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Research Article

Analysis and Optimization of Process Parameters for Kerf Identification in Abrasive Jet Machining of Hastelloy: A Software-Based Approach Using ANOVA

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ABSTRACT

A software-based approach, leveraging Analysis of Variance (ANOVA), is employed to analyze the influence of different process variables on kerf width and depth. AJM (Abrasive jet machining) has been widely utilized to cut diverse materials. It has been utilized for challenging-to-machine materials, primarily metals, employed in diverse industrial procedures within the fabrication sector. An extensive knowledge of the systems governing its process of cutting is necessary for ascertaining its effective application, given its numerous uses. The chemical, marine, and aerospace industries are seeing a sharp rise in demand for micro goods. Here, the super alloys that are strong and resistant to corrosion are crucial. Hastelloy is an alloy that can be machined using AJM but it is hard to do so using regular methods. On the AJM test rig, a Hastelloy C276 sheet having a 1 mm thickness was drilled with the help of various process parameters. This paper presents the RSM methodology for the improvement of the process parameters of Hastelloy C276 abrasive jet machining. The ANOVA(Analysis of Variance) and RSM Analysis were utilized to compare the outcomes. L15 Orthogonal Array for KERF experiments are carried out at various levels.

Keywords: Kerf, Jet Machining, ANOVA

Introduction

Hashish created the first AWJM technique in 1979, which established the groundwork to improve abrasive water jetting and greatly expanded the cutting capacity as well as the diverse applications as contrasted to pure water jetting [1]. The progress of abrasive water jets has since grown in significance for many nations. Over the past 30 years, the technology has advanced rapidly, and domestic research along with the overview of AJM tools and technology has also started.

Analysis of Variance (ANOVA) explores the application of a software-based ANOVA approach for optimizing process parameters in abrasive jet machining of Hastelloy. It delves into the identification of significant parameters affecting kerf geometry, the interaction effects between parameters, and the derivation of optimal settings. The study aims to provide a comprehensive framework for utilizing ANOVA in machining process optimization, contributing to the broader field of Computer Science and Management through an intersection of statistical analysis, software tools, and manufacturing process optimization.

The non-traditional cutting method, abrasive water jet machining applies high-pressure water for the creation of a high-velocity stream that is infused with the help of abrasive particles for different materials, including hard and soft ones. It is a versatile method that may be used for a range of manufacturing jobs, including surface preparation and cutting, and it offers several unique benefits, like low machining force, excellent mobility, and a minimal heat-affected cutting zone. AJM has undergone a significant makeover to better serve the needs of innovative businesses. A few manufacturing companies use AJM for material evacuation in hard-to-hard materials. Abrasive grit size, AIR pressure, standoff separation, , as well as abrasive flow rate are some of the machining parameters used in the AJM technique that affect the exhibition parameters (kerf top width, surface quality, decreasing edge, along with material evacuation rate). To achieve the desired quality, it is important to have the optimal parameter setting for

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the machining technique. The influence of procedure parameters on the AJM process's presenting qualities has seldom been disclosed by any scientists. Abrasive jet machining removes material from the outside of the action by using the pressure of a liquid stream. A combination of air and abrasives is permitted for influencing work surface through the nozzle at a speed of 200 to 400 m/s when air is employed as a medium. The high-speed rough particles dissolve the work material as they do so."The nozzle's width is approximately 0.4mm, and the standoff distance is maintained between 0.7 and 1.0 mm." The cutting activity has been cooled because of action of carrier gas as a coolant and the process may be effectively modified to change metal removal rate, which depends on the size of rough particles along with the stream rate. "The Process has so far been the subject of a thorough, point-by-point trial and hypothetical analysis. Abrasive jet machining removes material off the outside of the action by using the pressure of a liquid stream." A combination of air and abrasives is allowed to influence work surface through the nozzle at a speed of 200 to 400 m/s when air is employed as a medium. The high-speed rough particles dissolve work material as they do so. "Within 0.4 mm nozzle's widths and standoff distance is kept about 0.7–1.0 mm". The process, which depends on the size of the rough particles and the stream rate, can be efficiently adjusted to change the rate of metal removal. Because the action of the carrier gas is as a coolant, the cutting operation is cooled. An alloy's high quality and work-hardening characteristics make it extremely challenging to create with traditional machining methods. Therefore, unconventional methods like laser machining and AJM. One of the high-quality, safe-to-consume nickel-chromium super combinations is Inconel-718, which is utilized at extreme temperatures varying from -217-704°C. In the current analysis, Inconel-718 with an 8 mm thickness is taken into consideration. The employment of GA (Genetic Algorithm) and SA (Simulated Annealing) for the assessment of ideal procedure parameters in the AWJM process increased the precise computation of MRR along with kerf width simultaneously of the AWJM procedure on INCONEL 718 compound applying Taguchi dark social inquiry. Water weight is the process parameter that most affects MRR and Kerf width.AJM eliminates material from surface by degrading fine-grained grating particles that hit it quickly [2]. Composites' kerf breadth increased as standoff distance and pressure increased, but it decreased when feed rate increased [3].

Super alloys can be strengthened by precipitation hardening, solid-solvent heaviness, and work hardness techniques. They also withstand creep and oxidation well. Additionally, they can work in environments where high surface stability is needed as well as under high mechanical stress and high temperatures. A wrought corrosion-resistant alloy called HASTELLOY(r) C276 can withstand the emergence of grain boundary precipitates, which weaken corrosion resistance. Solution heat is applied to Hastelloy(r) C276 at 1121° C(2050° F) before being quickly quenched. Before use, the parts should first be solution-heated in the case of forging or hot forming. Alloy C-276 is one of the most popular corrosion-resistant alloys available today. It is employed in a variety of settings, from strongly reducing to moderately oxidizing ones. Chlorides, solvents, moist chlorine gas, hydrochloric acid, hypochlorite, chlorine solutions, acetic acid, sulfuric acid, and formic acid are all very resistant to alloy C-276. Alloy C-276 has high resistance to solvents, moist chloride vapor, hypochlorite, hydrochloric acid, chlorine solutions, formic acid, sulfuric acid, and acetic acid. Low chromium concentration is the limiting element when working in highly oxidizing environments; hence hot, concentrated nitric acid settings are undesirable.

