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Study and Analysis of Abrasive Water Jet Machining Process by Considering Industrial Waste as an Abrasive

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Abstract - In various uses in the manufacturing industry, industrial solidified waste may be recycated or reused as goods with value addition. Abrasive waterjet machining (AWJM) is a non-conventional method of processing that uses water and abrasive material to cut a large variety of products. This research focuses on the recycling and reuse of industrial waste aluminium oxide as an abrasive grain for abrasive waterjet process machining (AWJM). Abrasive sandblasting is the most frequent way of pushing abrasive materials under high pressure against a surface to lighten or roughen a smooth surface, contour a surface, or eliminate surface imperfections. The energy dispersive spectroscopy (EDX) analyses additionally assess the Scanning Microscopy (SEM) and the elementary composition, which involves the abrasive characterisation of particles such as the morphology and form of recycled aluminium grains. Aluminium alloy 6061 is used in this study material with hardening and chemical composition tests. Aluminium oxide abrasive grain performance indicators include feed rate, standoff distance, flow rate of abrasive, and cutting time. Measurement of geometry characteristics such as roundness, cylindricity, diameter and surface roughness after machining of AL6061 alloy. Find the most appropriate drilled hole using the Taguchi Grey analysis optimization approach. Due to the converted industrial aluminium oxide waste abrasive, which was beneficial for cutting alloy material AL6061, better diameter hole material has been achieved with a surface finish.

Keywords - Industrial waste Abrasive; Reuse or recycling; AWJD Process · Ra values ·Diameter · Circularity and Cylindricity.

1. INTRODUCTION

The steel industry is the second largest in the world, so it produces large amounts of industrial waste. The steel industry produces waste like sand blasted abrasive. The sand blasted abrasive is rejected as solid waste at the conclusion of its primary use, although it has some utility. This waste substance is chemically inert and non-biologically degradable, Shi C et al. [1]. Industrial waste dumping causes many environmental issues, including contamination of soil and water, Andreola F et al. [2]. In addition, it leads to increased costs for transferring solid waste from one area to another. Solid waste from the industry can be recycled or utilised for other uses as additional value goods. The sand blasted industrial waste abrasive like aluminium oxide. The recovery via a chemical separation process of aluminium oxide abrasive grains from waste alumina. This technique recovers all grains completely; however, it produces extra chemical waste, which has an environmental impact. It is best to adopt an affordable and environmentally favourable mechanical approach. During mechanical crushing, it produced different grit sizes of aluminium oxide abrasive grain, Sabarinathan P et al. [3]. Abrasive water jet processing is a novel, unconventional process that uses the high-speed erosion of materials using a water jet containing abrasive grains. Aluminium, rubber, Inconel, and Abrasive waterjet machining are used on different materials ranging from soft, ductile, and difficult to brittle, Korat MM and Acharya GD [4]. AWJ Drilling is a non-traditional technique for processing abrasive water jets. An extremely high-pressure water beam and abrasives, which are used for machining, are an important element of this technique. AWJ Drilling of the material implies that the substance is to be drilled with a maximum speed water jet with the entry of particles of abrasive. In industry, this process has been widely used to cut hard materials, mill slots, polish hard materials, clean polluted surfaces, and so on. The technique of cutting thick parts is also subject to material. AWJ is divided into two ways of jet production, namely abrasive air and abrasive and water (two stages) injection mixing jet. AWJ is divided into

