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Analysis and Optimization of Abrasive Water Jet Machining of EN9 material using Taguchi Method

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***Abstract** - The Objective of doing this research work was to know the effects of the various parameters like Traverse speed, Abrasive flow rate, and Standoff distance on the material En9. The experimental investigations were conducted to assess the influence of abrasive water jet machine process parameters on response parameters like material removal rate and surface roughness. The approach is based on Taguchi method and experiments are being carried out using L25 orthogonal array for the En9 material.*

***Keywords** - Traverse speed, Abrasive flow rate, Standoff distance, Material removal rate, Surface roughness, ANOVA and SN ratio.*

I. INTRODUCTION

Abrasive water jet machine is a nontraditional machining process. It is having the advantages over the other cutting technologies such as high versatility, high flexibility, small cutting forces and no thermal distortion. The term abrasive jet refers specifically to the use of a mixture of water and abrasive to cut hard materials such as metal or granite, while the terms pure water jet and water-only cutting refer to water jet cutting without the use of added abrasives, often used for softer materials such as wood or rubber.

It is one of the most recently developed manufacturing techniques in modern era for cutting the material. It is superior to many other cutting techniques in processing the different types of the materials and has found its extensive applications in the industry.

The advantages of water jet and abrasive jet were combined and the modified machine abrasive water jet machine was developed so to get the advantages of both the machines. In this method the stream of small abrasive particles is introduced in the water jet in such a way that water jet momentum is partly transferred to the abrasive particles. The limitation of abrasive water jet machine is it can generate loud noise and may produce the tapper edges on the cut especially when cutting at high traverse rates. Moreover it is costly and the operating cost is also high compare to other cutting technologies.

II. LITERATURE REVIEW

The prediction of the depth of cut was developed on the material stainless steel . It was developed through the empirical formula.

The theoretical and experimental results were compared on the various hard materials like glass and ceramic. The research work was that the by changing the process parameters like change in the pressure, nozzle tip distance on the different thickness of glass plates there effect is studied in detailed. It was detailed study by plotting the graphs and was concluded that the as the pressure increases the material removal rate also increases.

The effects of the various parameters was been study and the effects on the work piece by changing the process parameters.

The process analysis was been done by studying the effect on the surface of the hard materials like aluminum, ceramic and stainless steel.

The parametric analysis of various materials like Al-7075 and stainless steel was also been done to find the affecting parameters on the response parameters like surface roughness and material removal rate.

III. EXPERIMENTAL DETAILS

***Material Selection**:*

AWJM is capable of machining geometrically complex and hard material components that are precise and difficult to machine such as heat treated tools steels, composites, glasses, ceramics, super alloys, carbides , steels etc. I have selected the material EN9 as it is been widely used in the industrial application in metal forming, forging, squeeze casting and pressure die casting. Before conducting the practical the EN9 material specimen was tested at the laboratory of the manufacturer at S K Mittal Iron and Steel Rolling Mills Pvt Ltd. The Table 1 shows the chemical composition of the material and the results obtained after the test of the specimen.

Table 1 Chemical Composition

Chemical Name	Carbon %	Sulphur %	Phosphurus %	Silicon %	Manganese %
Obtained value	0.54	0.02	0.03	0.20	0.69
Required value	0.35-0.60	0.00-0.06	0.00-0.06	0.05-0.35	0.50-0.80

Design of Experiment based on Taguchi method:

In the experiment which is being carried out have three factors they are traverse speed, abrasive flow rate, standoff distance are the control factors on the machine AWJM DWJ 1520-FA at the Prasant Machine Tools, Ahmedabad. The nozzle diameter is 0.75mm, abrasive material aluminum oxide with mesh size 70, impact angle is perpendicular for the every readings in the experiment.

The Table 2 shows the parameters and their various levels. Now applying the Taguchi based design of experiment method was implemented and in that we used the L 25 Orthogonal array which provides the a set of proper readings which are well balanced during the experiments and taguchi's signal to noise ratio are the logarithmic functions of the desired output which helps for the optimization of the experiment for the EN9 material.

Table 2 Parameters and their levels

Parameters	Level 1	Level 2	Level 3	Level 4	Level 5
Traverse speed(mm/min)	50	55	60	65	70
Abrasive flow rate (gm/min)	250	300	350	400	450
Standoff distance(mm)	2	4	6	8	10

Work piece Specification:

L 25 Orthogonal array obtain is based on the control factors. The total 25 experiments are been conducted and then cut a piece of 20mm * 20mm with 15mm thickness remains. Mass of material removal is calculated based on the mass difference and the surface roughness is measured with the instrument called surface roughness tester Mitutoyo SJ-210.

