A Machinability Study of Mild Steel using Abrasive Water Jet Machining Technology

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ABSTRACT

Abrasive water jet machining is a non conventional machining process in which removal of material takes place by impact erosion of high pressure, high velocity of water and entrained high velocity of grit abrasives on a work piece. The objective of experimental investigation is to conduct research of machining parameters impact on Material removal rate and Surface roughness of work piece of Mild Steel (MS). The approach was based on Taguchi's method, analysis of variance and signal to noise ratio (SN Ratio) to optimize the Abrasive Water Jet Machining process parameters for effective machining and to predict the optimal choice for each AWJM parameter such as Traverse speed, Abrasive flow rate, and Standoff distance. There is L9 orthogonal array used by varying Transverse Seed, Abrasive flow rate, standoff distance respectively and for each combination we have conducted three experiments and with the help of Signal to Noise ratio we find out the optimum results for AWJM. It was confirmed that determined optimal combination of AWJM process parameters satisfy the real need for machining of Mild Steel (MS) in actual practice.

Keywords – *Abrasive Water Jet Machining, Garnet, Mild Steel*

1. INTRODUCTION

Abrasive Water Jet Machining is accepted effective technology for cutting various material as of its advantages over other non-conventional techniques such as No heat is generated in the cutting process, high machining versatility, minimum stresses on the work piece, high flexibility and small cutting forces, the abrasives after cutting can be reused which allows for possible reduction of the cutting cost of the process, machining can be easily automated. The process has some limitations and drawbacks. It may generate loud noise and a messy working Environment, the machining is not applicable for machining too thick pieces, limited number of materials can be cut economically, taper cutting is also a problem with water jet cutting in very thick materials.

As in the case of every machining process, the quality of AWJC process is significantly affected by the process tuning parameters. There are numerous associated parameters in this technique, among which water pressure, abrasive flow rate, jet traverse rate, standoff distance and diameter of focusing nozzle are of great importance but precisely controllable . The main process quality measures include attainable depth of cut, material removal rate and surface finish. Number of techniques for improving kerf quality and surface finish has been proposed.

2. WORKING PRINCIPLE

Abrasive water jet cutting is using high pressure water being forced through a small hole onto a concentrated area to cut materials. The Abrasive water jet cutting machine starts with a water pump. The water pump pressurizes the water and pumps it from a water tank or other water supply to the nozzle.

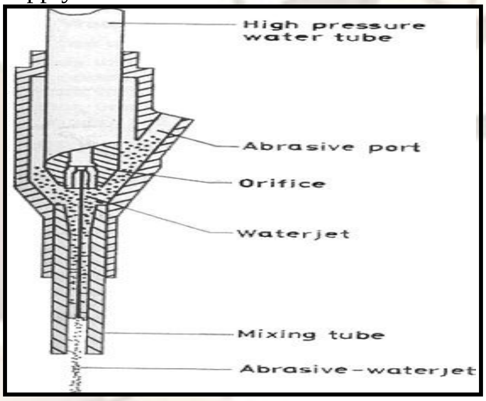

Fig.1: Abrasive Water Jet Machining

If there is an abrasive added it is normally added at the nozzle which has shown in Below Figure. A lot of water is forced through a small nozzle. This creates water with a lot of pressure. This pressure makes the particles "accelerate" and hits a very small area on the piece being cut.

All of the pressure onto the material being cut makes the material crack. It creates very small cracks and the pressure washes away the particles of material. The pressure eventually removes all of the material in the small area and this is the cut. The material being cut is in a catch tank that is full of water and other debris. The water is normally raised to just above the material to reduce the splash that may occur during cutting. All of the material that is being removed goes into the catch tank and can later be removed.

2.1 ABRASIVE WATER JET CUTTING MACHINE ELEMENT:

Abrasive water jet cutting machines have four basic elements: pumping system, abrasive feed system, abrasive water jet nozzle and catcher.

- The pumping system produces a high-velocity water jet by pressurizing water up to as high as 400 Mpa using a high-power motor. The water flow rate can be as high as 3 gallons per minute.
- To mix the abrasives into this high-velocity water jet, the abrasive feed system supplies a controlled quantity of abrasives through a port.
- The abrasive water jet nozzle mixes abrasives and water (in mixing tube) and forms a high velocity water abrasive jet. Sapphire, tungsten carbide, or boron carbide can be used as the nozzle material. There are various kinds of water abrasive jet nozzles.
- Another element of the system is a catcher, for which two configurations are commonly known: a long narrow tube placed under the cutting point to capture the used jet with the help of obstructions placed alternately in the opposite direction and a deep water-filled settling tank placed directly underneath the work piece in which the abrasive water jet dies out.