The Principal Process Parameters in AJM that Influence the KERF are

1. Gas Pressure 2. Nozzle Diameter 3. Nozzle Tip Distance (SOD).

The other process variables are held constant.

Literature

D V Srikanth and Dr. M. Sreenevasa Rao [4] reviewed that Ingulli C. N. (1967) [5] was the first to explain the effect of abrasive flow rate on material removal rate in AJM. They concluded, along with Sarkar and Pandey (1976), that after a threshold pressure, the MRR and penetration rate increase with nozzle pressure. J. Wolak (1977) and K. N. Murthy (1987) studied that the maximum MRR for brittle and ductile materials are obtained at different impingement angles: maximum MRR for ductile material impingement angle of 15-20 results in maximum MRR[6], and maximum MRR for brittle material normal to surface results in maximum MRR. According to Verma A.P. & Lal G.K. (1984) [7], the depth of erosion caused by abrasive He came to the conclusion that stand-off distance, mixture ratio, pressure, and grain size all affect the rate of material removal and penetration. At varying stand-off distance values, the greatest material removal and penetration rates are achieved. The maximum material removal rate is caused by the interaction of particle velocity and impingement area, whereas the maximum penetration rate seems to occur where particle velocity is maximum. Both the material removal rate and the penetration rate rise as the combination ratio increases. A material removal rate equation was proposed by Neema & Pandey (1977) [8] by equating the kinetic energy of the particles that were impinging on the work. Using an experimental methodology, Varun R & Dr. T S Nanjundeswaraswamy [9] conducted parametric studies on abrasive jet machining by Venkatesh (1984) [10], examining the effects of feed rate, spray angle, pressure, and abrasive grit. SOD, material removal rate, and grit size. Typical toughened glass and optical specimens were machined using silicon carbide powder and aluminum oxide. AJM made it simple to process these specimens, except in the event that Only compressive layers of toughened glass could be machined; drilling a hole was not an option[11]. Extreme wear was found at the exit nozzle, while the mixing chamber showed significant wear and the intake showed essentially no wear. nozzle. Huaizhong Li investigated [12] In order to comprehend the dynamic properties of a high-speed abrasive air jet, used CFD analysis to study [13] the resolution of the flow field and the description of the physical interactions between the carrying and abrasive media. When the abrasive media's sharpness increased from φ=1 to φ=0.6, the anticipated particle velocity improved in comparison to the measured velocities along the jet center line axis.The air jet's flow field was not substantially impacted by the particle's sphericity. Jurisevic, B., Brissaud, D., & Junkar, M. (2004) [14] monitored AJM using the sound detection approach. The RMS value of the sound signal in the time domain and the ACS of the signal power spectra in the frequency domain were the characteristics of the sound that the authors observed in relation to standoff distance. As the stand-off distance grows, so does the RMS value.as illustrated in the figure below for the 6.1 mm thick work piece.

An amorphous glass was used in experimental research to examine the influence of processing parameters, like groove width or hole diameter, on the created structural profile. The depth of cut along with kerf taper angle are used to analyze the results. It demonstrates that the kerf width is significantly influenced by stand-off distance. Arise in stand-off distance results in a notable rise in the hole diameter and kerf breadth [15].According to their study, kerf width (both top and base) serves as the execution measure, while SOD, pressure, abrasive mass stream rate, along with nozzle distance across are the process elements taken into account. [16].The impacts of Pressure, Stand-off-distance, and Kerf ratio on the generated form have been covered in this work. Along with the MRR, influence of Pressure, Stand-off-distance, along with Kerf ratio are contrasted with the materialscarried out in the experiment in a way that will make the findings useful for any upcoming research on advanced materials and the AJM process [17]. The only cold high-energy beam technique that offers multiple unique processing benefits for machining several materials is the abrasive jet (AJ). [18].

Abrasive jet Machining System

The An Abrasive Jet Machining (AJM) system is a non-traditional machining process[19]. That utilizes a high-velocity stream of abrasive particles carried by a gas or air medium to remove material from a workpiece. It is particularly effective[20]. For machining hard, brittle materials like ceramics, glass, and superalloys, including Hastelloy.

Key Components of an AJM System

Compressor: Provides the compressed air or gas[21]. (Commonly nitrogen, carbon dioxide, or clean air) required to propel abrasive particles.

Abrasive Feeder: Regulates[22]. The flow of abrasive particles into the gas stream.

Typical abrasives: Silicon carbide, aluminum oxide, glass beads, or sodium bicarbonate.

Mixing Chamber: Combines the abrasive particles with the carrier gas in a controlled manner to ensure a uniform abrasive mixture.

Nozzle: Converts the pressurized abrasive-air mixture into a high-velocity jet [23]. Nozzles are often made of wear-resistant materials like tungsten carbide or sapphire.

Workpiece Holder: Holds and positions the workpiece securely during machining to maintain precision.

Dust Collection System: Collects and filters out abrasive particles and debris generated during machining to maintain a clean working environment into its processing mechanisms [24].

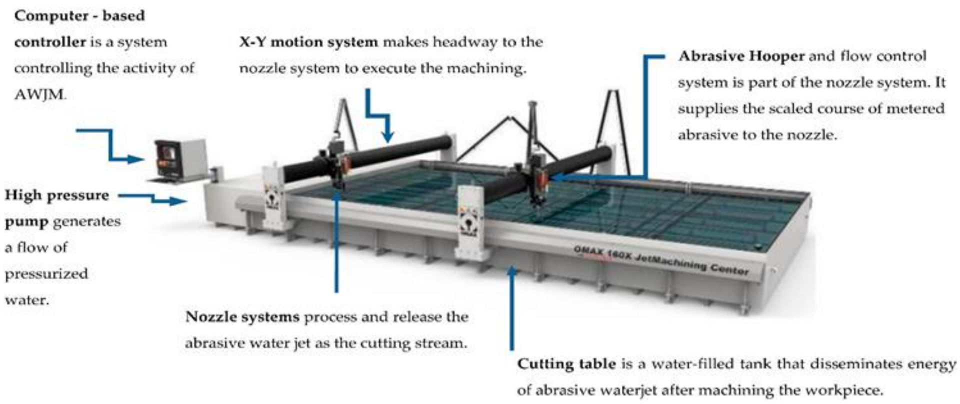

Figure1: AJM Mechanism and Components[5].