Table-3 Result table for MRR and Surface Roughness

Parameter name/Reading numbers.	**Traverse speed(mm/min)**	**Abrasive flow rate(gm/min)**	**Standoff distance(mm)**	**Material removal rate(gm/min)**	**Surface roughness(µm)**
1	50	250	2	3.25	2.75
2	50	300	4	3.49	2.92
3	50	350	6	3.63	3.20
4	50	400	8	3.64	3.38
5	50	450	10	3.62	3.70
6	55	250	4	3.58	2.94
7	55	300	6	3.60	3.36
8	55	350	8	3.68	3.57
9	55	400	10	3.65	3.58
10	55	450	2	3.71	2.88
11	60	250	6	3.97	3.26
12	60	300	8	4.09	3.58
13	60	350	10	3.93	3.74
14	60	400	2	3.95	2.90
15	60	450	4	4.03	3.06
16	65	250	8	4.14	3.64
17	65	300	10	3.95	3.82
18	65	350	2	4.10	3.02

19	65	400	4	4.20	3.19
20	65	450	6	4.23	3.50
21	70	250	10	4.16	3.83
22	70	300	2	4.06	3.08
23	70	350	4	4.07	3.17
24	70	400	6	4.11	3.49
25	70	450	8	4.14	3.70

Table 4 Results of ANOVA for Material Removal Rate

Factors	f	Sums of squares	Mean square of variance	Variance ratio	Percentage contribution
Traverse speed	4	1.51	0.300	33.33	88.23
Abrasive flow rate	4	0.05	0.012	1.33	2.94
Standoff distance	4	0.04	0.010	4.44	2.35
Error (e)	12	0.11	0.009	1	6.48
Total	24	1.70			

Table 5 Results of ANOVA for Surface Roughness

Factors	f	Sums of squares	Mean square of variance	Variance ratio	Percentage contribution
Traverse speed	4	0.02	0.050	62.5	0.77
Abrasive flow rate	4	0.16	0.040	50	6.17
Stand off distance	4	2.4	0.600	750	91.66
Error (e)	12	0.01	0.008	1	1.4
Total	24	2.59			

Table 6 SN Ratio table for MRR and Surface Roughness

Experiment No	MRR	Surface Roughness	SN ratio of MRR	SN ratio of Surface Roughness
1	3.25	2.75	10.237	-8.786
2	3.49	2.92	10.856	-9.307
3	3.63	3.20	11.198	-10.102
4	3.64	3.38	11.222	-10.578
5	3.62	3.70	11.174	-11.364
6	3.58	2.94	11.077	-9.366
7	3.60	3.36	11.126	-10.526
8	3.68	3.57	11.316	-11.053
9	3.65	3.58	11.245	-11.077
10	3.71	2.88	11.387	-9.187
11	3.97	3.26	11.975	-10.264
12	4.09	3.58	12.234	-11.077
13	3.93	3.74	11.887	-11.457
14	3.95	2.90	11.931	-9.247
15	4.03	3.06	12.106	-9.714
16	4.14	3.64	12.340	-11.222
17	3.95	3.82	11.931	-11.641
18	4.10	3.02	12.255	-9.600
19	4.20	3.19	12.464	-10.075
20	4.23	3.50	12.526	-10.881
21	4.16	3.83	12.381	-11.663

22	4.06	3.08	12.170	-9.771
23	4.07	3.17	12.191	-10.021
24	4.11	3.49	12.276	-10.856
25	4.14	3.70	12.340	-11.364

IV. RESULTS AND DISCUSSION

Effect on Material removal rate:

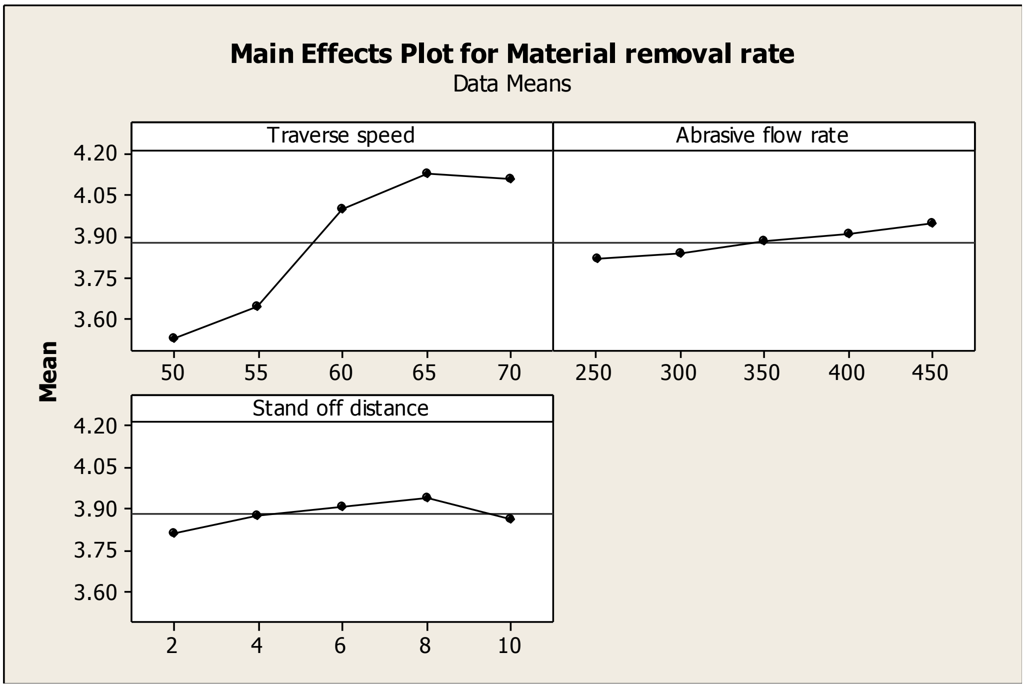

Figure 1: Main effect plot for MRR

Figure 1 shows the main effect plot for material removal rate at different parameters like traverse speed, abrasive flow rate and standoff distance for the material En9.

The table 4 shows the ANOVA results for the material removal rate to know the effect of various parameters on the material removal rate.

Hence it can be derived from the figure 1 that the maximum material removal rate can be obtained at the Traverse speed of 65 mm/min, Abrasive flow rate of 450 gm/min and Standoff distance of 8 mm.

Effect on Surface roughness:

Figure 2 shows the main effect plot for Surface roughness at different parameters like traverse speed, abrasive flow rate and standoff distance for the material En9.

The table 5 shows the ANOVA results for the Surface roughness to know the effect of various parameters on the material removal rate.

Hence it can be derived from the figure 2 that the maximum material removal rate can be obtained at the Traverse speed of 50 mm/min, Abrasive flow rate of 250 gm/min and Standoff distance of 2 mm.

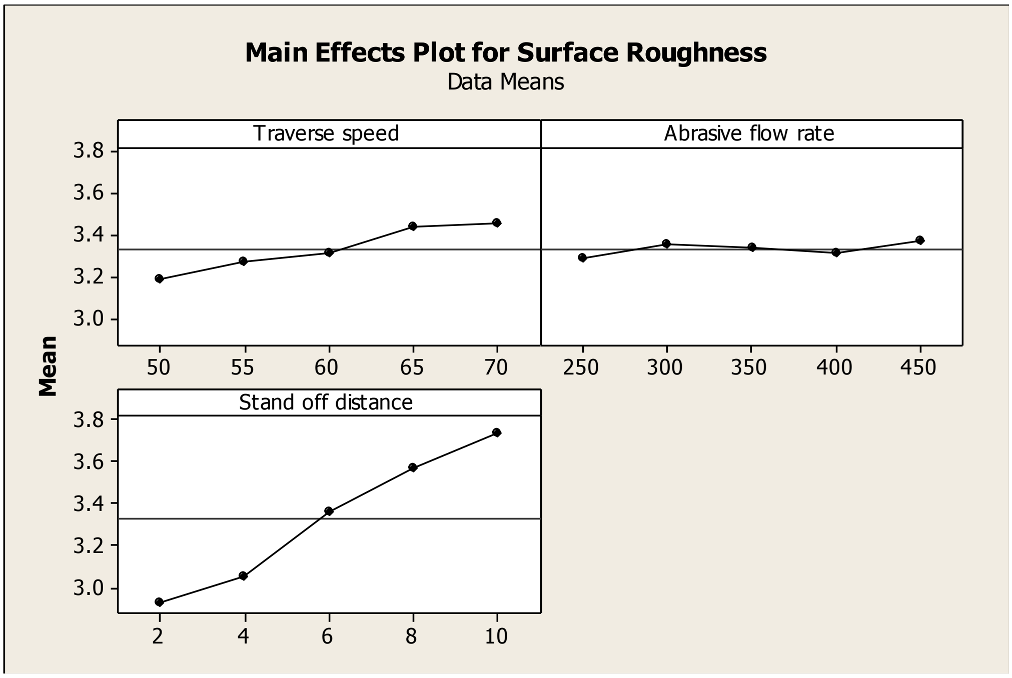

Figure 2: Main effect plot for Surface Roughness

V. CONCLUSIONS

After conducting the experiments and analysis, the following conclusions were derived.

- The Maximum Material removal rate can be obtained at the Traverse speed of 65 mm/min, Abrasive flow rate of 450 gm/min and Standoff distance of 8 mm.
- The Minimum Surface Roughness can be obtained at the Traverse speed of 50 mm/min, Abrasive flow rate of 250 gm/min and Standoff distance of 2 mm.

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