Surface Roughness Analysis in AWJM for Enhanced Workpiece Quality

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Abstract: Abrasive Water Jet Machining is a distinctive manufacturing process that effectively removes material from a workpiece by employing a high-pressure stream of water combined with abrasive particles. The final quality of the machined surface is directly influenced by various process parameters, such as the traverse speed, hydraulic pressure, stand-off distance, abrasive flow rate, and the specific type of abrasive used. In recent times, extensive research has been undertaken to enhance the performance of AWJM, with a specific focus on critical performance measures like surface roughness. This paper presents the latest advancements in AWJM research, with particular attention given to enhancing performance measures, implementing process monitoring and control, and optimizing process variables for applications involving high-carbon steel.

Keywords: AWJM, Process-parameter and Process-optimization

1. INTRODUCTION

Abrasive Water Jet Machining process is employed for machining various materials, encompassing a broad spectrum from soft to hard. The versatility of AWJM makes it

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especially suitable for machining challenging and hard-to-process materials, such as titanium, inconel, and others. A study was conducted by.[1] to investigate alumina ceramics surfaces generated and results suggested that a mixture of high water pressure, increased abrasive mass flow rate, reduced traverse speed, and shorter standoff distance is recommended to achieve smoother surfaces. [2] conducted a study to optimize the MRR of Stainless Steel 403 The L9 orthogonal array of the Taguchi method was employed to analyze the results. After analyzing the data, the researchers concluded that water pressure (WP) had the most significant influence on the work material,. [3] conducted a study to investigate the impact of process parameters and employed Taguchi's method along with optimize process. Their findings indicated that water pressure and traverse speed were the most significant parameters, while standoff distance had a relatively lesser impact on the process [4]showed a study to optimize the process parameters for abrasive water jet machining (AWJM) of Inconel 800H material using the Taguchi method and focusing on effective MRR and SR. The researchers confirmed that the determined optimal combination of factors met the practical requirements for machining Inconel 800H. Vishal Gupta and colleagues conducted a study focusing on minimizing kerf taper angle for machining of marble. Their findings indicated that the nozzle traverse speed was the most influential factor affecting the top kerf width and [5] conducted a study on the SR of Al-graphite composites fabricated through the squeeze casting process. The main aim of this research was to examine the influence of process parameters on AWJM in carbon alloys.

1. Selection of material and design of experiment

The chosen material for machining is High carbon steel, which serves as an example of HSTR alloys. The design variables can be summarized as Three levels of the traverse rate (150m/min, 200m/min, 250m/min),the abrasive flow rate (100 g/min, 150 g/min, 200 g/min) andstandoff distance (10mm, 15mm, 20mm,)

2. Experimental procedure

The initial step involved providing the AWJM machine with the cut piece profile through IGEMS 2017 software. The model data of the piece to be cut was then loaded into the AWJM machine via a data drive [6-8]. Afterward, the machine references were set, and the pump pressure for the abrasive feed was adjusted before commencing the experiment.The work piece was securely fixed and positioned on the machine table. The nozzle's reference with respect to the table and the work piece was also established. The process parameters were modified for each experiment, and the machining was carried out sequentially.The material was machined using an abrasive water jet at extremely high pressure, leading to erosion and chipping of the material [9-12]. Throughout the process, the machining time was meticulously measured using a stopwatch.Response Surface Methodology (RSM) is a technique used for designing experiments that aid in modeling. It involves employing mathematical and statistical techniques to establish correlations between the response and the variables under study. RSM is an empirical modelling approach focused on assessing relationships between controlled experimental factors and the observed outcomes of one or more selected criteria.in this study, 3 experimental factors were considered and these factors have the potential to influence the process yield being studied.

Table.1 observation result of surface roughness

S.No	Traverse rate	Abrasive flow rate	Standoff distance	Surface Hardness
1	250	100	10	2.56
2	200	150	10	2.15
3	200	150	15	1.98
4	300	150	15	3.25
5	200	150	15	1.89
6	250	100	20	2.59
7	200	150	15	2.35
8	150	150	15	2.48
9	200	150	20	3.12
10	200	150	15	3.16
11	150	200	20	4.23
12	200	150	15	3.99
13	200	150	15	2.98
14	250	200	10	3.96
15	250	200	20	3.25
16	200	200	15	4.12
17	150	100	20	4.26
18	150	100	10	4.29
19	200	100	15	3.78
20	150	200	10	4.28