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2 methods. In this type of injection, AWJ consists of injecting the abrasives through the mixing chamber into a maximum speed water jet stream, Putz M et al. [5]. AWJ Processing is among the most successful, unconventional means of shaping different types of structural materials. It is, in many ways, significantly better than other shaping techniques. Its benefit is that it offers tremendous adaptability in terms of material that can be cut with almost any metal and non-metal substrate other than diamond. Light alloys may be processed at about double the steel speed by abrasive waterjet machining. In addition, the abrasive waterjet cuts through a variety of thicknesses of aluminium alloys, from small sheets (less than 3 mm) to large plates of over 150 mm. The clean-cut surfaces exhibit high finishing quality and seldom need further finishing processes. The efficiency, area, and breadth of applications of high-pressure abrasive jet technology are all improving. Water pressure is the process parameter that governs the water jet form during cutting; water jet streams and aerodynamic strength increase with increasing pressure. This decreases the core area of the waterjet and the jet exit angle is increased. Jet geometry impacts the cut depth; if conical, the cutting depth can be reduced by the distance between the workpiece and the tool getting longer. Furthermore, when a specific working part thickness is exceeded, jet deflection occurs. The quality of the machining, particularly the depth of the cut, is important, as the cut's quality deteriorates as the jet impact depth increases. This can result from an unequal distribution of kinetic power of an abrasive medium. The machine therefore tends to leave obvious signs and striations on a lesser cutting surface, Kulisz M et al. [6]. Abrasive water jet machining influences very important parameters of the procedure, such as nozzle diameter, feed rate, pressure of the abrasive waterjet, flow rate of abrasive, and standoff distance. The abrasive jet nozzle diameter is intended to offer an effective abrasive mixture with the jet to produce a water-jet combination of high-speed abrasive agents. There's a distinction to be made between a nozzle for abrasive and a nozzle for water. The entrance of the abrasive to the high-pressure water stream is made possible via an aperture on the side of the abrasive jet nozzle. Both of these are mixed together in a mixing tube to release a jet nozzle. There is no opening or mixing tube with a pure jet nozzle, and high-pressure water goes out of the jewel. Boron or Tungsten carbide are commonly used as nozzle materials to reduce abrasive wear. The diameter of the abrasive nozzle was 1.2 mm in this investigation. The pressure of waterjet affects the penetration and removal rate of material. It affects how water and abrasive particles are distributed in the water jet process with abrasive particles. In this research set, 380 mpa is the pressure of waterjet. The flow rate of an abrasive in this research was between 200 and 400 grams/min. It is measured in millimeters. In this research, the amount of separation that is ideal is between 1 and 3 mm. Finally, an important parameter of AWJ machining is traverse rate. The traverse rate determines the abrasive waterjet process's ability to generate high-quality cut surfaces. The feed rate has an influence on the process cutting rate. In this research work, the traverse rate was between 153 and 340 mm/min. The Aluminium oxide abrasive was used in abrasive water jet studies on the AA2014 Aluminium alloy workpiece. For this investigation, the following factors have been examined: waterjet pressure, standoff distance, flow rate of abrasive, and traverse rate. Experimental written using the fuzzy logic approach values are compared to the prediction model, Verma K et al. [7]. The first region of damage, then smooth and rough surface cutting of aluminium alloy with the processing of the abrasive waterjet, are the three variation regions on the machined surface that are evaluated during microstructure examination, Caydas U and Hascalık A [8]. The processing material is 20 mm to 40 mm thick. They found that by lowering the traverse rate and allowing enough time for contact between the target and abrasive materials. This occurs in a significant throughout the cutting process, the quantity of abrasive particles. In denser and smoother materials, kerf width is a significant issue. Increasing the traversal rate can help minimize it. The material thickness of the job and the feed rate are also the main affecting elements for materials that have been hardened, according to the findings. The process parameters for the abrasive waterjet processing of AISI 4340 and Aluminium 2219 were optimized based on the multiple criteria number optimization method to maximize and reduce the response simultaneously. The abrasive water optimization of ductile material jet cutting full factor configuration of tests was used to refine the AWJ processing parameters of maximum power processes of AL2219 and low alloy steel. Thickness and speed were discovered to be highly influential parameters, whereas rates only affected surface roughness, Iqbal A et al. [9]. The roughness of the surface effects on the feed during the abrasive waterjet cut application were considered for this study. Presented AISI 304 steel traverse rate effects the decrease in the AWJ cut results of 304 inox steel improved service only for high quality specimens of 5 mm thickness, Akkurt A et al. [10]. Therefore, in this work, we converted industrial waste aluminium oxide abrasive with the cutting of AL6061 alloy workpiece on AWJ drilling. The input parameters are traverse rate, flow rate of abrasive, and standoff distance, while the output parameters are roundness, surface roughness, diameter, and cylindricity.

2. MATERIALS AND METHODS

2.1 Materials

The substance Aluminum 6061 is a magnesium-and silicone-containing alloy that is precipitation-hardened. Table 1 below provides a description of the chemical compounds in the alloy of AL6061. The pipe, ribbon, foil, wire, tube, and rod are all examples of this AL6061 alloy. It's one of the most affordable element alloys in the United States. The key elements for aluminium alloy selection are its high thermal conductivity, corrosion resistance, high strength, high electrical conductivity, appearance, reflectivity, and non-

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toxicity, formability, and non-magnetic characteristics. Aluminum 6061 alloy uses include aircraft maintenance, marine fitting, bicycle frames, transportation and braking components. It's also used for drilling and turning, paint removal, and surgery, among other things. It is well finished on the surface and may be anodised. It offers high resistance to corrosion in a variety of environments. The density of the material is 2.7 g/cm^3 and the elasticity modulus is E = 80 GPa. Figure 1 illustrates the AL6061 alloy dimensions of the specimen utilised in this investigation. The dimensions are 200 mm by 200 mm by 10 mm.

Table 1 Aluminium 6061 alloy chemical composition

No.	Element	Weight %
1	Silicon	0.64
2	Iron	0.51
3	Copper	0.34
4	Manganese	0.11
5	Magnesium	1.06
6	Chromium	0.22
7	Zinc	0.16
8	Titanium	0.001
9	Aluminium +	96.66

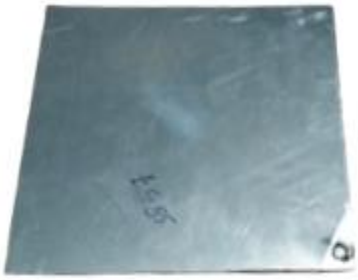

Figure 1 Aluminium 6061 alloy Specimen for Dimensions It is 200 mm long, 200 mm wide, and 10 mm thick

For its strength and hardness, aluminium oxide abrasive is utilised. Aluminum oxide crystals are used in several kinds of sandpapers. Furthermore, it is frequently employed in rectifying processes, notably cutting tools, with its low specific heat and low heat retention. Abrasive aluminium oxide is a chemical compound of aluminium and oxygen. It is often termed alumina, and may also, according to certain shapes or uses, be named aloxide, aloxite, or alundum. In this study, after polishing aluminium oxide abrasive, the recycled aluminium oxide abrasive density is 3.98 g/cm^3, the colour is blue, the hardness (Mohs scale) is 9, and the tenacity is brittle. The cost and cutting action of aluminium oxide abrasive grains in the abrasive water jet machining method must be evaluated before they are used. Aluminium oxide abrasive is a higher-hardness conventional abrasive than garnet abrasives. Recycled aluminium is more durable and harder than garnet abrasive. As a result, abrasive waterjet machining cuts with recycled solid waste aluminium oxide for further cuts, abrasive grains may be useful.

