



e-ISSN: 2319-8753 | p-ISSN: 2347-6710

IJRSET

International Journal of Innovative Research in
SCIENCE | ENGINEERING | TECHNOLOGY

INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

Volume 12, Issue 5, May 2023

ISSN INTERNATIONAL
STANDARD
SERIAL
NUMBER
INDIA

Impact Factor: 8.423

 9940 572 462

 6381 907 438

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Parametric Optimization of Abrasive Water Jet Machining of Ss 304 Material

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ABSTRACT: Abrasive water jet machine (AWJM) is a nonconventional machining technique in which, material removal takes place from the workpiece by impact erosion high pressure and high-velocity water jet mixed with abrasive material to provide a smooth surface finish. Experiments are conducted to study the influence of various process parameters of abrasive water jet machining on the Material removal rate (MRR) and Surface roughness (Ra) of SS304. Experiments are carried out using L16 Orthogonal array by varying Water Pressure (WP), abrasive flow rate (AFR), and stand of distance (SOD) for SS 304 material. Stainless steel 304 is high-alloy steel with good corrosion resistance and it's a very hard material. An abrasive water jet is an effective method for machining, cutting, and drilling stainless steel. In this paper, we, optimize the metal removal rate of stainless steel 304 in abrasive water jet machining. The MRR is optimized by using three parameters water pressure, abrasive flow rate, and stand-off distance and the L16 orthogonal array of the Taguchi method use to analyse the result. 16 experimental runs based on the L16 orthogonal array of the Taguchi method. Keywords- Abrasive water jet machine, stainless steel 304, garnet 80 mesh, L16 orthogonal array of Taguchi method, water pressure, abrasive flow rate, stand-off distance, MRR, S/N ratio.

KEYWORDS: Abrasive water jet, process parameter, optimization, Taguchi.

I.INTRODUCTION

Water jets were introduced in the United States during the 1970s, and were utilized merely for cleaning purposes. As the technology developed to include abrasive water jets, new applications were discovered. However, until recently this tool had not been used to a great extent in the construction industry. The water jet has shown that it can do things that other technologies simply cannot. From cutting thin details in stone, glass, and metals; to rapid hole drilling of titanium; to cutting of food, to the killing of pathogens in beverages and dips, the water jet has proven itself unique. Abrasive Water Jet Machining is an 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.

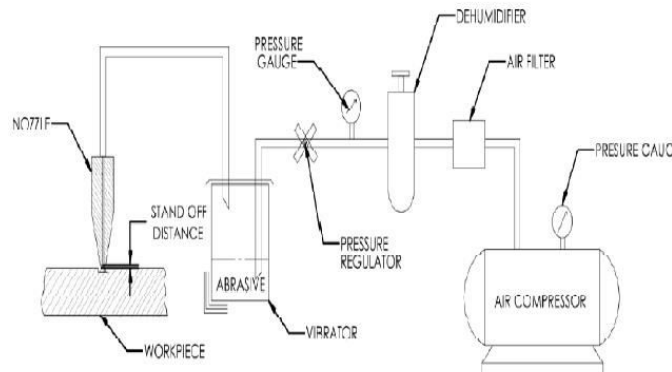


Fig 1: Systematic Layout of Abrasive Water Jet Machining

Abrasive water jet machine is an industrial machine in which we can cutting of the any types of materials i.e. softer materials and harden materials. In the abrasive water jet machine, the water is supplied at a very high pressure from

20,000-60,000psi and provides the good cutting and surface finishing. In the abrasive water jet machine, there is a orifice in which a nozzle fixed and through the nozzle water exit in the cutting stream formation, this nozzle is move in the xy axis as like in CNC machine. The abrasive water jet machining process is also called cold method or cold cutting method and with the cold method we can cut the any desired shape of material. Abrasive water jet cutting machine starts with a water pump. In the abrasive water jet machining, there is a mixture of garnet 80 mesh (abrasive) and water, which helps to cut the material simply and provides the good surface finishing. The abrasive water jet machine is more powerful than a pure water jet machine.

