"MODELING AND OPTIMIZATION OF PROCESS PARAMETERS DURING AWJM MACHINING OF DIE STEEL"

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ABSTRACT

In today's scenario of manufacturing process, it is very hard to develop intricate shape with conventional machining process. This led to the development of non-conventional machining process. In industries it is used as efficient and economic alternatives to conventional ones. Abrasive Water Jet Machining AWJM is non-conventional mechanical process. AWJM is useful to cut complex shape parts which is difficult with conventional machining process. Here AISI 52100 steel used for die application, after applying heat treatment to AISI 52100, its mechanical properties are improved and it's hard to machining. In this case AWJM is used for machining process. Quality and Productivity is performance indicator of any machining method, performance of AWJM is influenced by various input parameters. Selection of right improve parameter value improve output performance of machining and makes less difficult. For this aim to achieved high performance on AWJM, series of experiment is carried out to find effect of input parameter on output performance parameter. Three different process parameters were undertaken for this study; water pressure, nozzle transverse speed and abrasive flow rate. Experiments were conducted according to Taguchi's design of experiments. Analysis of variance (ANOVA) was used to evaluate the data obtained to determine the major significant process factors statistically affecting the kerf characteristics. The results revealed that the nozzle transverse speed was the most significant factor affecting the kerf width. Also regression equation used to predict kerf width for vary process parameter.

Keyword: *Abrasive water jet machine, kerf width, ANOVA, Surface roughness, material removal rate*

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1 INTRODUCTION

Erosion of material by solid particles accelerated by a high-speed water jet is the basic process of abrasive water jet (AWJ) machining. A typical commercial AWJ system consists of a pump, a mixing and acceleration section, a positioning system, and a catcher. Depending on the method of dosage of abrasive particles into the water jet, AWJs can be classified as injection jets or suspension jets. For practical cutting applications, injection jets are more commonly used, wherein an AWJ is formed by accelerating small solid particles (typically Garnet) through contact with a high-speed water jet. The high-speed water jet, in turn, is formed in an orifice placed on top of the mixing and acceleration head. The solid particles are dragged into the mixing chamber through a separate inlet by the low pressure created by the water jet in the mixing chamber. Mixing between the solid particles, water jet and air takes place in the mixing chamber, and the acceleration process occurs in the focusing tube. After the mixing and acceleration process, a high speed three-phase mixture leaves the tube at velocities of several hundred meters per second. [1]

2. DESIGN OF EXPERIMENT

Design of experiments was developed in the early 1920s by Sir Ronald Fisher at the Rothamsted Agriculture field Research Station in London, England. His initial experiments were concerned with determining the effect of various fertilizers on different plots of land. The final condition of the crop was not only dependent on the fertilizer but also on the number of other factors (such as underlying soil condition, moisture content of the soil, etc.) of each of the respective plots. Fishers used DOE which could differentiate the effect of fertilizer and the effect of other factors. Since that time the DOE has been widely accepted in agricultural as well as Engineering Science. Design of experiments has become an important methodology that maximizes the knowledge gained from experimental data by using a smart positioning of points in the space. This methodology provides a strong tool to design and analyze experiments; it eliminates redundant observations and reduces the time and resources to make experiments. We have used full factorial design, if the numbers of levels and numbers of factors known then the possible design L is

$$L=M^n \quad \dots (1)$$

Where, M = number of levels for each factor, and n = number of factors.