The quality and the removal rate of the workpiece products are determined by the aluminium oxide abrasive morphology and the abrasive particle size of aluminium oxide. The ideal requirement for AWJ machining is abrasive fine and coarse grains. It means spherical and irregular forms of abrasive particles. Figure 2 depicts the scanning microscopy of morphology (size and shape of particles of abrasive). It displays in Figure 3 the elemental peaks of an aluminium oxide abrasive. The primary weight of these fundamental peak abrasives is aluminium (51.43%) and oxide (42.88%).

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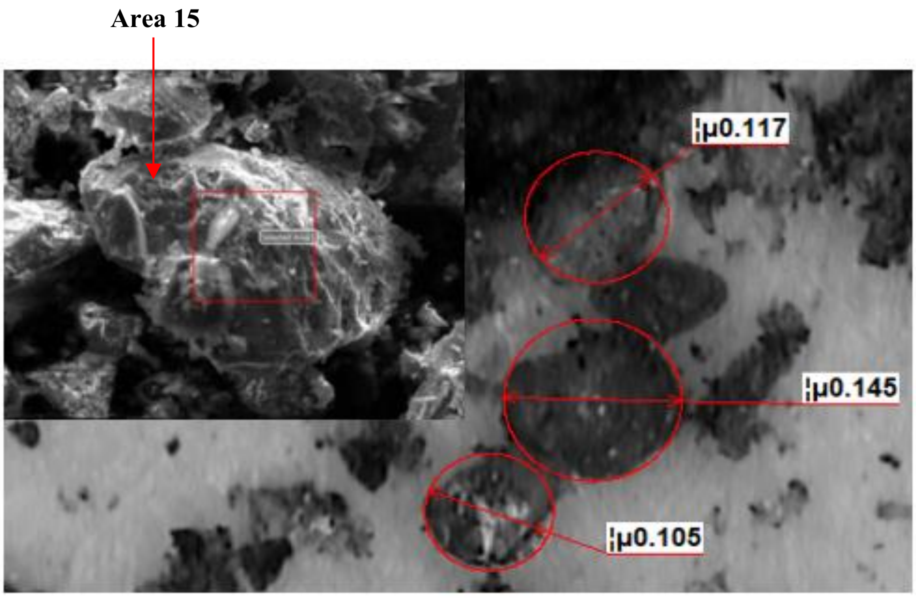

Figure 2 The abrasive aluminium oxide SEM morphological study

SEM analysis is a strong research method that employs a focused electric beam to generate complex, high-enhanced pictures of the surface topography of a material. Having discovered and assessed an area of interest using SEM, our specialists are permitted to examine this material further by means of energy scattering X-ray spectroscopy, or by means of an EDX examination. Performing visual surface examination using scanning electron microscopy helps to detect contaminants or unknown particles, which cause failure and material interaction. SEM analysis for the characterisation of particles is used, such as wearing waste created during mechanical wear testing, aside from surface assessment. A high magnification of our SEM study, the high-resolution picture enables users to understand the wear characteristics of their substances by determining the quantity, size, and shape of tiny particles.