Source: https://ro.ecu.edu.au/cgi/viewcontent.cgi?article=10406&context=ecuworkspost2013

1. Abrasive jet Machining System Setup:

Detail the system configuration, including the types of abrasives, water pressure, nozzle diameter, etc.

2. Parameter Selection:

Discuss the parameters you are analyzing with ANOVA, such as:

Pressure (P)

Abrasive flow rate (A)

Cutting speed (C)

Like material properties, nozzle distance, and abrasive size.

3. Describe the experimental setup and how data will be collected for analysis. Ensure clarity on how the kerf width is measured for each test condition.

4. Statistical Analysis Using ANOVA:

Explain how ANOVA will be used to analyze the variance between different factors and their interactions.

Detail the steps of the analysis, including how the software is used to input the data and perform the ANOVA.

The AJM Process and Benefits

Abrasive Jet Machining (AJM) is a non-conventional machining process that uses a high-velocity stream of abrasive particles carried by a gas (typically air or nitrogen) to erode material from a workpiece. This process is especially suited for machining hard and brittle materials like ceramics, glass, and superalloys such as Hastelloy. AJM is commonly used for applications requiring precision and intricate detailing[24].

Key Components of AJM:

Abrasive Particles: Silicon carbide, aluminum oxide, or glass beads are commonly used, depending on the application.

Carrier Gas: Compressed air or inert gases carry the abrasive particles.

Nozzle: Typically made of tungsten carbide or sapphire to withstand erosion[25]..

Workpiece: Material to be machined, which must have sufficient brittleness and hardness for effective erosion.

Operating Principle: The carrier gas propels abrasive[26]. particles at high velocity through a nozzle, impacting the workpiece. The material is removed by micro-chipping or brittle fracture due to the abrasive action.

Benefits of AJM

High Precision and Accuracy: AJM enables precise material removal with minimal impact on surrounding areas, making it ideal for creating fine details and intricate geometries[27].

Minimal Thermal Damage: Since the process is mechanical and does not involve heat generation, it prevents thermal distortion or damage to heat-sensitive materials.

Suitable for Hard and Brittle Materials: Materials like Hastelloy, ceramics, and glass, which are difficult to machine using conventional methods, can be efficiently processed using AJM[28].

No Tool Wear: Unlike conventional machining, AJM does not involve physical contact between the tool and the workpiece, reducing tool wear and the need for frequent replacements.

Versatility: AJM can perform a variety of operations such as drilling, deburring, engraving, cleaning, and cutting.

Clean and Contamination-Free: The process produces minimal contamination, making it suitable for applications in the aerospace, electronics, and medical industries[29].

Flexibility: AJM can be used to machine thin sections and fragile components without causing damage or deformation.

Eco-Friendly: The process does not involve the use of harmful chemicals, making it environmentally safer than certain chemical machining processes.

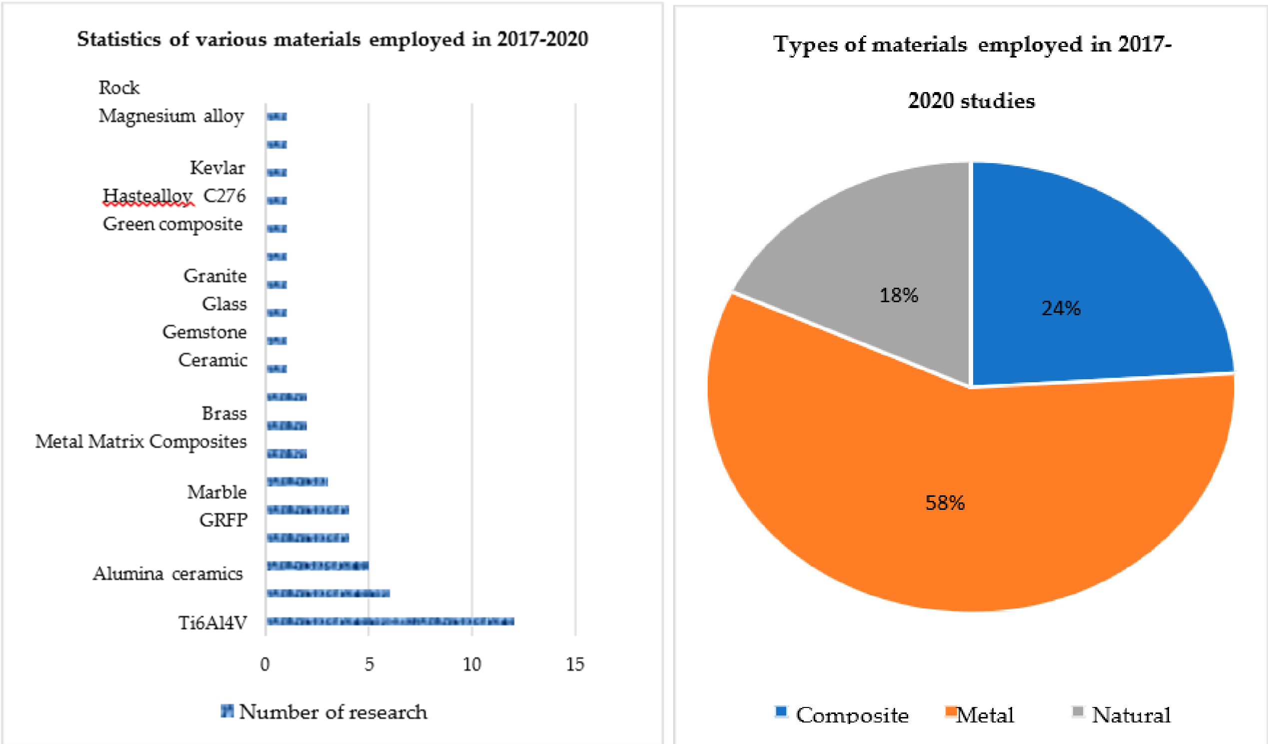

Figure 2: Statistics of (a) various workpieces employed in AJM applications and (**b**) material type from 2017 to 2020 publications reviewed in this" work.