3. PROPOSED WORK

A. **Selection of work-piece material**

From the review of the literature and companies observation, it is found that the material **AISI 521000** increasingly being used in dies application by providing of its high fracture toughness, extra strength, and hardness and wear resistance. Chemical composition of AISI 52100 is shown in Table 3.1

Table: 3.1 Chemical composition of AISI52100

	Carbon	Silicon Si	Su	Mangnese Mn	Phosphorus P	Nickel Ni	Chromium Cr
AISI52100	0.98	0.265	0.016	0.415	0.025	Nil	1.455

B. **Range of process parameter**

The three process cutting parameter in abrasive water jet machining are traverse speed, Abrasive mass flow rate, and water pressure. Other factors such as kind of material have a large influence, of course, but these three are the ones the operator can change by adjusting the controls, right at the machine

Table: 3.2 Range of process parameters

Parameters	**Unit**	**Level 1**	**Level 2**	**Level 3**
Traverse speed	Mm/min	100	200	300
Abrasive mass flow rate	g/min	150	250	350
Water pressure	MPa	250	350	450

4. TEST RESULTS

After the machining, kerf width is measured using optical microscope, measured MRR using digital weight balance meter and the surface roughness is measured by surface roughness tester.

Table 4.1: Testing Result

Sr no.	Traverse Speed [mm/min]	Abrasive mass flow rate[gm/min]	water pressure [MPa]	Top KW [mm]	Bottom KW [mm]	SR [μm]	MRR[mm3/min]
1	100	150	250	1.28	0.754	2.44	5.03
2	100	250	250	1.30	0.778	2.34	5.08
3	100	350	250	1.31	0.789	2.40	5.14
4	100	150	350	1.26	0.734	2.61	5.07
5	100	250	350	1.27	0.752	2.57	5.11
6	100	350	350	1.29	0.764	2.47	5.17
7	100	150	450	1.25	0.724	3.46	5.11
8	100	250	450	1.27	0.743	2.94	5.17
9	100	350	450	1.28	0.754	2.54	5.22
10	200	150	350	1.27	0.744	4.06	5.14
11	200	250	350	1.27	0.757	3.03	5.18
12	200	350	350	1.28	0.761	2.70	5.27
13	200	150	450	1.23	0.704	4.51	5.20
14	200	250	450	1.24	0.714	4.08	5.37
15	200	350	450	1.26	0.734	3.87	5.58
16	200	150	250	1.22	0.694	5.17	5.08
17	200	250	250	1.25	0.729	4.08	5.11
18	200	350	250	1.27	0.744	3.84	5.18
19	300	150	450	1.22	0.694	4.51	5.35
20	300	250	450	1.23	0.711	4.29	5.48
21	300	350	450	1.27	0.744	3.97	5.68
22	300	150	250	1.20	0.674	4.94	5.21
23	300	250	250	1.22	0.694	5.29	5.24
24	300	350	250	1.25	0.726	3.39	5.35
25	300	150	350	1.20	0.674	5.29	5.28
26	300	250	350	1.24	0.714	4.44	5.44
27	300	350	350	1.25	0.731	4.24	5.53

5. ANOVA ANALYSIS

Table 5.1: ANOVA %contribution

Parameters	**Kerf width** *%contribution*	**MRR** *%contribution*	**Roughness** *%contribution*
Traverse speed(mm/min)	43.36	46.18	69.6
Abrasive flow rate(g/m)	28.84	20.42	15.09
Water pressure (mpa)	16.66	22.71	12.62
Error	5.94	10.68	12.69

