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Performance Analysis of Abrasive Water Jet Machining Process for AISI 304 Stainless Steel

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Abstract
Abrasive waterjet machining (AWJM) is a non-conventional machining process capable to machine wide range of difficult-to-cut materials such as ceramics, alloys, composite materials, etc. This paper investigates the effect of various process parameters on kerf taper, surface roughness and power consumption which are important performance measures in abrasive waterjet machining. The variable process parameters considered here include water pressure, traverse speed, stand-off distance and abrasive flow rate. Experiments were conducted by varying these parameters for cutting AISI 304 austenitic stainless steel using abrasive waterjet machining process. The result showed that kerf taper and surface roughness increases while power consumption decreases with increase intraverse speed, stand-off distance and abrasive flow rate as well as reduction in water pressure.

Keywords: *Kerf taper, Surface roughness, Power consumption, Stainless steel, AWJM*

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INTRODUCTION

In abrasive waterjet machining process, material gets removed by erosion which is occurred due to impact of high velocity jet (mixture of water and abrasive particles) on surface to be machined. This process is environmentally friendly and less sensitive to material properties as it has no thermal effects. Several applications of abrasive jet machining process in different areas like aerospace, automotive, electronics, food, paper, steel industries, etc. have been reported by researchers [1]. The quality of abrasive waterjet machining is significantly affected bythe various process parameters, among which, abrasive flow rate, water pressure, standoff distance, jet traverse rate, and diameter of focusing nozzle are of great importance [2, 3]. Chen *et al.* have studied experimentally the effect of jet impact angle on the cutting quality [4]. Shimizu *et al.* studied the effect of abrasive particle size on jet structure that was formed at exit of the nozzle using high speed photography [5]. Srinivasu *et al*. have studied the influence of impingement angle and feed rate on the kerf geometry of silicon carbide [6]. Hu *et al.* investigated the effect of nozzle length on jet exit velocity using numerical technique and nozzle length was optimized to generate maximum jet velocity [7]. Jankovic *et al.* investigated the effects of feed rate, material thickness and abrasive flow rate on surface roughness [8].

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

Water Pressure

In abrasive water jet machining process, water pressure has a direct impact on metal removal rate. It is generally 2500 to 4000 bar.

Traverse Speed

It is the speed with which the nozzle moves in any direction. It is generally 100 mm/min to 5 m/min.

Stand-off Distance

It is the gap provided between the nozzle tip and the workpiece. It influences the metal removal rate, shape and diameter of cut. It is generally 0.25 to 2 mm.

Abrasive Flow Rate

Mass flow rate of the abrasive particles is a major process parameter that affects the metal removal rate in abrasive jet machining. It is generally 0.1 to 1 kg/min.

Performance Measures

Kerf Taper

Kerf taper angle is a quantity which is often used to reflect the inclination of the kerf wall from the top surface to the bottom of the kerf.

Surface Roughness

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

Power Consumption

It is the power consumed by abrasive water jet machine during machining operation.

EXPERIMENT

Two experiments were conducted using a KMT Streamline SL-V 50 abrasive water jet cutting machine. As a workpiece material, AISI 304 austenitic stainless steel 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 1.

Fig. 1: *Abrasive Water Jet Machine.*

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 pressure, traverse speed, stand-off distance and abrasive flow rate. The other process parameters were kept constant using the standard machine configuration (orifice diameter =0.76 mm; nozzle diameter =0.3 mm). Table 1 shows levels of each process variables.

Table 1: *Levels of Process Variables.*

Sr. No.	Parameter	Unit	Level-1	Level-2
1	Water pressure	bar	3400	3200
2	Traverse speed	mm/min	100	150
3	Stand-off distance	mm	1	2
4	Abrasive flow rate	gm/min	250	350

RESULTS AND DISCUSSION

By performing experiments, two pieces of SS 304 were cut as shown in Figure 2. The kerf taper was measured by using digital micrometer having least count 0.001 mm. The surface roughness was measured by surface roughness tester having resolution of 0.001 µm. The power consumption was measured with digital power meter. Table 2 shows results of both experiments.

Fig. 2: *Pieces of SS 304 Cut by AWJM.*

Table 2: *Experiment Results.*

Sr. No.	Performance Characteristic	Exp. 1	Exp. 2
1	Kerf taper (°)	1.72	2.23
2	Surface roughness (µm)	4.328	5.120
3	Power consumption (kW)	20.11	18.29

From result table, it can be seen that kerf taper and surface roughness increases with reduction in water pressure and increase in traverse speed, stand-off distance as well as abrasive flow rate. The power consumption decreases with reduction of water pressure and increase in traverse speed, stand-off distance as well as abrasive flow rate.

CONCLUSION

Experiments have been carried out by varying process parameters for abrasive water jet machining of AISI 304 stainless steel. The effects of water pressure, traverse speed, stand-off distance and abrasive flow rate on kerf taper, surface roughness and power consumption were investigated. The result showed that kerf taper 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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