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An Experimental Investigation to Study theEffect of Input Parameters on AISI 1080 using Abrasive Water Jet Machining

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Abstract: **This paper reports the experimental investigation using Abrasive Water Jet Machining on AISI 1080. The relevance of this study is to analyse the effect of process parameters of Abrasive Water Jet Machining on AISI 1080. For this experiment the response parameters considered are top kerf width, material removal rate and surface roughness while the input parameters considered are stand-off distance, traverse speed and abrasive mass flow rate. Experiments are performed using full factorial design for 3 input parameters at 3 levels and the process performance data for various parameters is analysed using ANOVA analysis. The experimental results show that the most influencing process parameter affecting the top kerf width and material removal rate is traverse speed, and for surface roughness, it is stand-off distance.**

Keywords — Abrasive Water Jet Machining (AWJM), AISI 1080, response parameters, process parameters, material removal rate (MRR), top kerf width, surface roughness, ANOVA analysis

I. INTRODUCTION

Among many of the non-conventional methods, AWJM is a relatively new machining technique. It is recognised as the most versatile and fastest growing process in the industry. No noxious gases or liquids are used in water jet cutting and water jets do not create hazardous materials or vapours. No heat affected zones or mechanical stressesare left on the AWJM surface. It is a versatile, productive and cold cutting process. There are so many process parameters that affect quality of machined surface cut by AWJM. Important process parameters which mainly affect the quality of machining are traverse speed, hydraulic pressure, stand-off distance, abrasive flow rate and types of abrasive. Important quality parameters in AWJM are Material Removal Rate (MRR), Surface Roughness(SR), kerf width, tapering of kerf. Many researchers have done work on abrasive water jet machine using various work piece materials [1-8]. However, the detailed investigation on the influence of predominant machining variables on AISI 1080 material is yet to be established. This paper attempts to study the effects of process parameters on output parameters using full factorial method as functions of traverse speed, abrasive mass flow rate and standoff distance as input parameters and response parameters taken into consideration are top kerf width, material removal rate (MRR) and surface roughness (Ra).

II. EXPERIMENTATION

AISI 1018 mild/low carbon steel has excellent weld ability and produces a uniform and harder case and it is considered as the best steel for carburized parts. AISI-1018 mild/low carbon steel offers a good balance of toughness, strength and ductility. Provided with higher mechanical properties, AISI-1018 hot rolled steel also includes improved machining characteristics and Brinell hardness.

Sample Specimen for experimentation: 10 mm thick plate of AISI 1018. Different properties of the specimen are shown in tables 1, 2 and 3.

Table 1: Chemical Composition of sample specimen

Element	Content
Carbon, C	0.14 - 0.20 %
Iron, Fe	98.81 - 99.26 % (as remainder)
Manganese, Mn	0.60 - 0.90 %
Phosphorous, P	≤ 0.040 %
Sulfur, S	≤ 0.050 %

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Table 2: Mechanical Properties of sample specimen

Properties	Metric
Hardness, Brinell	126
Hardness, Knoop (Converted from Brinell hardness)	145
Hardness, Rockwell B (Converted from Brinell hardness)	71
Hardness, Vickers (Converted from Brinell hardness)	131
Tensile Strength, Ultimate	440 MPa
Tensile Strength, Yield	370 MPa
Elongation at Break (In 50 mm)	15.0 %
Reduction of Area	40.0 %
Modulus of Elasticity (Typical for steel)	205 GPa
Bulk Modulus (Typical for steel)	140 GPa
Poisson's Ratio (Typical for Steel)	0.290
Machinability (Based on AISI 1212 steel. as 100% machinability)	70 %
Shear Modulus (Typical for steel)	80.0 GPa

Table 3: Electrical Properties of sample specimen

Properties	Metric
Electrical resistivityat 0°C (32°F)	0.0000159 Ω-cm
at 100 °C/ 212 °F	0.0000219 Ω-cm
at 200 °C/392 °F	0.0000293 Ω-cm

AISI-1018 Mild/Low Carbon Steel is used in making carburized parts that include worms, gears, pins, dowels, non- critical components of tool and die sets, tool holders, pinions, machine parts, ratchets, dowels and chain pins. It is widely used for fixtures, mounting plates and spacers. It provides high surface hardness and a soft core to parts that include worms, dogs, pins, liners, machinery parts, special bolts, ratchets, chain pins, oil tool slips, tie rods, anchor pins, studs etc. It is used to improve drilling, machining, threading and punching processes. It is used to prevent cracking in severe bends.