Source: https://www.sciencedirect.com/science/article/abs/pii/S2214785320303916

Methodology

Analysis of Variance (ANOVA) is a robust statistical technique used to analyze the influence of multiple factors and their interactions on a given response variable. By employing ANOVA in a software-based environment, researchers and practitioners can efficiently identify significant factors, quantify their effects, and derive optimal parameter settings with a high degree of confidence. This approach not only reduces experimental effort but also enhances the reproducibility and reliability of results.

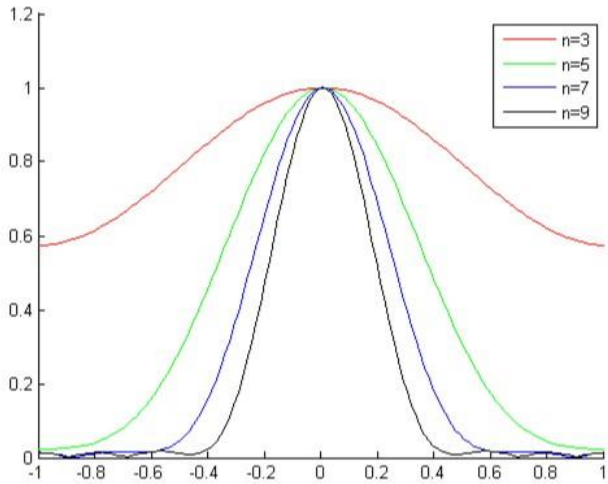

Figure 3: Tests work in Analysis of Variance (ANOVA)

Design of Experiments(DOE) a multivariate data analysis benefits from the addition of experimental design because it creates "structured" data tables, or data tables with a significant amount of structured variance. Then, multivariate modelling will be based on this underlying Structure; it will ensure reliable and stable models. The DOE Technique makes it possible to analyze numerous elements at once and most economically the ideal factor combination can be found by examining how each element affects the outcomes.

Response Surface Methodology

With a limited number of trials, RSM is a statistical method for designing experimental runs, assessing the independent and interacting effects of independent operating factors, and optimizing the process. The method's primary idea is the creation of mathematical models that are fitted to experimental data from the planned set of trials, followed by statistical analysis to validate the model. Selecting desired responses and screening independent factors are the initial steps in determining the best operating conditions for a system. Next, the experimental design method is chosen, and the experiments are conducted to get the results. Response graphs and analysis of variance are then applied to validate the model, and final optimal conditions are identified. The two most important RSM actions out of all the subsequent processes are choosing dependent responses and evaluating independent elements. Inaccurate specification of the elements could result in unanticipated outcomes. Additionally, choosing an appropriate experimental design strategy is crucial for estimating and assessing surface responses using one of the design strategies suggested in the literature, including FFD (full factorial design), DD (Doehlert design), Box–Behnken design(BBD), along withCCD (central composite design).

Response Surface Methodology (RSM) is a collection of mathematical and statistical techniques used to model and analyze problems in which a response of interest is influenced by several variables. It is widely used in the optimization of machining processes, including Abrasive Waterjet Machining (AWJM), to develop relationships between process parameters and performance measures.

RSM is often applied in AWJM to determine the influence of parameters such as water pressure, abrasive flow rate, stand-off distance, and cutting speed on outcomes like surface finish, material removal rate (MRR), kerf width, and cutting accuracy.

Box-Behnken Method:

“George E. P. Box and Donald Behnken in 1960” designed“Box-Behnken designs,” which are experimental designs for response surface methodology, with specific objectives:

• The 3 equally spaced values—typically denoted by codes −1, 0, and +1—are assigned to all factor, or independent variable. (The next objective requires a minimum of three levels.)

• The architecture must accommodate a quadratic model that includes squared terms, products of two components, linear terms, along with an intercept.

• The number of experimental points in the quadratic model should correspond to the number of coefficients; in practice, however, their designs are maintained between 1.5 and 2.6. The estimation variance should not vary much in the smallest (hyper)cube composed of the experimental points, but should only based on the distance from center, which is exactly accomplished for the fourand seven-component designs.

A second-order response surface model's parameters are estimated using BBD (Box and Behnken, 1960). These designs combine concepts from factorial trials, notably 2k full or 2k-1 fractional factorials, and incomplete block designs (BIBD or PBIBD). The treatment combinations are located in the center and at the midpoints of the process space's edges in this independent quadratic design. Only three tiers and a minimum of three components are needed to conduct an experiment. These patterns can be rotated or almost rotated. They are employed to maximize the quadratic, interaction, and main effects.

The criteria we decided on are:

- Pressure: 6, 7, 8kg/cm^2.
- Standoff Distance: 7mm, 8mm, 9mm.
- Nozzle diameter: 2mm, 3mm, 4mm.

Experimentation Work

To ascertain the intended output characteristics, a straight cut of 15 mm is done on each specimen during the experiment. Figure 4 displays the specimen samples created during the experiment. Five distinct spots were chosen throughout the cut's length on the specimen's bottom face to calculate the average bottom kerf width. To measure kerf width, a stereo zoom microscope was used. It features a trinocular body, a working distance of up to 100mm, and an objective lens zoom range of 0.65X to 4.5X.