6. MAIN EFFECTS PLOT

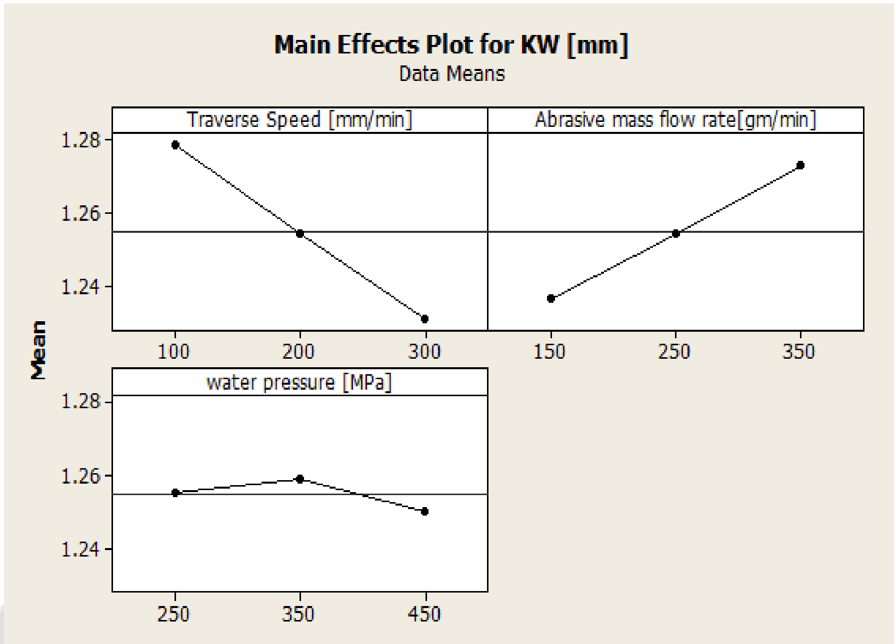

Fig: 6.1 Main effects plot for top kerf width.

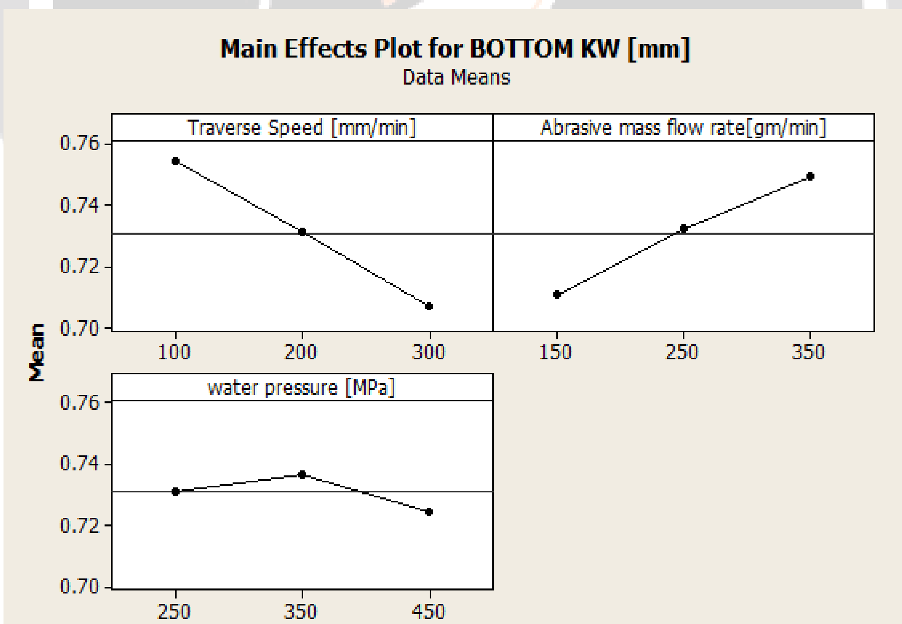

Fig: 6.2 Main effect plots for bottom kerf width.