3. EXPERIMENTAL WORK

(A) 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. Mild steel – Grade 250 plates were used as the specimens in this study.

(B) Equipment:

The equipment used for machining the samples was Water Jet Model: DWJ1525-FA which was equipped with SL-V50 pressure pump with the designed pressure of 290 Mpa . The machine is equipped with a gravity feed type of abrasive hopper, an abrasive feeder system, a pneumatically controlled valve and a work piece table with dimension of 3000 mm x 3000 mm. Sapphire orifice was used to transform the high-pressure water into a collimated jet, with a carbide nozzle to form an abrasive waterjet. set up of an abrasive water jet cutting process is The shown in figure.2.

- Voltage:- 415 V
- Frequency:-50 Hz
- Phases:- 3
- Power:- 3 kw
- Current:- 5.8 A
- Table size: 3000×3000 mm
- Travel: X Axis: 3000mm ,Y Axis: 3000mm,
  Z Axis: 250mm

Fig: 2 - Setup of AWJM with Cutting table

3.1 Design of Experiment (DOE)

Design of experiments (DOE) is a powerful tool that can be used in a variety of experimental situations. DOE techniques enable designers to determine simultaneously the individual and interactive effects of many factors that could affect the output results in any design. To achieve a thorough cut it was required that the combinations of the process variables give the jet enough energy to penetrate through the specimens.

Most researchers identified Abrasive water jet machining process parameters that greatly affect Response parameter. The Process Parameter like Standoff distance, impact angle, traverse rate, number of passes, abrasive material, abrasive particle size, abrasive shape, and abrasive mass flow rate, focusing tube diameter and focusing tube length water pressure orifice diameter etc. In this paper we have selected process parameter as Traverse rate (mm/min), Abrasive flow rate (gm/min) and Stand of distance (mm) to analyze its effect onr MRR (gm/min) and Surface Roughness (µm) in AWJM.

3.2 CONTROL PARAMETER:-

Factor A: Traverse speed (mm/min)
Factor B: Abrasive flow rate (gm/min)
Factor C: Stand of distance (mm)

Factors with level value:-

Factors	**Level 1**	**Level 2**	**Level 3**
Traverse speed(mm/min)	350	300	250
Abrasive flow rate(gm/min)	250	300	350
Stand of distance(mm)	2	6	10

Table: 1 -Factor with level value

3.3 CONSTANT PARAMETERS:

Fixed Parameter	**Set Value**
Abrasive type	Garnet
Abrasive Size	80Mesh(0.180mm)
Water flow rate	5.6 ltr/min
Orifice diameter	0.25mm
Nozzle diameter	1 mm
Impact angle	90^0
Focusing tube diameter	0.8 mm
Work piece thickness	10 mm

Table: 2 -Fixed parameter

3.4 L9 ORTHOGONAL ARRAY WITH THREE FACTORS:-

For each experiment, the machining parameters were set to the pre-defined levels according tothe orthogonal array.

Sr. No.	**Traverse speed (mm/min) (A)**	**Abrasive flow rate (gm/min) (B)**	**Stand of distance (mm) (C)**
1	350	250	2
2	350	300	6
3	350	350	10
4	300	250	6
5	300	300	10
6	300	350	2
7	250	250	10
8	250	300	2
9	250	350	6

Table:.3 - L9 Orthogonal array with Three Factors

4. RESULT AND DISCUSSIONS

Surface roughness is one of the most important criteria, which help us determine how rough a workpiece material is machined. In all the investigations it was found that the machined surface is smoother near the jet entrance and gradually becomes rougher towards the jet exit. This is due to the fact that as the particles moves down they loose their kinetic energy and their cutting ability deteriorates. By analyzing the experimental data of the selected material, it has been found that the optimum selection of the four basic parameters, i.e., water pressure, abrasive mass flow rate, nozzle traverse speed and nozzle standoff distance are very important on controlling the process outputs such as surface

Sr. No.	Traverse speed (mm/min) A	Abrasive flow rate (gm/min) B	Stand of distance (mm) C	Time (min)	MRR (gm/min)	SR (µm)
1	350	250	2	0.850	43.130	4.457
2	350	300	6	0.816	44.898	5.349
3	350	350	10	0.783	46.808	5.234
4	300	250	6	1.000	36.667	4.137
5	300	300	10	0.900	40.741	5.804
6	300	350	2	0.916	40.029	5.046
7	250	250	10	1.100	33.334	4.511
8	250	300	6	1.080	33.846	4.635
9	250	350	2	1.060	34.375	3.963