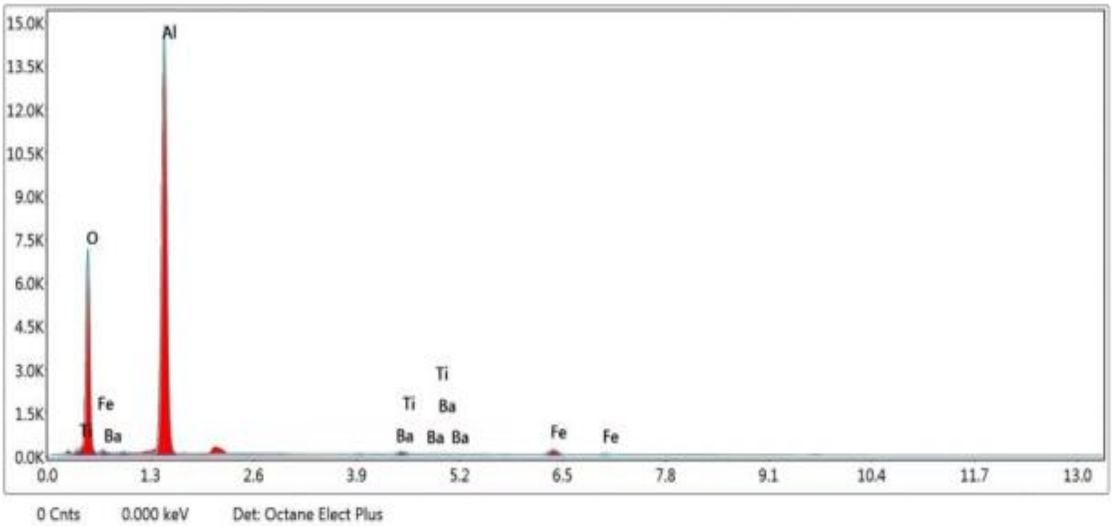

Figure 3 The abrasive aluminium oxide EDX Test

Specific energy-scatter ray spectroscopy, commonly known as EDX, EDS, or EDAX, offers further knowledge throughout the SEM examination process of the surface material. The EDX analysis is used to get a sample's elemental composition and to offer a quantitative result more than the SEM analysis. The combination of SEM and EDX analyses provides a full metallurgical assessment with chemistry composition and elemental research. EDAX APEXTM is a new suite of micro-analysis software which offers a fresh and highly structured work-flow for the rookie technician or experienced micro-analyst. The display configurations may be adapted and saved for any spectrum, image, and data view preferences by the users, with resizable floating and tabbed windows. With more comprehensive use, the analyst will notice significant and advanced capabilities such as right-click and live-time quantitative analysis completely rectified.

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2.2 DOE – The Design of Experiments

The term "experiment" is used in a very specific meaning to describe an inquiry in which the system under study is within the investigator's control. In this way, experiments are conducted in a manner that allows us to see and determine the reasons for changes being noticed in the output reaction to the processor inputs. There are several experiments necessary for investigating and discovering anything about any process under the conditions of huge inputs to achieve the desired results. The term Design of Experiment (DOE) is therefore an extremely useful approach in all regions of the world for the purpose of reducing the quantity of experiments and achieving a decent quality of research. Taguchi's technique offers a straightforward, effective, and consistent way of optimizing experimental designs for cost and quality performance. The fundamental aim of the Taguchi technique is to reduce process variance via rigorous experiment design. Table 2 provides experiments versus control variables and levels. In addition, Table 3 included nine experimental scenarios for AWJ input response parameters with an expected range.

Table 2 The Experiment's Control Variables and Their Settings

Control of Variable	Traverse rate (mm/min)	Flow rate of abrasive (gram/min)	Standoff Distance (mm)
Level-I	153	200	1
Level-II	192	300	2
Level-III	340	400	3

Table 3 Experiment design with expected range

Exp No.	Traverse rate (mm/min)	Abrasive flow rate (gram/min)	Standoff Distance (mm)
1	153	200	1
2	153	300	2
3	153	400	3
4	192	200	2
5	192	300	3
6	192	400	1
7	340	200	3
8	340	300	1
9	340	400	2

The AWJ pressure in this investigation was 380 mpa. In the abrasive process, it's a parameter of the fundamental process. The abrasive waterjet's force of motion relies on water pressure. If no material removal occurs, the pressure is lower than the pressure range set by the threshold. The pressure equivalent efficient cutting limits also apply to the critical range of pressure. When prolonged beyond this step, the machining process is useless. The pressure of the waterjet is closely connected to the depth of penetration and removal of materials. It influences the flow of water and particles of abrasive within the jet. In this research, the aluminium 6061 alloy workpiece diameter was 10 mm. Abrasive jet nozzles are meant to offer an effective abrasive mixed with jet water as well as generate a combination of high-speed abrasive water jets. So, the nozzle diameter was 1.2 mm in this investigation.

3. RESULTS AND DISCUSSION

3.1 Circularity or Roundness

Circularity is a two-dimensional tolerance that determines how near to the entire mathematical circle is a cylindrical, spherical or conical cross-section. The circularity of drilled holes for varied machining circumstances with varying Traverse rate, Standoff distance, and flow rate of abrasive are shown in Table 4. The comparison of circularity values is shown in Figure 4. The lowest circularity value of AWJ drilled hole 2 is 0.0315 mm with input response parameters of TR-153 mm/min, AFR-300 gram/min, and

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SoD-2 mm. It takes 18 seconds to machine. So, the least roundness of the hole takes the maximum possible machining time during the drilling operation of AWJM.

Table 4 Drilled holes' circularity

Ex. Level	Feed rate in [mm/min]	Flow rate of abrasive in [gram/min]	Standoff Distance in [mm]	Circularity in [mm]
1	153	200	1	0.0588
2	153	300	2	0.0315
3	153	400	3	0.0969
4	192	200	2	0.0588
5	192	300	3	0.1207
6	192	400	1	0.1135
7	340	200	3	0.3007
8	340	300	1	0.0727
9	340	400	2	0.0503