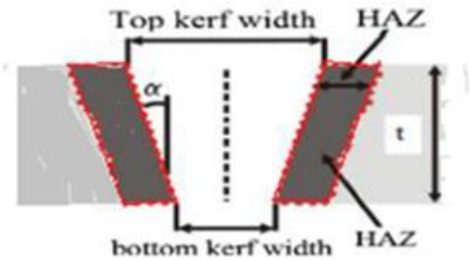

Figure 4. Specimen samples created during the experiment

Geometrical Features the Kerf Characteristics

The focused "stream of abrasive particles that are released from a nozzle by the highly pressured air and driven towards" working item is what causes material removal in abrasive jet machining (AJM).1–3 AJM has recently demonstrated a great deal of promise in the of micro-device production, particularly in the production of accurate holes and channels. However, to identify the ideal process parameters and facilitate further advancements "of this methodology, it is crucial to have a well-established and trustworthy relationship between input parameters along with their intended output results, like material removal rate as well as kerf taper. Many researchers have examined the surface quality produced by AJM to gauge the impact of process variables. It was discovered that the produced surface had a reverse bell-mouthed shape, with the target material's entry side diameter varying according to the process parameter values. The nozzle diameter and SoD (standoff distance), defined as the distance from nozzle exit to the target surface of workpiece, as illustrated in Figure" 4, were identified as more critical parameters influencing the configuration of machined surface.

Kerf Taper of AJM Machining Process

One feature of abrasive water jet cutting that is of great importance is kerf geometry. Its entry is wider, and as the jet cuts into the material, its width shrinks, creating kerf. Wang et al.'s findings support this. Half of the kerf width fluctuation per millimeter of depth of cut (or penetration) is known as the kerf taper. One unfavorable aspect of the AJM machining procedure is the kerf taper. It is a measurement of the drilled hole's geometric distortion. The difference between the drilled hole's inlet and exit diameters divided by the thickness of the sheet is a dimensionless quantity that is often stated in millimeters per millimeter. The AJM test rig was used for the experiment. The experiment was conducted at a constant 8 kg/cm² pressure.

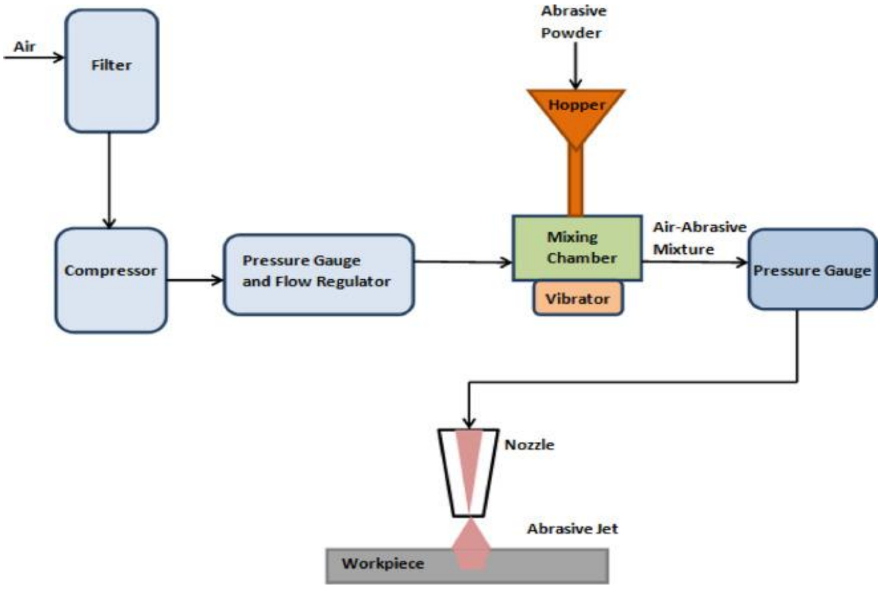

Figure 5: Schematic representation of AJM.

Because Hastelloy is extremely challenging to machine at lower pressures, this has been done. The following are the main elements of the experimental setup. Depending on the BBD and the Response surface approach, experiments are conducted. The Hastelloy sheet is the material utilized in the experiment, and the MRR(Material Removal Rate) is a performance indicator for the variables of the procedure. Silicon carbide and 40 micron-sized aluminum oxide are the abrasives that are used.

In the past, AJM has been effectively applied for cutting a broad range of materials, involving ceramics and traditional steels. The traversal rate, standoff distance, angle of impact, and other AJM process factors all affect how intense and effective the cutting process is. Numerous studies have been performed for the determine of process variables, such as kerf taper, surface roughness, along with top kerf width, affect cutting performance metrics. One feature of abrasive jet cutting that is of great importance is kerf geometry. As illustrated in Figure 6, including "top kerf w_t being wider compared to bottom kerf w_b Abrasive Jet will often open a tapered slot, with kerf taper/kerf" taper angle normally T being utilized for the representation of the properties.

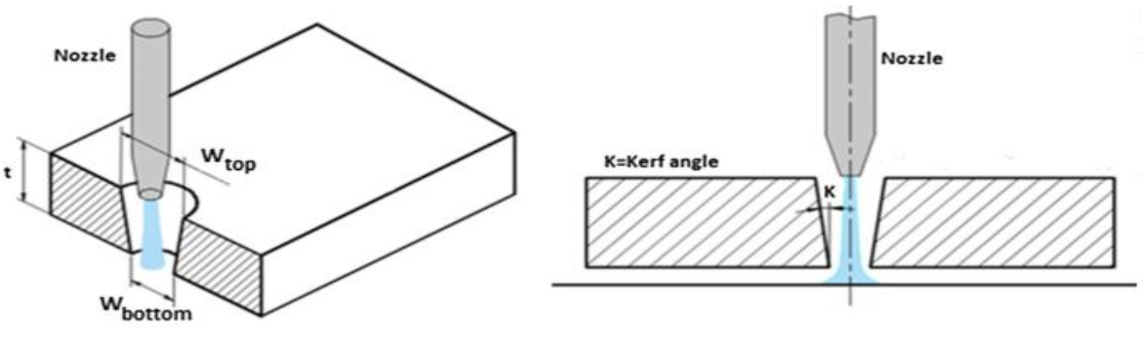

Figure6: Schematic Representation of Kerf Geometry of an Abrasive Jet cutting

Response Surface Regression for KERF

ANOVA tables that indicate the significance of each machining parameter.

