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Research Article

Parametric Optimization of Abrasive Waterjet Machining for Mild Steel: Taguchi Approach

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Abstract

In this paper experimental investigation is carried to study the effect of parameters, viz water pressure, Traverse speed, and Standoff distance, of Abrasive Waterjet Machine (AWJM) for mild steel (MS) on surface roughness (SR).Further Taguchi's method, analysis of variance and signal to noise ratio (SN Ratio) are used to optimize the considered parameters of abrasive Water Jet Machining. In Taghuchi's design of experimentation, L9 orthogonal array is formulated and it can be concluded that water pressure and transverse speed are the most significant parameters and standoff distance is sub significant parameter.

Keywords: *Waterjet machining, MS, Taguchi, Anova, S/N ratio, surface roughness.*

1. Introduction

The abrasive waterjet machine is an effective technology for processing various materials. In this process the metal removal takes place by impact erosion of high pressure, high velocity of water with high velocity of abrasives on a work piece. The abrasive waterjet offers several advantages over conventional cutting techniques as it environmental friendly and it can cut metals and nonmetals also.

This machining process will not give a good surface finish. It is one of the major machining characteristics that play an important role in determining the quality of machined components. In this study the processparameters on surface roughness, which is an important cutting performance, is optimized. Taguchi's design of experiments was carried out in order to collect surface roughness values. Experiments were conducted in varying water pressure, nozzle traverse speed and standoff distance for cutting mild steel using abrasive water jet cutting process. The effects of these parameters on surface roughness have been studied based on the experimental results.

A few studies which were carried out on an optimization of parameters of AWJM for different materials like Leeladhar Nagdeve et al [2012] applied Taguchi method to find optimum process parameters of AWJM for cutting Al 7075.The input parameters are Traverse speed, Abrasive flow rate, Standoff distance and Abrasive grit size. Output parameters are metal removal rate (MRR) and surface roughness.. The main observations are the Traverse Speed is the most significant factor on MRR during AWJM. While Abrasive Flow Rate, Standoff distance, and Abrasive Grit Size are sub significant in Influencing. M. Chithiraiponselvan et al [2012] applied Taguchi method to find optimum process parameters of AWJM for cutting aluminum. The input parameters are Water pressure, nozzle traverse speed, abrasive mass flow rate and standoff distance. Output parameter is surface roughness. Water pressure has the most effect on the surface roughness. LeeladharNagdeve et al [2012] applied Taguchi method to find optimum process parameters of Abrasive Water Jet Machining (AWJM) for cutting aluminum. The input parameters are Pressure, Stand of distance, Abrasive flow rate, Traverse rate. And output parameters are Material Removal Rate, Surface Roughness. Their main observations are the Pressure is the most significant factor on MRR during AWJM. Meanwhile standoff distance, Abrasive flow rate and Traverse rate are sub significant in influencing. In case of surface Roughness Abrasive flow rate is most significant control factorM. Chithiraiponselvan [2012] was applied Taguchi method to find optimum process parameters for AWJM for cutting Grey cast iron. They conducted experiments by taking input parameters are Water pressure, Traverse speed, Mass flow rate, Standoff distance. And output parameter is Surface Roughness. Their mainobservations are the water pressure has the most effect on the surface roughness.

M. A. Azmir1 et al [2007] applied Taguchi method to find optimum process parameters of Abrasive Water Jet Machining (AWJM) for cutting kevlar reinforced phenolic composite. They conducted experiments by taking input