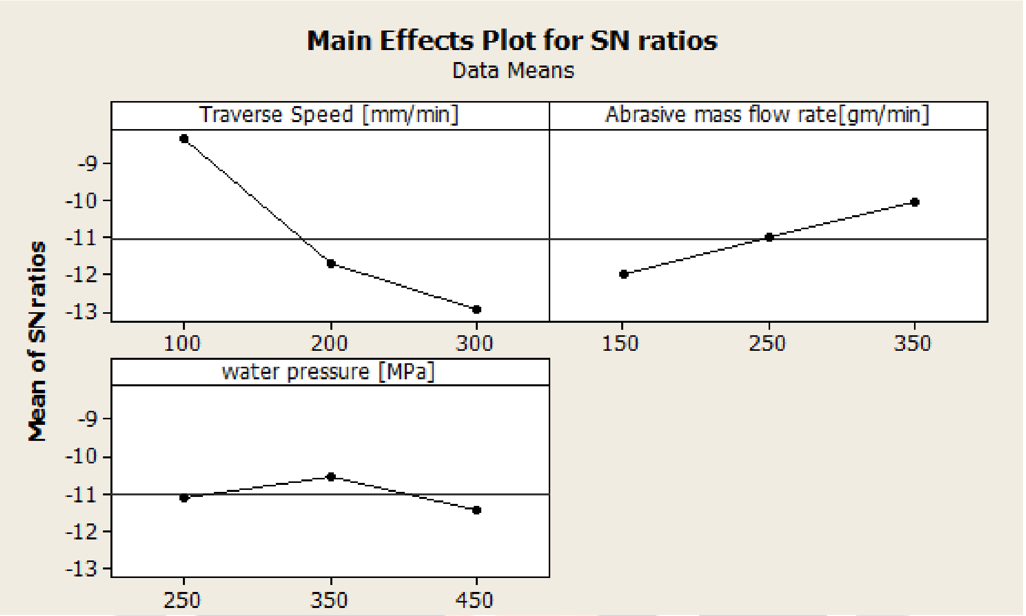

Fig: 6.3 Main effects for roughness

7. GREY RELATIONAL ANALYSIS

In grey relational generation, the normalized data corresponding to Lower-the-Better (LB) Criterion can be expressed as:

$$Xi(k) = \frac{\max yi(k) - yi(k)}{\max yi(k) - \min yi(k)}$$

For Higher-The-Better (Hb) Criterion, The Normalized Data Can Be Expressed As:

$$Xi(k) = \frac{yi(k) - \min yi(k)}{\max yi(k) - \min yi(k)}$$

Where xi (k) is the value after the grey relational generation, min $y_i(k)$ is the smallest value of $y_i(k)$ for the k_{th} response, and max y_i (k) is the largest value of $y_i(k)$ for the k_{th} response. An ideal sequence is x_0 (k) for the responses. However, if there is ‘‘a specific target value’’, then the original sequence is normalized using,

$$Xi(k) = 1 - \frac{|yi(k) - OB|}{\max\{\max yi(k) - OB, OB - \min yi\ (k)\}}$$

The purpose of Grey relational grade is to reveal the degrees of relation between the sequences say, [x0 (k) and xi (k), i =1, 2, 3…, n]. The Grey relational coefficient can be calculated using the preprocessed sequences. The Grey relational coefficient is defined as follows

$$\xi i(k) = \frac{min\Delta + \theta max\,\Delta}{\Delta i\,(k) + \theta max\,\Delta};$$

The Grey relational grade γi can be computed as: $yi = \frac{1}{n}\sum_{k=1}^{n} \xi i\ (k)$

Table 7.1: GRC and GRG and GRG NO.

No.	Normalized responses				GRC				GRG
	Top KW	Bottom KW	SR	MRR	Top KW	Bottom KW	SR	MRR	
1	0.272727	0.304348	0.966102	0	0.647059	0.621622	0.34104	1	0.65243
2	0.090909	0.095652	1	0.076923077	0.846154	0.839416	0.333333	0.866667	0.721392
3	0	0	0.979661	0.169230769	1	1	0.337915	0.747126	0.77126
4	0.454545	0.478261	0.908475	0.061538462	0.52381	0.511111	0.354994	0.890411	0.570081
5	0.363636	0.321739	0.922034	0.123076923	0.578947	0.608466	0.351609	0.802469	0.585373
6	0.181818	0.217391	0.955932	0.215384615	0.733333	0.69697	0.343423	0.698925	0.618163
7	0.545455	0.565217	0.620339	0.123076923	0.478261	0.469388	0.446293	0.802469	0.549103
8	0.363636	0.4	0.79661	0.215384615	0.578947	0.555556	0.385621	0.698925	0.554762
9	0.272727	0.304348	0.932203	0.292307692	0.647059	0.621622	0.349112	0.631068	0.562215
10	0.363636	0.391304	0.416949	0.169230769	0.578947	0.560976	0.545287	0.747126	0.608084
11	0.363636	0.278261	0.766102	0.230769231	0.578947	0.642458	0.394913	0.684211	0.575132
12	0.272727	0.243478	0.877966	0.369230769	0.647059	0.672515	0.362854	0.575221	0.564412
13	0.727273	0.73913	0.264407	0.261538462	0.407407	0.403509	0.654102	0.656566	0.530396
14	0.636364	0.652174	0.410169	0.523076923	0.44	0.433962	0.549348	0.488722	0.478008
15	0.454545	0.478261	0.481356	0.846153846	0.52381	0.511111	0.509499	0.371429	0.478962
16	0.818182	0.826087	0.040678	0.076923077	0.37931	0.377049	0.924765	0.866667	0.636948
17	0.545455	0.521739	0.410169	0.123076923	0.478261	0.489362	0.549348	0.802469	0.57986
18	0.363636	0.391304	0.491525	0.230769231	0.578947	0.560976	0.504274	0.684211	0.582102
19	0.818182	0.826087	0.264407	0.492307692	0.37931	0.377049	0.654102	0.503876	0.478584
20	0.727273	0.678261	0.338983	0.692307692	0.407407	0.424354	0.59596	0.419355	0.461769
21	0.363636	0.391304	0.447458	1	0.578947	0.560976	0.527728	0.333333	0.500246