Based on the distinction among“ top surface diameter and the bottom surface diameter, width of cut (KERF) is determined. Execution of the resulting KERF values for 15 tests is prioritized randomly. Table 1 displays the BBD matrix with three variables and a response (KERF”).

Table “1: Factor selection for Optimal Response

Pr	6	7	8
SOD	7	8	9
ND	2	3	4”

Table 2: DOE “L_{15} Orthogonal Array of Design of Experiments (Response Surface Methodology”)

“Pr	SOD	ND	KERF
6	8	4	2.5
7	8	3	3.5
8	8	2”	5
8	7	3	5
7	9	2	4
8	9	3	4.5
7	7	4	4
7	7	2	3.5
8	8	4	5
6	8	2	2.5
7	8	3	3
7	8	3	3
6	9	3	3
6	7	3	2.5
7	9	4	3

Response Surface Regression: KERF versus Pr, SOD, ND

Table 3: Coded Coefficients

“**Term**	**Coef**	**SE Coef**	**T-Value**	**P-Value**	**VIF**
Constant	3.167	0.154	20.61	0.000	
Pr	1.1250	0.0941	11.96	0.000	1.00
ND	-0.0625	0.0941	-0.66	0.006	1.00
SOD	-0.0625	0.0941	-0.66	0.026	1.00
Pr*Pr	0.354	0.139	2.56	0.051	1.01
ND*ND	0.229	0.139	1.65	0.159	1.01
SOD*SOD	0.229	0.139	1.65	0.159	1.01
Pr*ND	-0.000	0.133	-0.00	1.000	1.00
Pr*SOD	-0.250	0.133	-1.88	0.119	1.00
SOD*ND	-0.375	0.133	-2.82	0.037	1.00”

Table 4: Model Summary

S	**R-sq.**	**R-sq.(adj)**	**R-sq.(pred)**
0.266145	97.07%	91.80%	72.11%

Table 5: Analysis of Variance

“Source	DF		Adj SS	Adj MS	F-Value	P-Value
Model	9		11.7458	1.3051	18.42	0.003”
Pr	1		10.1250	10.1250	142.94	0.000
Linear	3		10.1875	3.3958	47.94	0.000
SOD	1		0.0313	0.0313	0.44	0.026
Square	3		0.7458	0.2486	3.51	0.057
ND*ND	1		0.1939	0.1939	2.74	0.159
ND	1		0.0313	0.0313	0.44	0.006
“SOD*SOD	1		0.1939	0.1939	2.74	0.059
Pr*Pr	1		0.4631	0.4631	6.54	0.051
2-Way Interaction	3		0.8125	0.2708	3.82	0.091
Pr*ND	1		0.0000	0.0000	0.00	1.000
Pr*SOD	1		0.2500	0.2500	3.53	0.119
SOD*ND	1		0.5625	0.5625	7.94	0.037”
Error	5		0.3542	0.0708		
Pure Error	2		0.1667	0.0833		
Lack-of-Fit	3		0.1875	0.0625	0.75	0.615
Total	14		12.1000			

Regression Equation in Uncoded Units

KERF	=	7.11.83 Pr0.85 SOD + 1.56 “ND+0.354 Pr*Pr +0.229 SOD*SOD+0.229 ND*ND 0.250 Pr*SOD0.000 Pr*ND -0.375 SOD*ND”

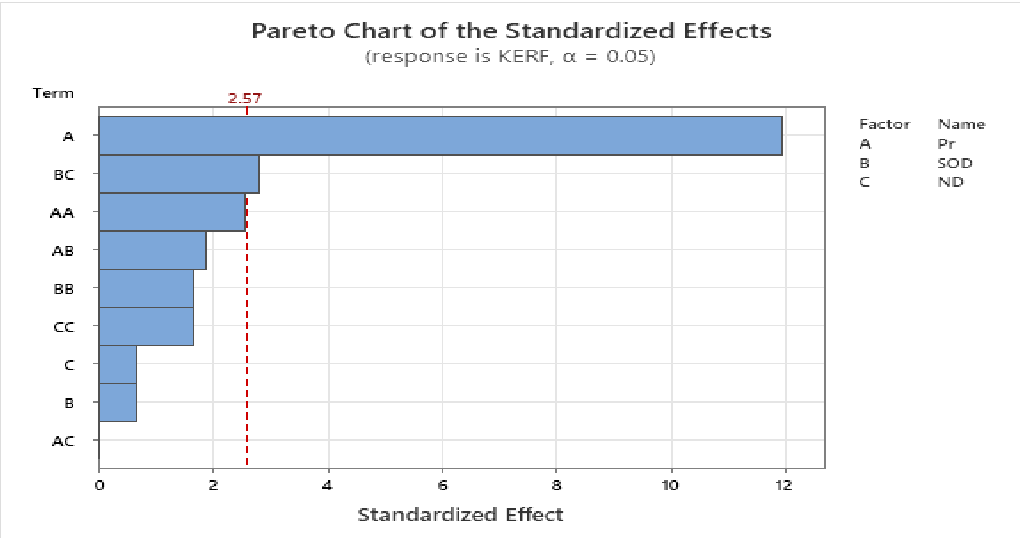

Figure 7: Pareto Chart Represents the Effect of Parameters on Response

Regression Equation in Uncoded Units

KERF	=	7.11.83 Pr0.85 SOD + 1.56 "ND + 0.354 Pr*Pr + 0.229 SOD*SOD + 0.229 ND*ND 0.250 Pr*SOD0.000 Pr*ND -0.375 SOD*ND"

Table 6: Response Optimization: KERF Parameters

"Response	Goal	Lower	Target	Upper	Weight	Importance
KERF	Minimum		2.5	5	1	1

Solution. Solution	Pr	SOD	ND	KERF Fit	Composite Desirability
1"	6	7.06061	2.36364	2.33033	1