2. Result and discussion

The probability of obtaining an F-value of this magnitude due to noise is 20.43%, which suggests a lack of statistical significance. Model terms with p-values less than 0.0500 are considered statistically significant. p-values better than 0.1000 designate that model terms are not statistically significant [13-15].A normal plot of residuals used to assess the normality of the residuals in a statistical model. This type of plot is commonly utilized in regression analysis, ANOVA and other statistical modeling techniques to examine the normality assumption for the residuals.If the normality assumption is violated, it can impact the validity of the statistical inferences drawn from the model, necessitating further investigation or data transformation [16-20]. The effectiveness of the power transform in achieving the desired outcomes can be assessed using these graphical methods, as shown in Fig.1[21,22].The choice of the appropriate power transform depends on the data's characteristics and the specific objectives of the analysis. Common power transforms include the square root, logarithmic, and Box-Cox transformations. The Box-Cox transformation, demonstrated in Fig.2.[23,24]

Table.2 ANOVA result

Source	SS	df	MS	F	p
Model	8.08	9	0.8979	1.72	0.02043
A-Tranverse	1.62	1	1.62	3.10	0.01087

rate					
B-Abrasive flow rate	0.5570	1	0.5570	1.07	0.03256
C-Standoff distance	0.0044	1	0.0044	0.0085	0.09285
A-B	0.5512	1	0.5512	1.06	0.03279
A-C	0.0450	1	0.0450	0.0864	0.07749
B-C	0.0722	1	0.0722	0.1386	0.07175
A^2	0.8288	1	0.8288	1.59	0.02359
B^2	3.44	1	3.44	6.60	0.0279
C^2	0.2329	1	0.2329	0.4470	0.05189
Residual	5.21	10	0.5211		
Fit	1.96	5	0.3927	0.6046	0.07028
Error	3.25	5	0.6495		
Total	13.29	19			