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parameters Pressure, Abrasive-mass flow rate, and Standoff distance Traverse rate. And output parameters are surface roughness and kerf taper ratio. The traverse rate is the most significant control factor on surface roughness during AWJM followed by hydraulic pressure. Meanwhile, standoff distance and abrasive mass flow rate are insignificant in influencing. In case of traverse rate is the most significant control factor followed by standoff distance. Hydraulic pressure and abrasive mass flow rate are considered insignificantVaibhav.j.limbachiya et al [2011] applied Taguchi method to find optimum process parameters of Abrasive Water Jet Machining (AWJM) for cutting en8, acrylic and aluminium. They conducted experiments by taking input parameters Traverse Speed and Abrasive mass flow rate. And output parameter is MRR. The conclusions are MRR increase By increasing abrasive mass flow rate, Increasing speed (50 to 70) is also increase MRR, MRR increase for En8 - 484.50 to 606.98 mm3/min, Acrylic 243.20 to 303.94 and Aluminium - 44.08 to 55.43Prof.Kamlesh et al [2013] applied Taguchi method to find optimum process parameters of Abrasive Water Jet Machining (AWJM) for cutting Mild Steel. The input parameters are Traverse speed, Abrasive flow rate, Stand of distance. And output parameters are Material Removal Rate, Surface Roughness. . The optimal condition for MRR is Traverse Speed 350 mm/min; Abrasive flow Rate 350 g/min; standoff distance 10 mm;for SR is Traverse Speed 250 mm/min; Abrasive flow Rate 250 g/min; standoff distance 6 mm; Abrasive grit Size 60 μm The observations are the Traverse Speed (TS) is the most significant factor on MRR during AWJM. In case of surface Roughness Abrasive Flow Rate is most significant control factor.

From the literature survey, it is observed that many works has been reported on waterjet machining process on the materials like aluminum,Grey cast iron,kevlar reinforced phenolic composite,en8, and acrylic but researches on AWJM of mild steel is very few.Kamalesh et al [2013] conducted Taguchi technique on mild steel with process parameters abrasive flowrate; stand-off distance and transverse speed. So by taking Water pressure into consideration with stand-off distance and transverse speed as the other process parameters the present work is carried out and optimal values are obtained.

2. Experimental Work

2.1 Material

Mild steel is the most common form of steel because its price is relatively low while it provides material properties that are acceptable for many applications. It is often used when large quantities of steel are needed, for example as structural steel. It is the most versatile form of steel.

2.2 Designs of Experiments

The experimental layout for the machining parameters using the L9 orthogonal array was used in this study. This array consists of three control parameters and three levels, as shown in table1. In the Taguchi method, most all of the observed values are calculated based on 'the smaller the better'. Thus in this study, the observed values of SR is set to be at minimum condition. Experimental trial was performed with three simple replications at each set value. The optimisation of the observed values was determined by comparing the standard analysis and analysis of variance (ANOVA) which was based on the Taguchi method.

Table 1 parameters and levels

Control Parameters	**Levels**		
	Level 1 minimum	Level 2 Intermediate	Level 3 Maximum
Water Pressure(psi)	35000	45000	55000
Traverse speed (mm/min)	80	200	320
Stand of distance(mm)	1	2.5	4

2.3 Constant Parameters

Table 2 constant parameters

jet impact angle	90°
orifice diameter	0.35 mm
nozzle length	76.2 mm
nozzle diameter	1.05 mm
abrasive material	80 mesh garnet
average diameter of abrasive particles	0.18 mm
Garnet consists of chemically	36% FeO, 33% SiO_2, 20% Al_2O_3, 4%MgO, 3% TiO_2, 2% CaO and 2% MnO_2.

For each experiment, the machining parameters were set to the pre-defined levels according tothe orthogonal array. All machining procedures were done using a single pass cutting. The supply pressure, transverse speed and standoff distance is controlled through the controller in the operator control stand. The surface finish parameter employed to indicate the surface quality in this experiment was the arithmetic mean roughness (Ra). Work piece surface roughness Ra was measured by a surface roughness equipment model " TAYLOR HOBSON". Surface roughness was measured at the centre of the cut for each specimen. Each measurement of Ra was taken three times and their arithmetic mean was calculated as to minimize the error.