Table 7: Multiple Response Prediction

Variable	Setting
Pr	6
SOD	7.06061
ND	2.36364

Response	Fit	SE Fit	95% CI	95% PI
KERF	2.330	0.247	(1.695, 2.966)	(1.397, 3.264)

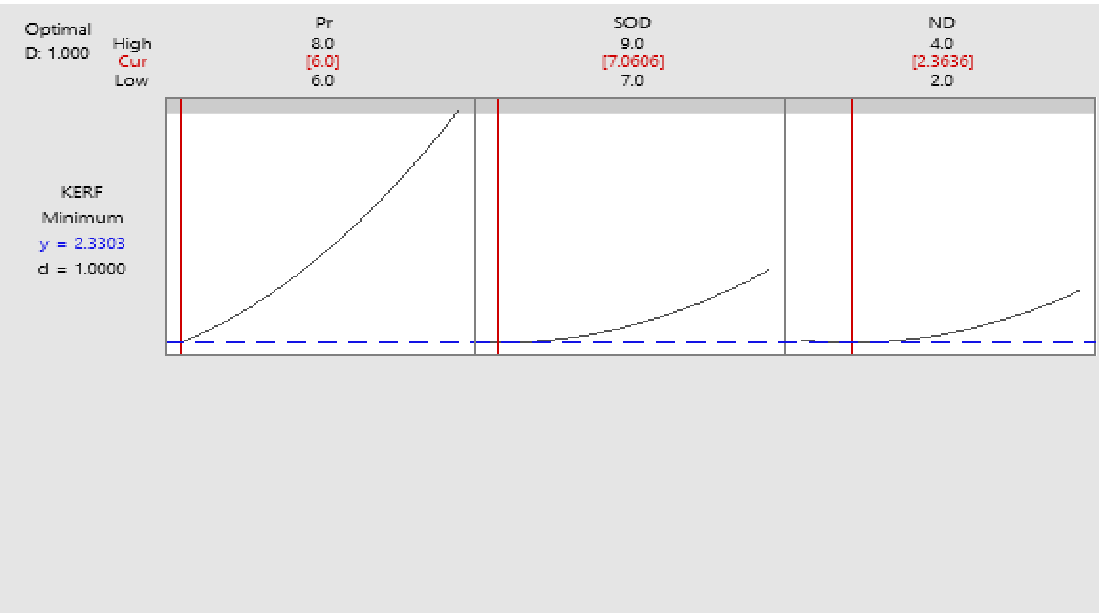

Figure 8: Optimisation plot of Kerf vs Pr,SOD, ND

Factorial Plots for KERF

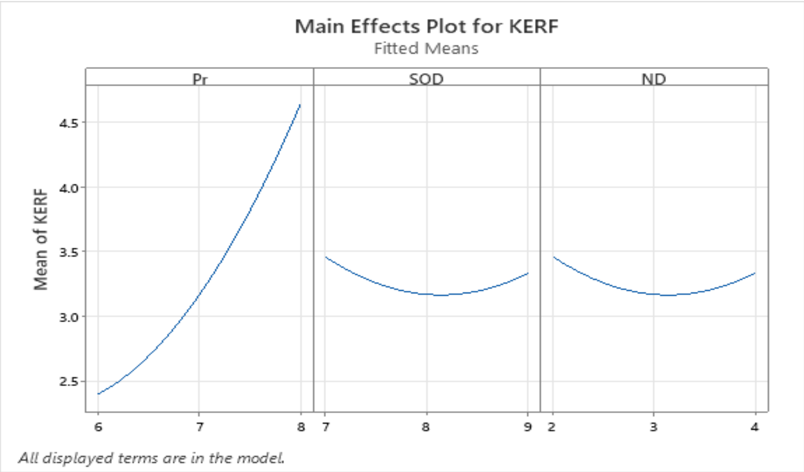

Figure 9: Main Effects Plot of Kerf vs Pr, SOD & ND

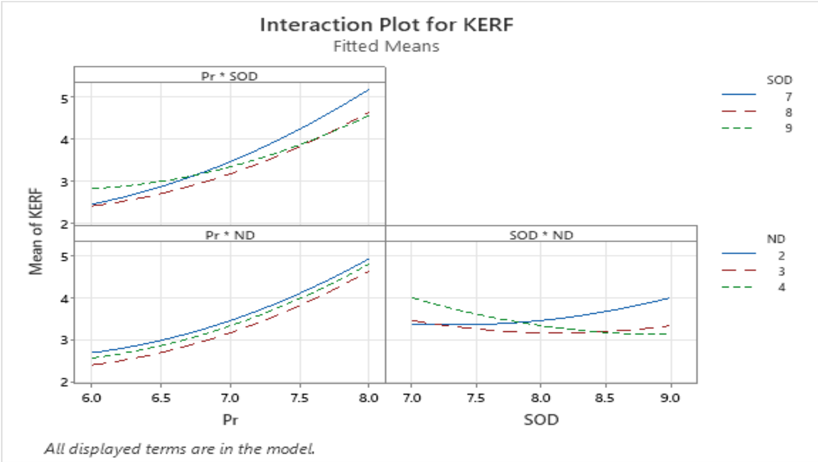

Figure 10: Interaction Plot of Kerf vs Pr, SOD & ND

Contour Plots of KERF

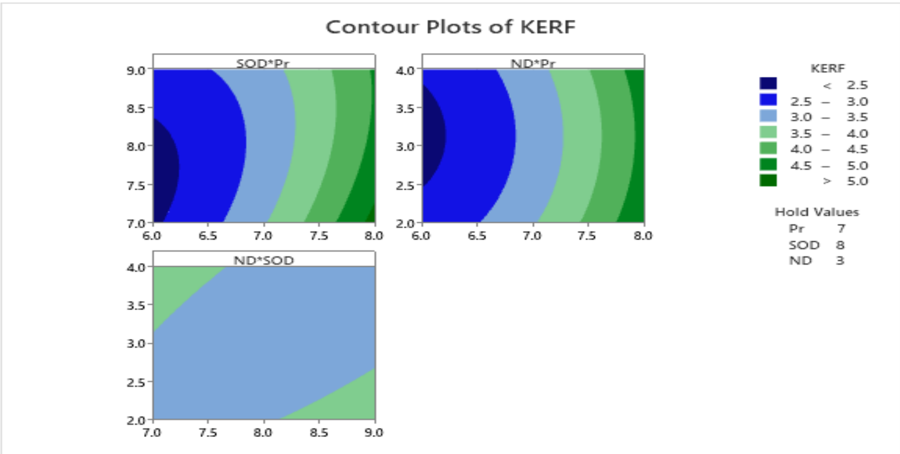

Figure 11: Contour Plot of Kerf vs Pr,SOD, ND

Surface Plots of KERF

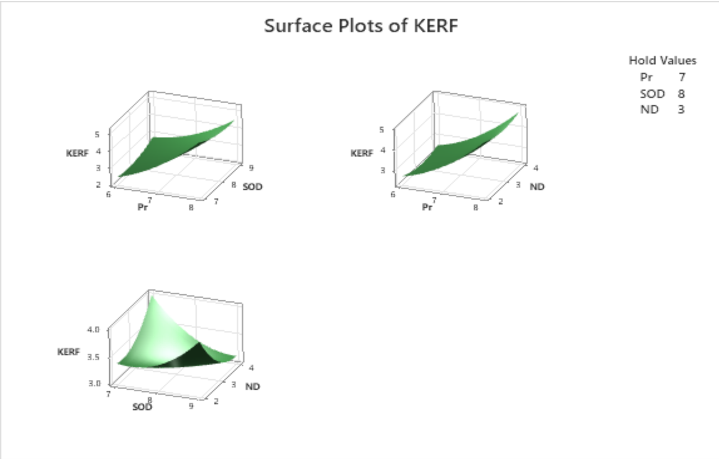

Figure 12: Surface Plot of Kerf vs Pr,SOD, ND

Validation by using ANOVA

General Linear Model: KERF vsPr, SOD, ND

Method

“Factor coding	(-1, 0, +1”)

Factor Information

“Factor	Type	Levels	Values
Pr	Fixed	3	6, 7, 8
SOD	Fixed	3	7, 8, 9”
ND	Fixed	3	2, 3, 4

Analysis of Variance

“Source	DF	Adj SS	Adj MS	F-Value	P-Value
Pr	2	10.5881	5.29407	36.30	0.000
SOD	2	0.2252	0.11258	0.77	0.494
ND	2	0.2252	0.11258	0.77	0.494
Error	8	1.1667	0.14583		
Lack-of-Fit	6	1.0000	0.16667	2.00	0.370
Pure Error	2	0.1667	0.08333		
Total	14”	12.1000			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0.381881	90.36%	83.13%	63.84%

Coefficients

“Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	3.708	0.110	33.64	0.000	
Pr					
6	-1.007	0.150	-6.70	0.000	1.24

7	-0.236	0.132	-1.78	0.113	1.25
SOD					
7	0.139	0.150	0.92	0.383	1.24
8	-0.153	0.132	-1.15	0.282	1.25
ND					
2	0.139	0.150	0.92	0.383	1.24
3	-0.153	0.132	-1.15	0.282	1.25”

