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Analysis Of Surface Roughness In Abrasive Waterjet Cutting Of Stainless Steel

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***Abstract*-Abrasive waterjet (AWJ) cutting is one of the recently developed manufacturing technologies. It is superior to many other cutting techniques in processing various materials, particularly in processing difficult-to-cut materials. This technology is being increasingly used in various industries. This paper assesses the influence of process parameters on surface roughness which is an important cutting performance measure in abrasive waterjet cutting of stainless steel (SS304). The objective of this paper is to select control factors and there levels for further study. To select the level of parameter one variable at a time analysis (OVAT) is use. The input parameters are pressure within pumping system, abrasive material grain size, stand-off distance, nozzle speed and abrasive mass flow rate. Also the effect of input parameter on surface roughness is analyzed for machining Stainless steel (SS304).**

Keywords-Abrasive Waterjet Machining, Surface Roughness, One Variable at a Time Analysis

I. INTRODUCTION

Abrasive waterjet machining (AWJM) technology was first commercialized in the late 1980's as a pioneering breakthrough in the area of non-traditional processing technologies. It is used to cut the target materials with a fine high pressure water- abrasive slurry jet. AWJM is superior to many other cutting techniques in processing various materials, such as no thermal distortion on the workpiece, high machining versatility to cut virtually any material and small cutting forces. This technology has found extensive applications in industry [1], particularly in contouring or profile cutting and in processing difficult-to-cut materials such as ceramics and marbles [2], and layered composites [3].

One Variable at a time analysis (OVAT) analysis is very much important tool utilized widely in engineering analysis. A control factors and there levels are selected for experimentation by using OVAT analysis. The main purpose of performing OVAT analysis is to clear that whether the selected process parameters having influence on quality characteristic. OVAT analysis perform by varying one process parameter from lower to higher value by keeping all other process parameter constant, and measure the effect on quality characteristic [4].

II. EXPERIMENTAL WORK

With the help of standard test specification manuals, discussion with concerned engineers and also with the help of research paper it strongly felt that performance of AWJM process bears a direct relationship with input parameters such as pressure within pumping system, abrasive material grain size, standoff distance, nozzle speed and abrasive mass flow rate. The purpose of this OVAT analysis is to select control factors and there levels for experimentation. Levels of input parameters are selected on basis of following analysis [5]

Experiments are carried out by taking the set of respective values. The surface roughness is measured in µm. SR is measured using surface texture measuring instrument having following specification.

Description: Surface Texture measuring instrument
Type: SURFCOM 130A- Monochrome
Manufacturer: TOKYO SEIMITSU CO.LTD
Procedure: JIS B0651-1996, ISO 3274 and DIN4772

III. EXPERIMENTAL RESULTS AND ANALYSIS

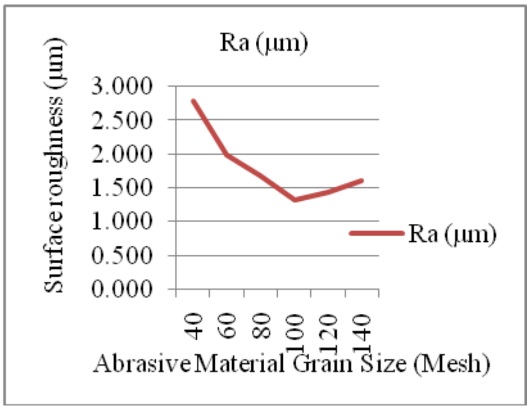
A. Effect of abrasive material grain size

The experiment is perform by varying AMGS, assuming all other remain parameter are constant (Table I). The response characteristic i.e. surface roughness is measured on surface testing machine. The relationship between surface roughness and abrasive material grain size is shown in Graph 1.

In case of the abrasive material grain size, an abrasive with smaller mesh number has a larger average value of particle size and fewer particles per unit weight. Graph 1 illustrates that the lower surface roughness is obtained by an abrasive with larger mesh number, while the higher roughness are achieved by an abrasive with smaller mesh number [3].