22	1	1	0.118644	0.276923077	0.333333	0.333333	0.808219	0.643564	0.529613
23	0.818182	0.826087	0	0.323076923	0.37931	0.377049	1	0.607477	0.590959
24	0.545455	0.547826	0.644068	0.492307692	0.478261	0.477178	0.437037	0.503876	0.474088
25	1	1	0	0.384615385	0.333333	0.333333	1	0.565217	0.557971
26	0.636364	0.652174	0.288136	0.630769231	0.44	0.433962	0.634409	0.442177	0.487637
27	0.545455	0.504348	0.355932	0.769230769	0.478261	0.497835	0.584158	0.393939	0.488549

8. CONCLUSION

The AISI52100 has been cut by abrasive water jet cutting machine. The conclusions relevant to this investigation are outlined below:

1. The surface roughness increase with increase traverse speed from 100 to 300 mm/min, when the other two parameter are kept constant as well as surface roughness decrease with increase abrasive mass flow rate and water pressure 150 to 350 gm/min and 250 to 350 MPa.
2. While studying the effect of the cutting parameters on the top kerf width and bottom kerf width, it was observed that both the traverse speed and abrasive mass flow rate play equally important roles in the effect on the both kerf width. The role of the water pressure given is not crucial to the same extent. The optimum condition for machining to reduce kerf width would be A3 B1 C3. The traverse speed kept at 00 mm/min, the laser power kept at 750 watt and the gas pressure kept at 3 bar.
3. From These studies, it has been seen that the kerf width play very important role in qualities of water jet cutting object.
4. The optimum condition for machining to reduce surface roughness would be A1 B3 C3. The cutting speed kept at 300 mm/min, the abrasive mass flow rate kept at 150 gm/min and the water pressure 450 MPa.
5. While studying the effect of the cutting parameters on the surface roughness, it was observed that both the traverse speed and abrasive mass flow rate play equally important roles in the effect on the surface roughness. The role of the water pressure given is less crucial to the same extent.
6. Through use of regression equation, engineer can manipulate range of cutting traverse speed, abrasive mass flow rate and water pressure for this particular work- material. Also it has been find out and predicted kerf width, material removal rate and surface roughness at any combination of process parameter.
7. The optimal parameter values are at traverse speed 100 mm/min, abrasive mass flow rate 350 gm/min and 250 MPa water pressure. At these parameters the values of top and bottom, surface roughness and MRR are 1.28 mm, 0.754 mm, 2.44 µm and 5.03 mm3/min respectively.

8. It is shown that the performance characteristics of the AWJM process, namely water jet pressure, abrasive flow rate and standoff distance are improved together by using Grey Relational Analysis.

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