The equipment used for machining the samples was AWJM Abrasive model 2626 OMAX Jet Machining Centre equipped with OMAX High- Pressure Pump with the design pressure of 345MPa (50,000 psi) and the nozzle diameter was 0.75mm. The OMAX variable speed, high-pressure pump is an electrically driven, variable speed, positive displacement, crank shaft drive triplex pump designed for use with the OMAX precision jet machining system and other applications requiring high pressure water required by the OMAX jet machining system to operate.The pump control panel provides a keypad display screen, and pumps start/stop controls. Tables 4 and 5 show machine dimensions and standard model specification respectively.

Table 4: Machine Dimensions

Footprint (with controller)	9' 8" x 6' 0" (2,946 mm x 1,829 mm)
Weight (tank empty)	3,000 lb (1,364 kg)
Height (with scissor plumbing)	7' 8" (2,340 mm)
Operating Weight	6,517 lb (2,962 kg)

Table 5: Standard Model Specifications

Material Support Slat	4" x 1/8" Galvanized Steel
Maximum Supported Material Load	400 lbs/sq ft (1,950 kg/sq meter)
Electrical Requirements	3-Phase, 380-480 VAC ±10%, 50-60 Hz
Noise Level	Below 80 dBA at one meter for submergedcutting
Speed	180 in/min (4,572 mm/min)
Accuracy	±0.001" (±0.025 mm)
Repeatability	±0.001" (±0.025 mm)
Ballbar Circularity	±0.003" (±0.076 mm)

A full factorial design includes effect of all main factors and interaction of factors, 3^3 full factorial design is selected for experimental work [9]. The levels of input parameters chosen for experiment are shown in Table 6 and the final results of experimental runs by full factorial design are shown in table 7.

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Table 6: Levels of Process Parameters

Parameter	Unit	Level 1	Level 2	Level 3
Traverse Speed (A)	mm/min	80	120	160
Abrasive Mass Flow Rate (B)	g/min	150	200	250
Stand-Off Distance (C)	mm	0.5	0.75	1

Table 7: Experimental Readings

Sr no.	Traverse Speed [mm/min]	Abrasive mass flow rate [g/min]	stand-off distance [mm]	Top kerf width [mm]	MRR [mm3/min]	SR [µm]
1	80	150	0.5	1.65	4.125	2.15
2	80	150	0.75	1.67	3.987	2.27
3	80	150	1	1.68	3.874	2.35
4	80	200	0.5	1.62	4.105	2.25
5	80	200	0.75	1.67	4.055	2.31
6	80	200	1	1.69	3.935	2.38
7	80	250	0.5	1.71	4.055	2.31
8	80	250	0.75	1.72	3.897	2.39
9	80	250	1	1.78	3.982	2.43
10	120	150	0.5	1.54	4.256	2.1
11	120	150	0.75	1.59	4.125	2.16
12	120	150	1	1.65	3.981	2.31
13	120	200	0.5	1.6	4.684	2.18
14	120	200	0.75	1.61	4.472	2.24
15	120	200	1	1.63	4.394	2.31
16	120	250	0.5	1.59	4.875	2.29
17	120	250	0.75	1.62	4.612	2.31
18	120	250	1	1.64	4.321	2.41
19	160	150	0.5	1.59	5.135	1.98
20	160	150	0.75	1.6	5.256	2.11
21	160	150	1	1.64	5.298	2.24
22	160	200	0.5	1.57	5.235	2.11
23	160	200	0.75	1.59	5.365	2.21
24	160	200	1	1.62	5.371	2.27
25	160	250	0.5	1.57	6.125	2.19
26	160	250	0.75	1.61	6.235	2.21
27	160	250	1	1.62	6.324	2.37

III. RESULTS AND DISCUSSION

Main Effects Plot for Top kerf width

The main effects plot of top kerf width versus traverse speed, abrasive mass flow rate and stand of distance are shown in figure 1.

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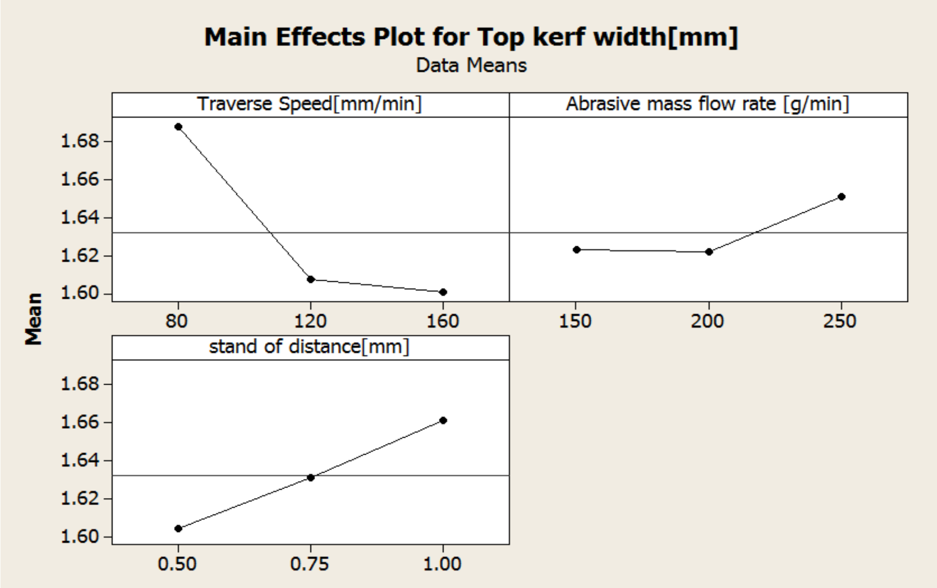