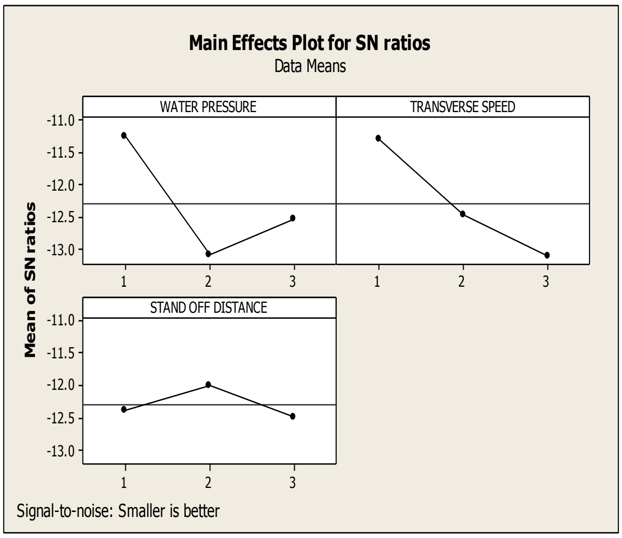
2.4 L9 Orthogonal Array with Three Factors

Table 3: Design of experiments

sr. no.	water pressure (psi)	traverse speed (mm/min)	Stand-off distance (mm)	surface roughness	Signal to noise ratio

1	**35000**	**80**	**4**	3.32	-10.42
2	**35000**	**200**	**2.5**	3.526	-10.95
3	**35000**	**320**	**1**	4.173	-12.42
4	**45000**	**80**	**2.5**	3.953	-11.94
5	**45000**	**200**	**1**	4.753	-13,58
6	**45000**	**320**	**4**	4.9	-13.82
7	**55000**	**80**	**1**	3.78	-11.55
8	**55000**	**200**	**4**	4.44	-12.97
9	**55000**	**320**	**2.5**	4.526	-13.12

Graphs 1Main Effect plot for SN Ratios V/s. Factors



Above plot shows the main effect plot of Surface Roughness at different parameters like Water pressure, Traverse speed, and Stand of distance in Abrasive water jet machining process of MS. Above plot evaluates the main effects of each factor for various level conditions. According to the above graphs the surface Roughness decreases with three major parameters. SR will be minimum in the case of water pressure (P) at level 1(35000) Traverse Speed (S) at level 1 (80), in the case of and in the case of Standoff distance (D) at level 2(2.5). So the optimal parameter setting for minimum surface roughness is P (35000), S (80), and D (2.5).

From the above ANOVAtest can conclude that water pressure and traverse speed had significant F values and standoff distance had low F value so water pressure and standoff are significant parameters.

Table 4: Predicted Optimum Condition for surface roughness

Parameters	Level	Actual value
Water Pressure	**1**	**35000 Psi**
Traverse Speed	**1**	**80 mm/min**
Stand of Distance	**2**	**2.5 mm**

Table 5: Table for ANOVA, F-TEST with 95% confidence interval ($F_{0.05,2,6}$=5.14)

Factors	Sum of squares	Degrees of freedom	Mean squre	F	Contribution (%)
Water Pressure	5.002	2	2.501	22.77	47.58 (1)
Traverse Speed	4.786	2	2.393	21.79	45.52 (2)
Stand of Distance	0.067	2	0.0335	0.305	0.64 (3)
Error	0.6589	6	0.1098167		6.3
Total	10.5139	8			

3. Conclusions

This paper presents effect of various parameters like water pressure, transverse speed and standoff distance on surface roughness in AWJM of mild steel. Analysis of variance (ANOVA), F-test and SN Ratios are used to draw the following conclusions.

Traverse Speed (S) is the most significant factor on SR during AWJM. Meanwhile water pressure and Standoff distance is sub significant in influencing. The recommended parametric combination for optimum surface roughness is P (35000), S (80), and D (2.5).

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