TABLE I. EXPERIMENTAL DESIGN AND RESULT FOR AMGS

AMGS (Mesh)	SoD (mm)	PwPS (MPa)	NS (mm/min)	AMFR (g/s)	Ra (µm)
40	2.5	225	175	5	2.788
60	2.5	225	175	5	1.996
80	2.5	225	175	5	1.681
100	2.5	225	175	5	1.325
120	2.5	225	175	5	1.434
140	2.5	225	175	5	1.611



Graph 1: Effect of Abrasive Material Grain Size on Roughness

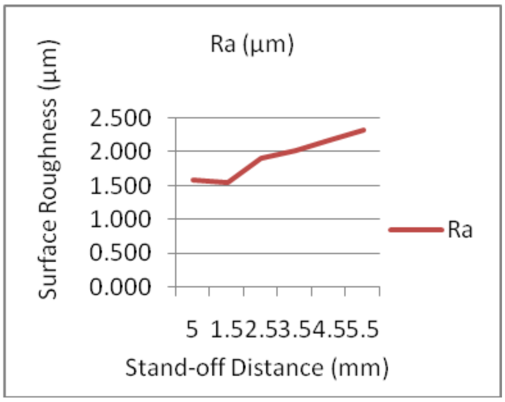
B. *Effect of stand-off distance*

Similarly experiment is performed by varying SoD (Table II). The relationship between surface roughness and stand-off distance is shown in Graph 2.

TABLE II. EXPERIMENTAL DESIGN AND RESULT FOR SOD

AMGS (Mesh)	SoD (mm)	PwPS (MPa)	NS (mm/min)	AMFR (g/s)	Ra (µm)
80	5	225	175	5	1.585
80	1.5	225	175	5	1.542
80	2.5	225	175	5	1.892
80	3.5	225	175	5	2.010
80	4.5	225	175	5	2.171
80	5.5	225	175	5	2.317

In case of the stand-off distance, higher stand-off distance results in higher surface roughness. Basically, higher stand-off distances are related to the effective jet diameter. That is, when the jet spreads out of the nozzle, it diverges and the effective jet diameter is reduced. Earlier analysis has proved that the higher stand-off distances result in a constant increase in the surface roughness [4].



Graph 2: Effect of Stand-off Distance on Roughness

C. *Effect of pressure within pumping system*

Now experiment is perform by varying the PWPS, other parameter are kept constant (Table III). The relationship between surface roughness and pressure within pumping system is shown in Graph 3.

TABLE III. EXPERIMENTAL DESIGN AND RESULT FOR PWPS

AMGS (Mesh)	SoD (mm)	PwPS (MPa)	NS (mm/min)	AMFR (g/s)	Ra (µm)
80	2.5	25	175	5	1.123
80	2.5	75	175	5	1.322
80	2.5	150	175	5	1.350
80	2.5	225	175	5	1.494
80	2.5	300	175	5	1.570
80	2.5	375	175	5	1.581

In case of the water pressure, higher water pressure increases the kinetic energy of the individual particles inside the jet and enhances their capability for the material removal. However, higher water pressure may also result in random particle collisions between particles due to the acceleration and also due to more energy disbursement from the abrasives to the area bombarded by the waterjet; rougher cut surfaces can be obtained. As shown in Graph 3, the surface roughness increases with an increase in water pressure [6].

The increase in particle velocity at the abrasive nozzle exit and particle fragmentation inside the abrasive nozzle caused the positive effect on surface roughness. However, high waterjet pressure can generate negative effects; the abrasive particles can lose cutting ability when they become too fragmented. Also, the abrasive nozzle and elements of the intensifier pump wear faster. These adverse effects could be criteria for determining the optimal waterjet pressure.

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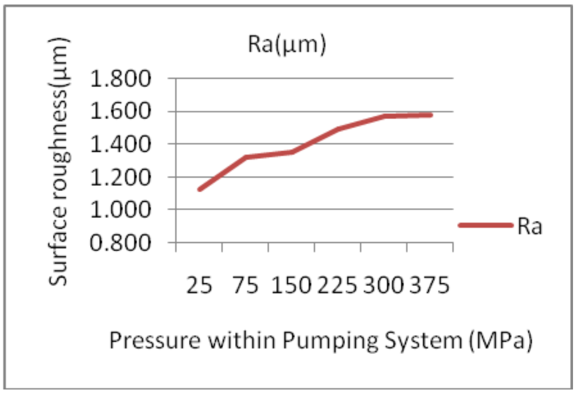


Graph 3: Effect of Pressure within Pumping System on Roughness

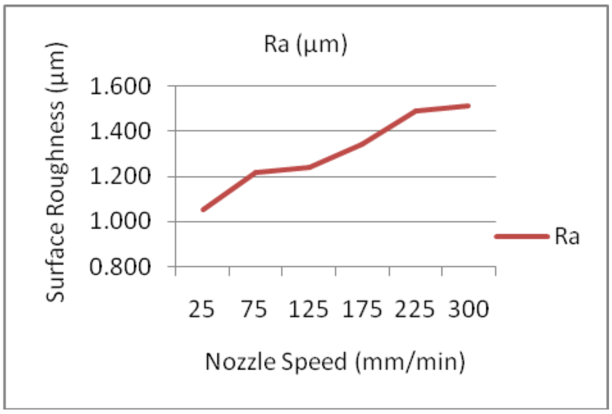
D. Effect of nozzle speed

The experiment is perform by varying NS, assuming all other remain parameter are constant (Table IV). The response characteristic i.e. surface roughness is measured on surface testing machine. The relationship between surface roughness and is nozzle speed shown in Graph 4.