Figure 1: Effect of control factors on top kerf width

Figure 1 shows that lower top kerf width is minimum at traverse speed 160 mm/min, abrasive mass flow rate 150 gm/min and stand of distance 0.50mm. The graph is generated by use of minitab-16 statistical software for top kerf width. From figure 1, it can be observed that the optimum combination of each process parameter for lower top kerf width will be at high traverse speed [A3], low abrasive mass flow rate [B1] and low stand of distance [C1].

Main Effects Plot for Material Removal Rate

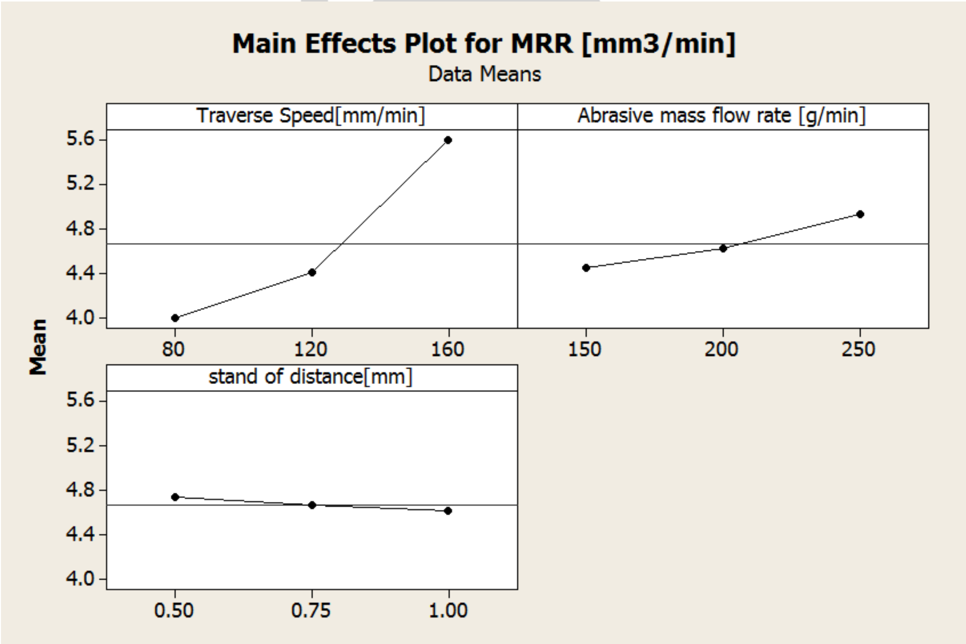

Figure 2: Effect of control factors on MRR

Figure 2 shows that higher material removal rate is maximum at traverse speed 160 mm/min, abrasive mass flow rate250 gm/min and stand of distance 0.50 mm. From the figure, it has been concluded that the optimum combination of each process parameter for higher material removal rate will be achieved at traverse speed [A3], abrasive mass flow rate [B3] and stand of distance [C1].

Main Effects Plot for Surface Roughness

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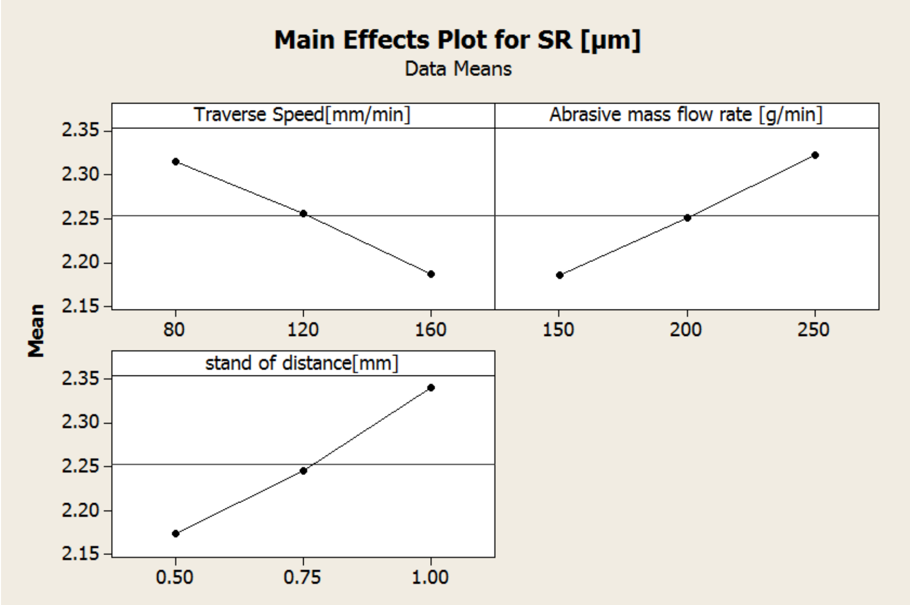