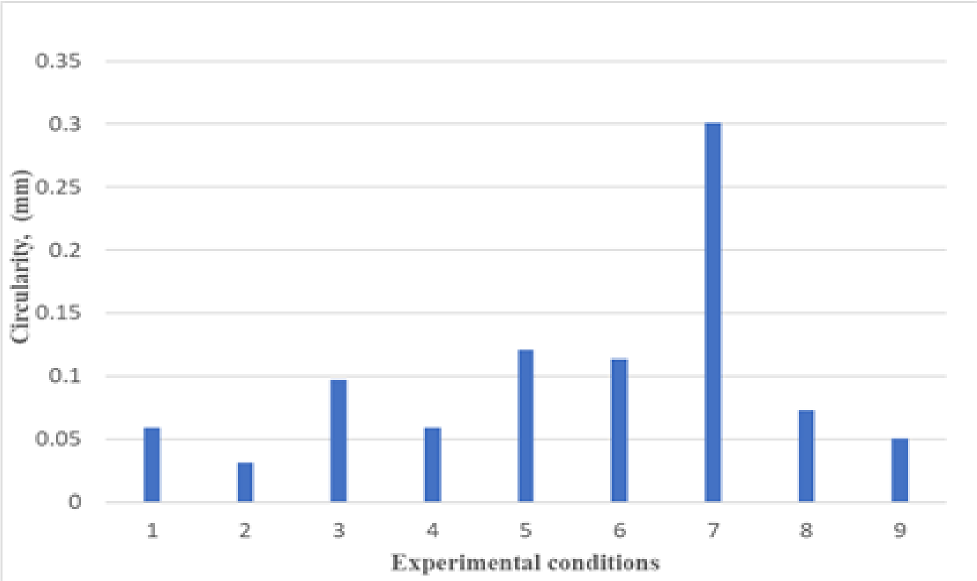

Figure 4 AWJ drilled holes' circularity values

3.2 Diameter

Drilled hole 1 to 9 checking diameter in the Vision measuring system (VMS) with a 3 measuring point circumference of the drilled hole. The diameter of drilled holes for varied machining circumstances with varying Traverse rate, Standoff distance, and flow rate of abrasive are shown in Table 5. The comparison of diameter values is in Figure 5. The lowest hole of 7 diameter is 10.01 mm with input response parameters of TR-340 mm/min, AFR-200 gram/min, and SoD-3 mm. It takes 8 seconds to run the machine. So, the least diameter of hole takes minimum machining time during the drilling operation of Abrasive waterjet machining.

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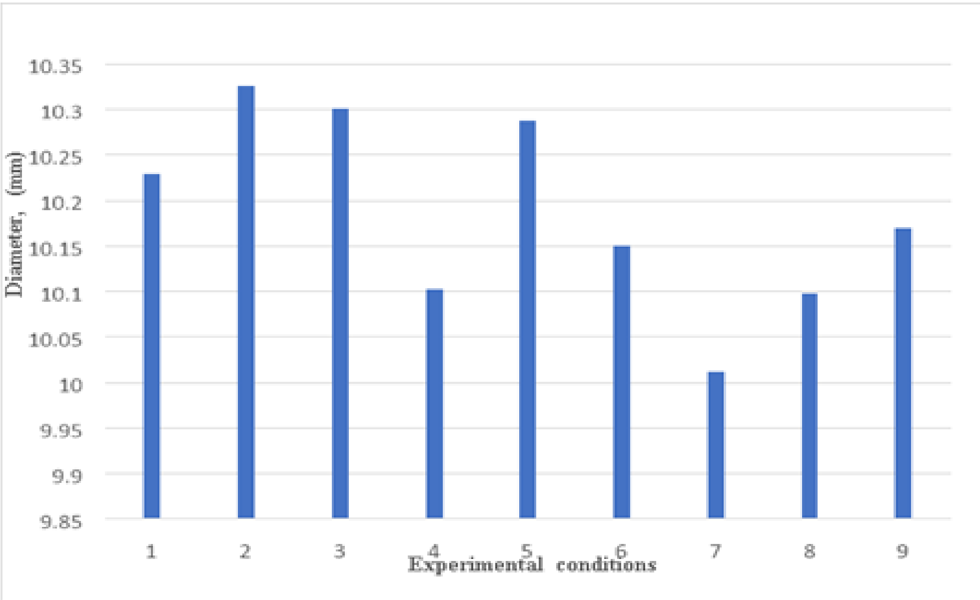
Table 5 Diameter of drilled holes

Ex. Level	Traverse rate in [mm/min]	Flow rate of abrasive in [gram/min]	Standoff Distance in [mm]	Diameter in [mm]
1	153	200	1	10.2301
2	153	300	2	10.3256
3	153	400	3	10.3017
4	192	200	2	10.1021
5	192	300	3	10.2883
6	192	400	1	10.1509
7	340	200	3	10.0114
8	340	300	1	10.0984
9	340	400	2	10.1700

Figure 5 Diameter values of AWJ drilled holes



3.3 Cylindricity

Cylindricity measures are for elements with the same diameter over their whole length. The cylindricity of drilled holes for varied machining circumstances with varying Traverse rate, Standoff distance, and flow rate of abrasive are shown in Table 6. The comparison of cylindricity values is shown in Figure 6. The lowest cylindricity value of AWJ drilled hole 2 is 0.1438 mm with input response parameters of TR-153 mm/min, AFR-300 gram/min, and SoD-2 mm. It takes 18 seconds to machine. So, the least cylindricity of the hole takes the maximum possible machining time during the drilling operation of Abrasive waterjet machining.