II.PROBLEM STATEMENT

Parametric Optimization of Abrasive Water Jet Machining of Stainless Steel 304 material.

III.PROCESS VARIABLES AND PERFORMANCE MEASURES

The performance of any process depends on selection of process parameters. For improvement of performance measures, thorough knowledge of the effect of process variables is required. So, to investigate the effect of process variables on performance of AWJM, following parameters are considered in this paper.

Process Variables

1. Stand off distance-(1mm-6mm)

Stand off distance is defined as the distance between the face of the nozzle and the work surface of the work. SOD has been found to have considerable effect on the work material and accuracy. A large SOD results in flaring of jet which leads to poor accuracy.

2. Abrasive flow rate-(100-500gm/min)

Abrasive flow rate is the flow of abrasive particles of unit mass per unit time. Parameters like Depth of cut and Surface finish are depends upon Abrasive flow rate. As the Abrasive flow rate increases Material removal rate also increases.

3. Water Jet Pressure:-(18,000-40000psi)

Abrasive water jet cutting uses a high-pressure jet of water (typically 180–400 MPa) with an abrasive powder in suspension. The jet is directed at the workpiece, which is moved as cutting progresses. The method is principally aimed at the cutting of holes or shapes in sheet material.

Performance Measures

1.Material Removal Rate

Metal Removal Rate (MRR) is the rate at which the material is removed from the workpiece. The MRR is defined as the ratio of the amount of metal removed from the workpiece in mm to the time taken for machining in minutes.

$MRR = \frac{(\text{Initial weight} - \text{Final weight}) \text{ in grams}}{(\text{machining time in minutes})}$

$$MRR = \frac{W_i - W_f}{T}$$

2.Surface Roughness

Surface roughness is an irregularity generated on cut surface of workpiece by abrasive water jet.

IV.EXPERIMENTAL IMPLEMENTATION

16 experiments were conducted using a MAXIEM 2040 Jet Machining Centre abrasive water jet cutting machine. As a workpiece material, SS 304 was used. It is the most versatile and most widely used stainless steel. It is used in the industrial, architectural, and transportation fields. Abrasive water jet machining, which does not create a significant heat affected zone, is more useful for machining of SS 304 for modern applications. The abrasive water jet machine is shown in Figure 2 and 3



Fig. 2 : MAXIEM 2040 Jet Machining Fig. 3: Abrasive Water Jet Machining

Although abrasive water jet machining involves a large number of variables and almost all variables affect the performance of the process, only few major variables were considered in the present study. Those are: water jet pressure, stand-off distance and abrasive flow rate. Table 1 shows levels of each process variable

Table 1: Levels of Process Variables

Factors	Level 1	Level 2	Level 3	Level 4
Water pressure	30000	33000	36000	39000
Abrasive Flow Rate	0.160	0.220	0.280	0.340
SOD	1	1.5	2	2.5

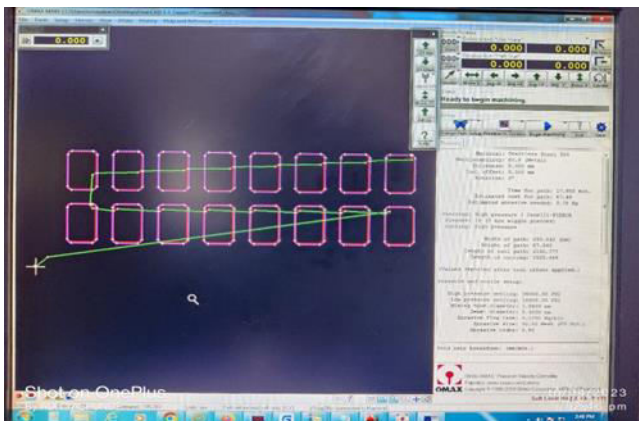


FIG 4: MACHINING PATH



FIG5: MACHINED WORK PIECE

V.MATERIALS AND METHODS

SS304 Specification	
Carbon	0.08
Silicon	0.75
Manganes	2.00
Phosphorus	0.045
Sulphur	0.030
Nickel	8.00-10.5
Chromium	18.00-20.00
Nitrogen	0.10