TABLE IV. EXPERIMENTAL DESIGN AND RESULT FOR NS

AMGS (Mesh)	SoD (mm)	PwPS (MPa)	NS (mm/min)	AMFR (g/s)	Ra (µm)
80	2.5	225	25	5	1.053
80	2.5	225	75	5	1.220
80	2.5	225	125	5	1.241
80	2.5	225	175	5	1.341
80	2.5	225	225	5	1.491
80	2.5	225	300	5	1.510

In AWJ process, as the waterjet nozzle speed moves faster, less number of particles is available which pass through a unit area. Thus, less number of impacts and cutting edges will be available per unit area that results in rougher surfaces. Consequently, the surface roughness is higher at higher levels of the traverse speed for all the experiment shown in Graph 4.



Graph 4: Effect of Nozzle Speed on Roughness

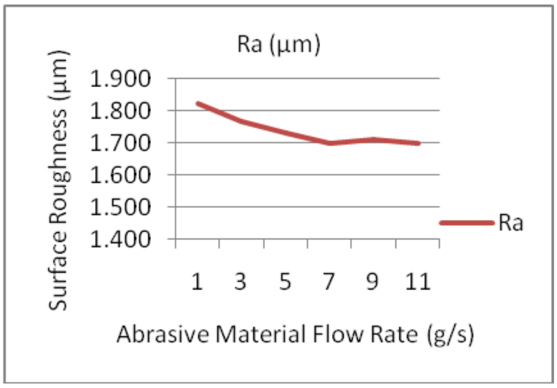
E. Effect of abrasive mass flow rate

The experiment is perform by varying AMFR, assuming all other remain parameter are constant (Table V). The response characteristic i.e. surface roughness is measured on surface testing machine. Graph 4 is showing the relationship between surface roughnesses and is AMFR.

TABLE V. EXPERIMENTAL DESIGN AND RESULT FOR AMFR

AMGS (Mesh)	SoD (mm)	PwPS (MPa)	NS (mm/min)	AMFR (g/s)	Ra (µm)
80	2.5	225	175	1	1.823
80	2.5	225	175	3	1.765
80	2.5	225	175	5	1.732
80	2.5	225	175	7	1.700
80	2.5	225	175	9	1.712
80	2.5	225	175	11	1.700

In case of the abrasive mass flow rate, the higher the abrasive flow rate, the higher the number of particles involved in the mixing and cutting processes. An increase in abrasive flow rate means a proportional increase in the cut depth. When the abrasive flow rate is increased, the cut surface becomes smoother and low surface roughness see which process factor has a significant effect on the surface roughness of the SS304 specimen [7].



Graph 5: Effect of Abrasive mass Flow Rate on Roughness

IV. SELECTED PARAMETERS AND THERE LEVELS

With the help of standard test specification manuals, discussion with concerned engineers, OVAT analysis and also with the help of research papers the control parameter and there levels are selected as shown in Table IV. This process parameter and selected levels are use for further study.

TABLE VI. SELECTED PARAMETERS AND THERE LEVELS

Control Factors	Levels			Unit
	1	**2**	**3**	
AMGS	60	80	100	Mesh
SoD	1.5	2.5	3.5	mm
PwPS	150	225	300	MPa
NS	125	175	225	mm/min
AMFR	3	5	7	g/s

V. CONCLUSIONS

OVAT analysis is very much important tool utilized widely in engineering analysis. This work is a part of ongoing research project and the preliminary results are presented in this article. Based on the results of the work, following conclusions could be made:

In general, higher levels of the process parameters excluding the abrasive size resulted in higher surface roughness in the workpiece. The lower surface roughness is obtained by an abrasive with larger mesh number, while the higher roughness is achieved by an abrasive with smaller mesh number. As waterjet nozzle speed increases, surface roughness increases. It is preferable to have moderate nozzle speed. Through this analysis it is concluded that the higher stand-off distances result in a constant increase in the surface roughness. In case of the water pressure, higher water pressure increases the kinetic energy of the individual particles inside the jet and enhances their capability for the material removal. Surface roughness decrease as mass flow rate increases.

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