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Table 6 Cylindricity of drilled holes

Ex. Level	Traverse rate in [mm/min]	Flow rate of abrasive in [gram/min]	Standoff Distance in [mm]	Cylindricity in [mm]
1	153	200	1	0.2085
2	153	300	2	0.1438
3	153	400	3	0.1870
4	192	200	2	0.1917
5	192	300	3	0.1986
6	192	400	1	0.2081
7	340	200	3	0.6304
8	340	300	1	0.1667
9	340	400	2	0.2263

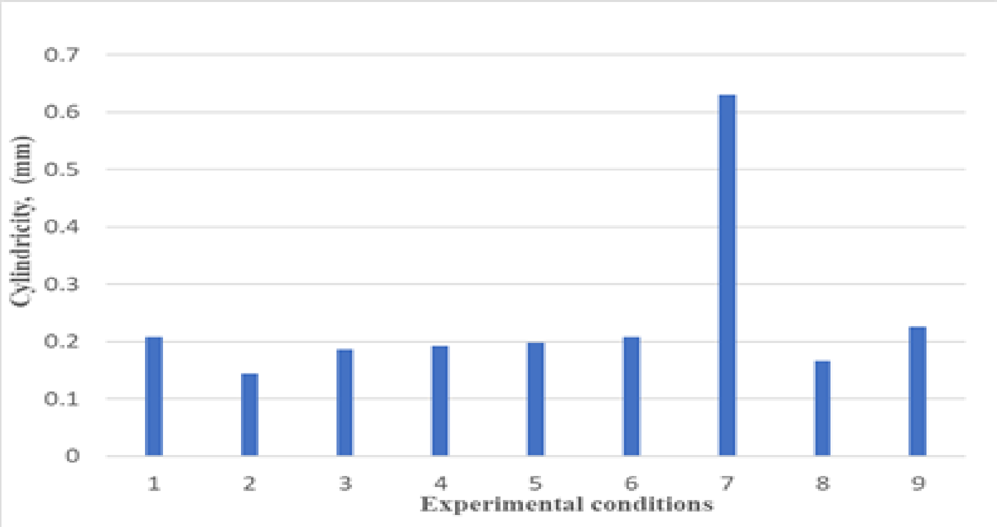

Figure 6 AWJ drilled holes' cylindricity values

3.4 Surface Roughness

The average roughness, Ra, is the mathematical average absolute height of the profiles throughout the evaluation length. The surface roughness of drilled holes for varied machining circumstances with varying Traverse rate, Standoff distance, and flow rate of abrasive are shown in Table 7. A comparison of Ra values is presented in Figure 7. AWJ hole 2 has the lowest roughness of surface of 1.325 microns with input response parameters of TR-153 mm/min, AFR-300 gram/min, and SoD-2 mm. It takes 18 seconds to machine. So, the least surface roughness of the hole takes the maximum possible machining time during the drilling operation of Abrasive waterjet machining. Also, the second lowest surface roughness of AWJ drilled hole 7 is 1.437 microns with input response parameters of TR-340 mm/min, AFR-200 gram/min, and SoD-3 mm. It takes 8 seconds to run the machine. So, the second least surface roughness of the hole takes the minimum machining time during the drilling operation of AWJ.

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Table 7 Surface roughness of drilled holes

Ex. Level	Traverse rate in [mm/min]	Flow rate of abrasive in [gram/min]	Standoff Distance in [mm]	Ra values in [micron]
1	153	200	1	1.660
2	153	300	2	1.325
3	153	400	3	1.785
4	192	200	2	2.845
5	192	300	3	1.500
6	192	400	1	1.880
7	340	200	3	1.437
8	340	300	1	1.730
9	340	400	2	2.559

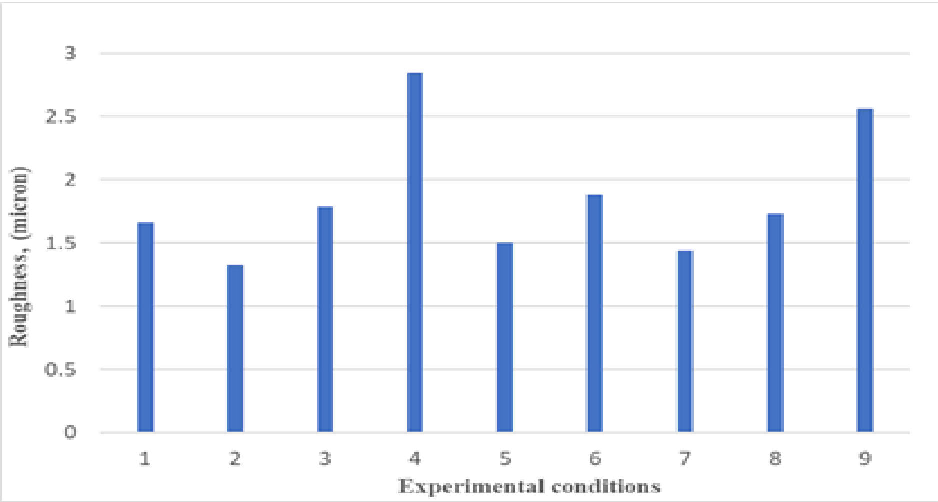

Figure 7 Ra values of AWJ drilled holes

3.5 Multi Performance Optimization Using Taguchi Grey Analysis

The Taguchi Grey analytical technique combines all the evaluated performance features into a single value which can subsequently be utilised as a single feature in issues of optimization. The Taguchi Grey analysis is extensively used to measure the degree of connection between grey relational grade sequences. Grey analysis improves multi-response control settings using grey relation grading.