Table 2. Chemical Composition

Taguchi's experimental design was used to construct the design of experiments (DOE). In this paper we have selected machining process parameters namely Water Pressure, Abrasive flow rate (grams/min) and Standoff distance (mm) to analyze its effect on MRR (grams/min) and Surface Roughness (μm) on AWJM for SS 304. The selected process parameters were evaluated in three levels as shown in Table 1.

TABLE 3. CONSTANT MACHINING PARAMETER

Abrasive type	Garnet
Abrasive Size	80Mesh
Nozzle diameter	0.7
Orifice diameter	0.3
Work piece thickness	5mm

The machining parameters as shown in Table 3 were kept constant.

Constant machining parameters refer to the specific settings and conditions that remain unchanged during a machining operation. These parameters play a crucial role in achieving consistent and predictable results in machining processes

Table 4. L16 Orthogonal array with machining parameters

Sr.no	Water Pressure	Abrasive Flow Rate	Standoff distanc
	30000	0.160	1
2	30000	0.220	1.5



3	30000	0.280	2
4	30000	0.34	2.5
5	33000	0.06	1.5
6	33000	0.22	1
7	33000	0.28	2.5
8	33000	0.34	2
9	36000	0.16	2
10	36000	0.22	2.5
11	36000	0.28	1
13	36000	0.34	1.5
13	39000	0.16	2.5
14	39000	0.22	2
15	39000	0.28	1.5
16	39000	0.34	1

For each experiment, the machining parameters were set to the pre-defined levels according to the orthogonal array as shown in Table 4.

VI.RESULTS AND DISCUSSIONS

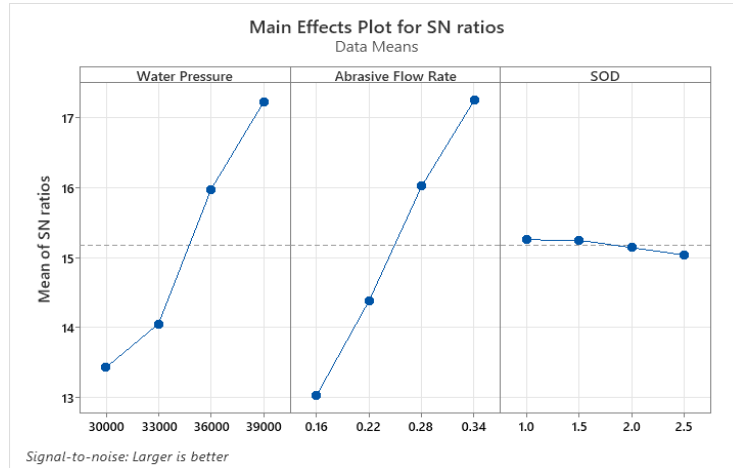
Surface roughness is indeed a crucial quality control parameter in assessing a production process. In the present investigation, it was observed that the machined surface exhibited varying smoothness along the jet path. Specifically, the surface near the jet entrance was smoother compared to the surface towards the jet exit. This phenomenon can be attributed to the behavior of the particles involved in the process. As the particles move along the jet path, they experience a reduction in kinetic energy, leading to a decrease in their cutting ability. Consequently, the surface roughness increases gradually towards the jet exit. This observation highlights the importance of understanding and controlling the factors influencing the process outputs. In the experimental analysis of the selected material, it was determined that three fundamental parameters play a vital role in controlling the process outputs, such as material removal rate and surface roughness. These parameters are: abrasive flow rate, transvers speed, standoff distance. To analyze the effects of each of these parameters, a series of experiments were conducted while keeping the other parameters constant. The results of these experiments are presented in Table 3, providing insights into the relationship between the selected parameters and the process outputs, such as material removal rate and surface roughness.