Table: 4 –Result Table

roughness. The effect of each of these parameters is studied while keeping the other parameters considered in this study as constant

4.1 ANOVA ANALYSIS

4.1.1 Main effect plot of MRR

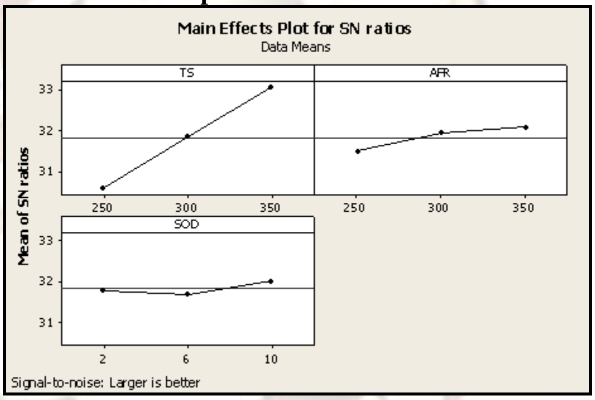

Fig.3:- Main Effect plot for SN Ratio (MRR) v/s Factors

- Above plot shows the main effect plot of MRR at different parameters like Traverse speed, Abrasive flow rate and Stand of distance in Abrasive water jet machining process of MS
- Main effects of MRR of each factor for various level conditions are shown in above figure. According to above figure the MRR increases with three major parameter TS, AFR, and SOD. MRR is maximum in the case of **Traverse Speed (TS)** at **level 1 (350)**, in the case of **Abrasive flow Rate (MFR)** at **level 1 (350)**, and in the case of **Standoff distance (SOD)** MRR will be maximum at **level 1 (10)**. So the optimal parameter setting for the MRR found **TS (350) MFR (350) SOD (10).**

4.1.2 Main effect plot of SR:

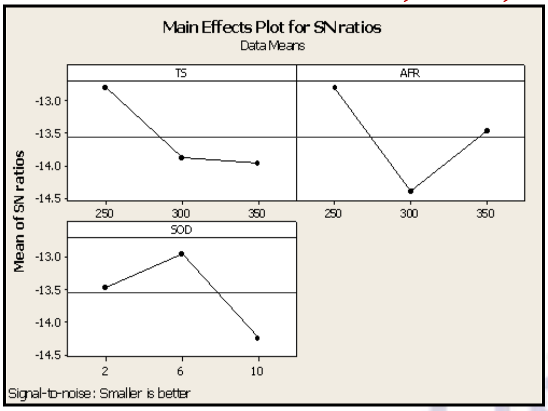

Fig.4: Main Effect plot for SN Ratios (Surface Roughness) V/s. Factors

- Above plot shows the main effect plot of Surface Roughness at different parameters like Traverse speed, Abrasive flow rate 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 figure the surface Roughness decreases with three major parameter TS, AFR, and SOD. SR will be minimum in the case of **Traverse Speed (TS)** at **level 1 (250)**, in the case of **Abrasivw flow Rate (AFR)** at **level 1 (250)**, and in the case of **Standoff distance (SOD)** at **level 2(6)**. So the optimal parameter setting for minimum surface roughness is **TS (250) MFR (250) SOD (6)**.

4.2 Optimum Control Parameter Level

The ANOVA for desired response provide the significant factor. Therefore the optimal level of a significant control factor is the level with the greatest SN Ratio. Optimizing the output parameter is achieved by selecting the significant control factor at their optimum level. Control factor that are not significant can be set at any level.

Response	Traverse speed (mm/min)	Abrasive flow rate (gm/min)	Stand of distance (mm)
MRR	350	350	10
Surface Roughness	250	250	6

Table: 5 -Optimum control parameter level

5. Conclusion

In this presents analysis of various parameters and on the basis of experimental results, analysis of variance (ANOVA), and SN Ratio the following conclusions can be drawn for effective machining of MILD STEEL (MS) by AWJM process as follows:

- Traverse Speed (TS) is the most significant factor on MRR during AWJM. Meanwhile Abrasive Flow Rate and Standoff distance are sub significant in influencing. The recommended parametric combination for optimum material removal rate is **TS (350) MFR (350) SOD (10).**
- In case of surface Roughness Abrasive Flow Rate is most significant control factor and hence the optimum recommended parametric combination for optimum surface Roughness is **TS (250) MFR (250) SOD (6) .**

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