200gm/min, stand off distance 3mm, water pressure 260MPa and traverse speed 150mm/min (Figure 4).

Table 5: Effect on Kerf Width

Level	AFR	SOD	WP	TS
1	-3.408	-1.106	-3.323	-3.298
2	-3.405	-3.618	-3.417	-3.386
3	-3.493	-5.583	-3.567	-3.624
Delta	0.088	4.477	0.244	0.326
Rank	4	1	3	2

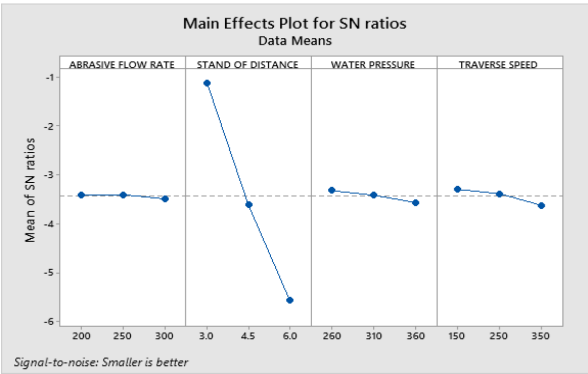

Figure 4: Mean Effects Plot of Kerf Width

Kerf width = 0.1574 + 0.000022 AFR + 0.25556 SOD + 0.000433 WP + 0.000283 TS (3)
Kerf width for optimum input combinations is 1.08351 mm.

5. Conclusions

The conclusions made based on the experimental investigations of AWJM on Aluminum 2219 alloy are as follows;

1) Travers speed and stand off distance has the major effect on material removal rate, surface roughness and kerf width.
2) Abrasive flow rate and water pressure has significantly less affected as compared to traverse speed and stand of distance
3) The optimum combination for material removal rate, surface roughness and kerf width has also been identified.

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