Table5:Experimentation for MRR and SR

Sr.no	Water Pressure	Traverse Speed (mm/mi n)	Abrasive flow rate gms/mm)	Stand offdistance(mm)	MRR (gms/mi n)	SR
1	30000	0.160	1	1	4.012	11.18
2	30000	0.220	1.5	1.5	4.300	11.47
3	30000	0.280	2	2	4.930	10.59
4	30000	0.34	2.5	2.5	5.714	8.23
5	33000	0.16	1.5	1.5	4.000	6.79
6	33000	0.22	1	1	4.300	6.32
7	33000	0.28	2.5	2.5	5.580	6.98
8	33000	0.34	2	2	6.750	3.74
9	36000	0.16	2	2	4.670	5.62
10	36000	0.22	2.5	2.5	5.930	5.64
11	36000	0.28	1	1	7.110	6.09
12	36000	0.34	1.5	1.5	7.970	4.06
13	39000	0.16	2.5	2.5	5.390	4.48
14	39000	0.22	2	2	6.880	3.75
15	39000	0.28	1.5	1.5	8.191	3.49
16	39000	0.34	1	1	9.180	3.59

In this experiment we got a maximum Material removal rate and minimum surface roughness at level 15.

6.1. Material Removal Rate (MRR)



- When water pressure increases material removal rate is also increases. we got optimum material removal rate(MRR) at a highest point of water pressure because larger is better.
- Higher water pressure leads to an increases in the velocity of the water jet.as a result the kinetic energy of water jet increses,enabling it to remove material more efficiently.consequently,a higher water pressure generally leads to a hihher MRR.
- When Abrasive Flow Rate increases MRR is also increases.we got optimum MRR at a highest point of abrasive flow rate.
- A higher abrasive flow rate means a grater concentration of abrasive particles in the eater jet stream.as a result,there is an increased number of abrasive particles interacting with the material being cut.This leads to more efficient material removal,resulting in a higher MRR.
- For Stand Of distance(SOD) is opposite from water pressure and abrasive flow rate.
- Higher the Stand Of distance lower the MRR.so we got higher MRR at a lowest point of Stand Of Distance.
- A shorter standoff distance allows for a more forced cutting action.
- Decreasing the stand off distance reduces the distance that water jet or abrasive praticles need to travel to reach the workpiece.this results in a more concentrated cutting force or impact energy which enhances the material removal process.consequently leads to a higher MRR.

6.2. Surface Roughness (SR)



- When water pressure increses surface roughness decereses(smoothen surface).so we get optimum surface roughness at higher point of water pressure.

- High water pressure can have a significant impact on the erosion and wear of surface. when water flows over a rough surface under high pressure, it can exert greater forces on the surface irregularities, leading to increased erosion and wear. over time this can smooth out the surface and reduce its roughness.
- When abrasive flow rate increases surface roughness decreases. so we got optimum surface roughness at higher point of abrasive flow rate.
- The higher the abrasive flow rate, the greater the amount of abrasive particles being propelled towards the surface. This increased momentum leads to more effective material removal, resulting in a reduction in surface roughness.
- Increasing the abrasive flow rate typically leads to more aggressive material removal during the surface finishing or machining process. as a result, the surface roughness tends to decrease.
- When we increase the stand of distance we get a smoother surface at a particular point and then again we get a rougher surface.
- So we get a smoother surface at a higher point of stand of distance.

VII. CONCLUSION

Experiments have been carried out by varying process parameters for abrasive water jet machining of SS 304 stainless steel. The effects of water jet pressure, Abrasive flow rate, stand-off distance, surface roughness and Material Removal Rate were investigated. The result showed that Material Removal Rate and surface roughness increases while power consumption decreases with increase in traverse speed, stand-off distance and abrasive flow rate as well as reduction in water pressure. By increasing levels of process variables, more number of experiments can be performed and their results can be useful in selection of process parameters for improvement of performance characteristics of abrasive water jet machining process.

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