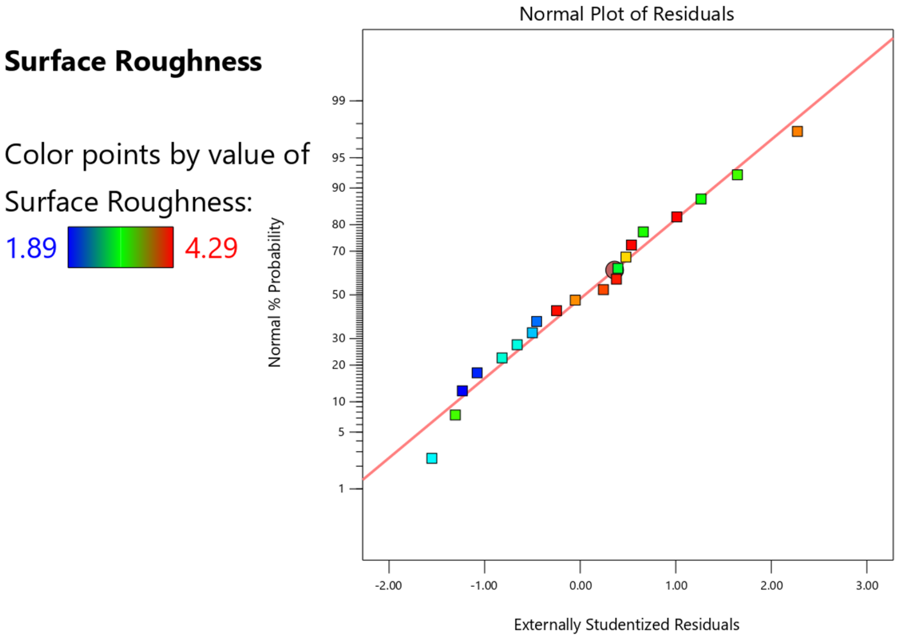

Figure 1 Normal plot of residuals

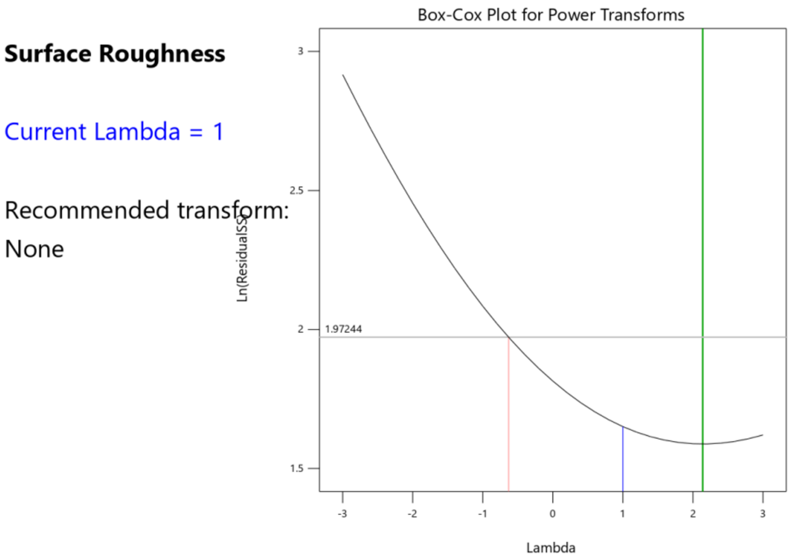

Figure 2 BOX -COX plot for power transforms

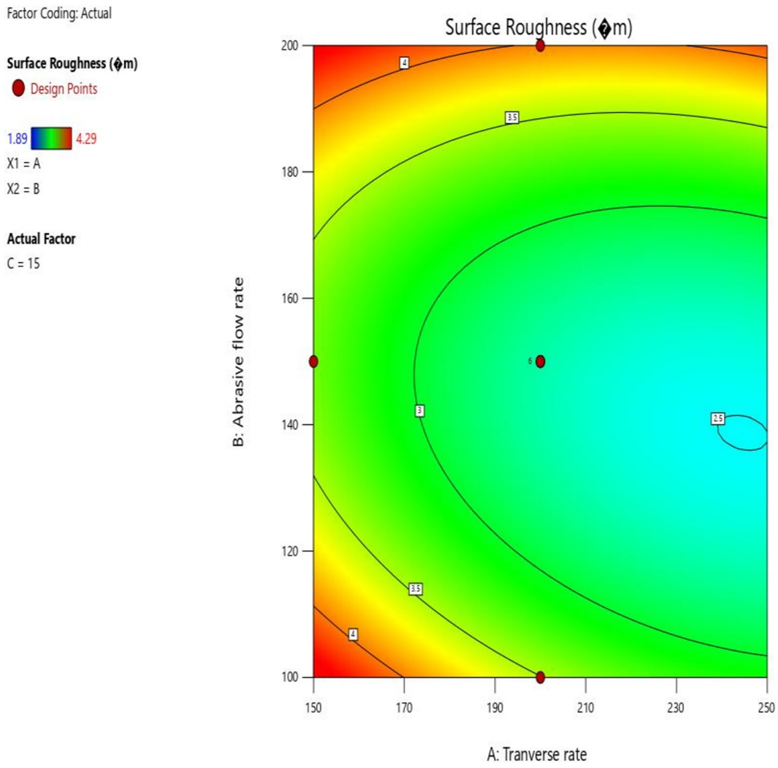

Figure 3Transverse Rate vs Abrasive flow rate

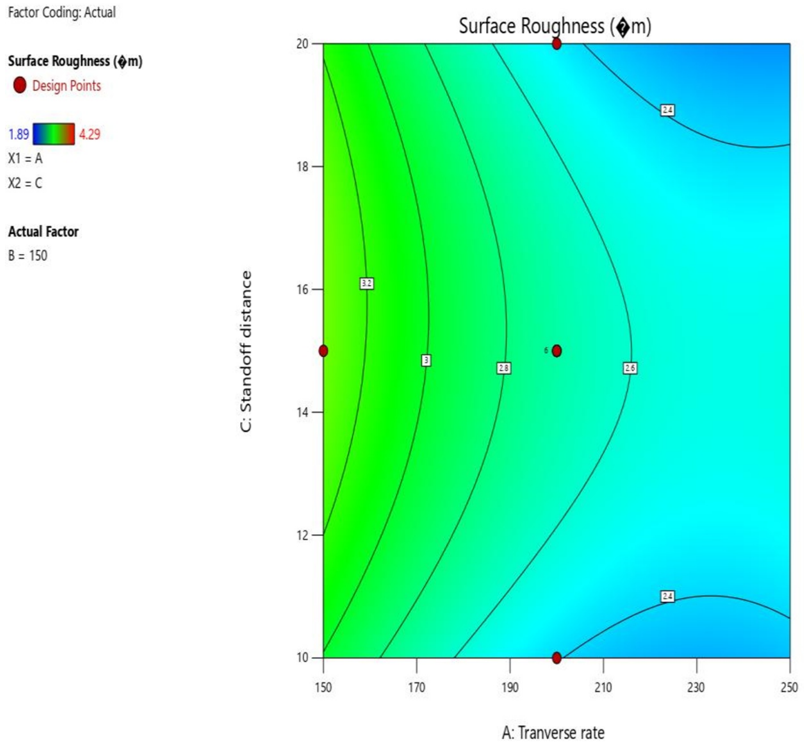

Figure 4Transverse rate vs Standoff distance

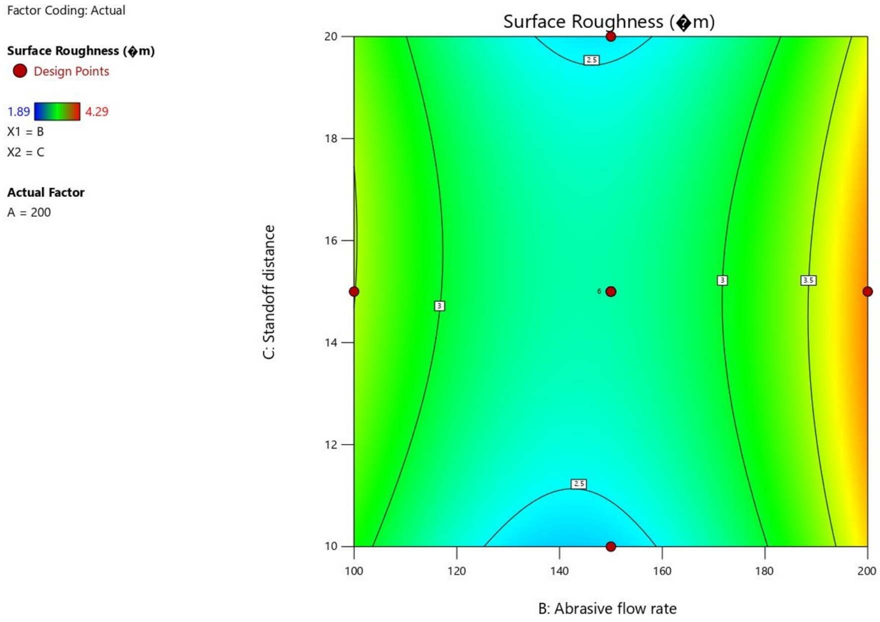

Figure 5Abrasive flow rate vs Standoff distance

The relationship between Transverse rate and Abrasive flow rate is depicted in Fig.3. It was observed that initially, as the Transverse rate reduced from 150m/min, the Surface Roughness (SR) also reduced. However, when the Transverse rate was increased from 220 m/min, the SR increased.Fig.4 illustrates the interaction between Transverse rate and Standoff distance. It was found that the SR increased as the Standoff distance decreased up to 150 g/min, after which the SR value decreased. The increase in flow rate at the point of contact under different conditions might be responsible for the drop in SR.Similarly, the interaction effect of surface roughness parameters with the remaining condition of Abrasive flow rate and Standoff distance is shown in Fig.5. The maximum and minimum surface roughness values recorded were 4.29µm and 1.89 µm, respectively. These values were associated with the parameter levels 150 m/min, 100 g/min & 10mm, and 200 m/min, 150 g/min & 15mm. Furthermore, Transverse rate was found to be the most noteworthy factor contributing to surface roughness increment, followed by other factors

3. Conclusion

- RSM has been proposed as a way of investigating the AWJM process parameters for High Carbon Steel. Response Surface Methodology (RSM) is a technique used for designing experiments.traverse rate, abrasive flow rate and standoff distance are taken as surface roughness input factors.
- The surface roughness measurements yielded a maximum value of 4.29 µm and a minimum value of 1.89 µm. These readings corresponded to the parameter combinations of 150 m/min, 100 g/min, and 10mm, as well as 200 m/min, 150 g/min, and 15mm respectively.
- It is revealed that a decrease in the transverse rate from 150 m/min led to a decrease in SR. Conversely, an upsurge in the transverse rate from 220 m/min resulted in an increase in SR.

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