Figure 3: Effect of control factors on SR

Figure 3 shows that lower surface roughness is minimum at traverse speed 160mm/min, abrasive mass flow rate150 gm/min and stand of distance 050mm. From this figure, it has been concluded that the optimum combination of each process parameter for lower surface roughness will be achieved at traverse speed [A3], abrasive mass flow rate [B1] and stand of distance [C1].

Analysis of Variance

Analysis of Variance for Top Kerf Width

Table 8: ANOVA Table for Top Kerf Width

Source	DF	Seq SS	Adj SS	Adj MS	F	P	% Contribution
Traverse Speed	2	0.041867	0.41867	0.020933	39.09	0	58.26
Abrasive Mass Flow Rate	2	0.004822	0.004822	0.002411	4.5	0.024	6.71
Stand-Off Distance	2	0.014467	0.014467	0.007233	13.51	0	20.13
Error	20	0.010711	0.010711	0.000536			14.90
Total	26	0.071867	0.071867				
R-Sq = 85.10% R-Sq (adj) = 80.62%							

According to the analysis done by the MINITAB16 software, if the values of probability are less than 0.05, it indicated that the factors are significant to the response parameters. Comparing the p-value to a commonly used α- level = 0.05, it is found that if the p- value is less than or equal to α, it can be concluded that the effect is significant, otherwise it is not significant.

As per the ANOVA result shown in table 8, it is observed that the traverse speed, abrasive mass flow rate and stand of distance influencing parameters for Top Kerf Width, because the value of p for all process parameters are less than 0.05, so they are influencing parameter for Top Kerf Width. It is also observed that the highest influencing parameter for top kerf width is traverse speed with a contribution of 58.26%.

Analysis of Variance for Top Kerf Width

Table 9: ANOVA Table for Material Removal Rate

Source	DF	Seq SS	Adj SS	Adj MS	F	P	% Contribution
Traverse Speed	2	12.2932	12.2932	6.1466	87.88	0	82.73
Abrasive Mass Flow Rate	2	1.0982	1.0982	0.5491	7.85	0.003	7.39
Stand-Off Distance	2	0.0692	0.0692	0.0346	0.49	0.617	0.47
Error	20	1.3988	1.3988	0.0699			9.41
Total	26	14.8594	14.8594				
R-Sq = 90.59% R-Sq (adj) = 87.76%							

From table 9, it is observed that the traverse speed and abrasive mass flow rate and are influencing parameters for Material removal rate. Here, the value of p for traverse speed and abrasive flow rate is less than 0.05 p values whereas the P value of stand of distance is 0.617 which is less than 0.05, therefore, stand of distance is not effective on MRR. It is also clearly seen

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that traverse speed has the highest influence on MRR which is 82.73%.

Analysis of Variance for Surface Roughness

Table 10: ANOVA Table for Surface Roughness

Source	DF	Seq SS	Adj SS	Adj MS	F	P	% Contribution
Traverse Speed	2	0.073622	0.073622	0.036811	43.31	0.000	24.25
Abrasive Mass Flow Rate	2	0.085489	0.085489	0.0042744	50.29	0.000	28.16
Stand-Off Distance	2	0.127489	0.127489	0.063744	74.99	0.000	41.99
Error	20	0.017	0.017	0.00085			5.60
Total	26	0.3036	0.303600				
R-Sq = 94.40% R-Sq (adj) = 92.72%							

From Table 10, it is clearly observed that all the three parameters have the p value of 0.000 and hence all of them are considered to be the influencing parameters for surface roughness. However, the highest influencing parameteris stand-off distance with the contribution of 41.99%.

IV. CONCLUSION

The effect of selected input parameters using abrasive water jet machining on the output responses like top kerf width, MRR and surface roughness are studied by experimentation performed using full factorial design of experiment on AISI 1080 material.

From the analysis of variance, it can be concluded that the most significant abrasive water jet machining process variable influencing top kerf width of AISI 1080 is traverse speed followed by stand-off distance and abrasive mass flow rate.

For material removal rate, the significant order of parameters is traverse speed and abrasive mass flow rate. Stand- off distance has a negligible effect on material removal rate.

In case of surface roughness stand-off distance is the highest influencing parameter followed by abrasive mass flow rate and traverse speed.

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