[a] S/N (signal-to-noise) ratio

The signal-to-noise ratio is employed in the Taguchi technique to monitor process stability and to analyse deviations from intended values as a performance feature. The logarithmic function is the signal-to-noise ratio obtained by evaluating the ratio of signal (middle) to noise (standard deviation). S/N Ratios are calculated following Eq. 1.

$$\left[\frac{S}{N}\right]_{STB} = -10 \log\left[\frac{1}{n} \sum_{i=1}^{n} {y_i}^2\right] \quad (1)$$

If n is the experiment number, y_i represents the ith experiment's response value. STB represents smaller-is-better.

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Table 8 Diameter (Signal-to-Noise Ratio Response Table)

Level	A	B	C
1	-20.24	-20.10	-20.14
2	-20.16	-20.20	-20.17
3	-20.08	-20.18	-20.17
Delta	0.16	0.10	0.03
Rank	1	2	3

In Table 8, the diameter of the signal-to-noise ratio response is listed, and in Fig 8, the diameter of the SN ratios' principal effects is shown.

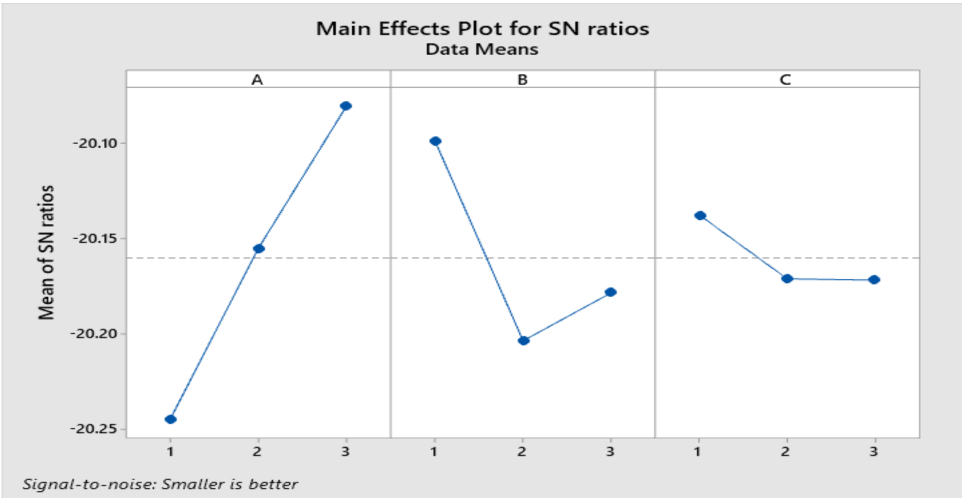

Figure 8 Diameter of SN ratios' principal effects

In Table 9, the surface roughness of the response from signal to noise ratio is listed, and in Fig 9, the surface roughness of the SN ratios' principal effects is shown.

Table 9 Surface roughness (Signal-to-Noise Ratio Response Table)

Level	A	B	C
1	-3.960	-5.544	-4.882
2	-6.029	-3.576	-6.562
3	-5.357	-6.226	-3.901
Delta	2.069	2.650	2.661
Rank	3	2	1

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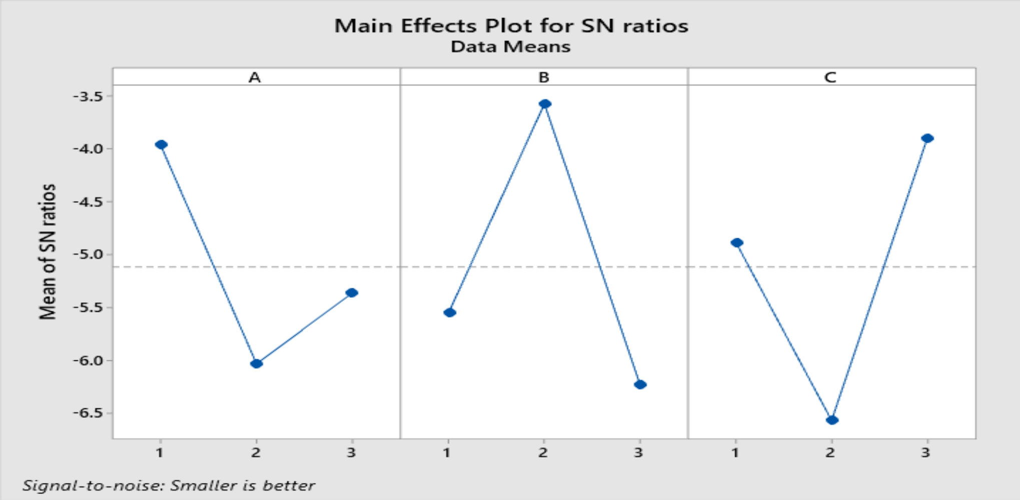

Figure 9 Surface roughness of SN ratios' principal effects

[b] Normalization of S/N Values

Data preparation is conducted to normalize the original sequences to a similar sequence in the zero-to-one range. This technique of normalizing pre-processing data in a sequence group is known as grey relational creation. To prepare data for pre-processing, grey relational analysis, the modified sequences' responses may be classified into two quality categories: smaller-is-better and larger-is-better. Eq. 2 may be used to normalize the sequence for smaller-is-better.

$$p_q(\mathrm{r})=[\max s_q(\mathrm{r})-s_q(\mathrm{r})]/[\max s_q(\mathrm{r})-\min s_q(\mathrm{r})] \quad (2)$$

when p_q(r) indicates the reference order of the ith experiment after pre-processing and s_q(r) indicates the first mean order of the answers.

[c] The Deviation Coefficient

Following the normalisation of the sequence, Eq. 3 is used to determine the reference's deviation sequence. The deviation coefficient is calculated between values of zero and one.

$$\phi_{0i}(\mathrm{r}) = |p_0(\mathrm{r})-p_q(\mathrm{r})| \quad (3)$$

When there is a deviation, the reference and comparability sequence refers to ϕ_{0i}(r), p_0(r) and p_q(r).

[d] The Grey Coefficient of Relation (GRC)

The grey relationship coefficient is established with Eq. 4. use.

$$Gx_i = [\phi_{min}+\mathrm{M}\phi_{max}]/[\phi_{0i}(\mathrm{k})+\mathrm{M}\phi_{max}] \quad (4)$$

where Gx_i is the GRC of the several response variables calculated accordingly ϕ_{min} & ϕ_{max}, the response variable's minimum and maximum variances. The identifying or distinguishing coefficient is denoted by M, defined in the vicinity of zero to one.

[e] The Grey Relation of Grade (GRG)

The Grey relation of grade has been subsequently computed by means of averages of the Grey coefficient of relation for every response variable, as given in Eq. 5.

$$GRG_i = [GRC_d+GRC_{sr}]/2 \quad (5)$$

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where GRG_i indicates the GRG value for the ith experiment determined, GRC_d represents the value of GRG determined for the diameter and GRC_{sr} signifies the grey relational grade value was calculated for the surface roughness. Table 10 shows the GRG outcomes.

Table 10 GRC and GRG values

Hole No.	GRCd	GRCsr	GRG	Rank
1	0.588474	0.772216	0.680345	6
2	0.5	1	0.75	3
3	0.519478	0.719433	0.619455	8
4	0.77408	0.5	0.63704	7
5	0.531099	0.860333	0.695716	4
6	0.690702	0.685946	0.688324	5
7	1	0.904004	0.952002	1
8	0.781249	0.741275	0.761262	2
9	0.66285	0.537243	0.600047	9

In Table 10, the GRG values were organised in decreasing order, with the greater GRG value representing the top rank, which provides the best drilling results. The ranking of various AWJ drilling conditions on AL6061 alloy is shown in Table 10. The Rank 1 attained at hole no.7 is indicated by a higher grey relational grade, and the matching parameter setting is Aluminium oxide abrasive with a 3 mm standoff distance (SoD), 340 mm/min traverse rate (TR), and a 200 gram/min abrasive flow rate (AFR).

After machining 10 mm in diameter, a total of 9 drilled holes in the hard metal Aluminium 6061 alloy with L-9 design are taken into hole features in analysis. The geometrical features of the hole, such as cylindricity, circularity, or roundness, the diameter of the hole, and the roughness of the surface were measured in the laboratory. The results of the geometrical features are tabulated and shown in graphs to analyze the results. Diameter and surface roughness results are optimized using grey analysis by Taguchi. This is employed to optimize the multi-functionality of process parameters. As a result, a better diameter hole with a higher surface quality was achieved. The optimum diameter of the hole and the roughness of the surface are acquired at an aluminium oxide abrasive feed rate of 340 mm/min and a 3 mm distance between the AWJ nozzle and the workpiece.

4. CONCLUSIONS

Abrasive water jet drilling tests on Aluminium 6061 alloy with Aluminium oxide industrial waste as an abrasive were carried out in this research. The traverse rate, flow rate of abrasive particles, and distance between the AWJ nozzle and the workpiece are utilised to drill 9 holes in AL6061 alloy. Other variables affecting the geometry of the hole characteristics, such as the diameter and roughness of the surface, were also examined. The main findings are summarized below.

- The lowest diameter was obtained by the employment of Aluminium oxide abrasive with a 3 mm Standoff distance, 340 mm/min feed rate and 200 gram/min AFR.
- A superior surface finish with a TR-340 mm/min, AFR-200 gram/min, SoD-3 mm has been generated using an abrasive aluminium oxide.
- least circularity and cylindricity of the drilled hole 2, traverse rate 153 mm/min takes 18 second machining time and this time is greater than another different traverse rate machining of the drilled hole. So, the least roundness and cylindricity of the hole takes maximum possible machining time during drilling operation of Abrasive waterjet machining.
- The best parameter configurations for improving drilled hole characteristics while drilling with an abrasive waterjet were presented in grey analysis in Taguchi. Available as the best parameter configurations for the manufacture of the lowest diameter and surface roughness of the drilling abrasive waterjet hole, the aluminium oxide abrasive, the traverse rate is 340 mm/min, and there is a 3 mm distance between the workpiece and the AWJ nozzle.

It has been found that converted industrial solid waste aluminium oxide is beneficial to cut the material of aluminium alloy and get improved hole properties in the AL6061 alloy with the usage of Abrasive waterjet machining.

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