Regression Equation

KERF	=	3.7081.007 Pr_6 -0.236 “Pr_7 + 1.243 Pr_8+0.139 SOD_70.153 SOD_8+0.014 SOD_9 +0.139 ND_20.153 ND_3+0.014 ND_4.”

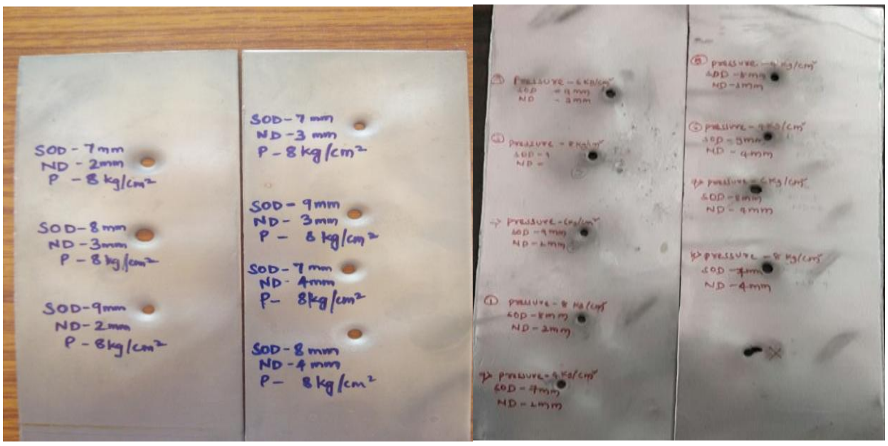

Figure 13: Haste Alloy Plates of Different Thicknesses Machined by AJM.

Conclusion

With their great efficiency and environmental friendliness, abrasive water jets are an unconventional processing method that has a big chance of becoming one of the primary technical tools for processing in the future. Using regression analysis and the response surface methodology, this investigation efficiently examines and reports on the process parameter optimization. The ideal values for achieving the most favorable response were discovered to be 8kgf/cm2 pressure, 4mm nozzle diameter, and 9mm standoff distance. The response optimization can further enhance the “outcomes. The optimization of the different process parameters was accomplished with the aid of RSM. The contribution of each Individual Parameter can be precisely calculated using ANOVA. On MRR & KERF the influence of parameters was examined applying the ANOVA module’s General Linear Model. Action at its peak is found at larger-is-better MRR was” determined to be nozzle diameter (4mm), air pressure (8kg/cm2), and SOD (9mm). Smaller is better: Where Optimal Performance is Found Air pressure (8kg/cm2), SOD (9mm), and along with nozzle diameter (3mm) were recognized as KERF. For MRR and KERF, the R-square values were 94.88% and 92.03, respectively. Significant research in AJM is demonstrated in a prior debate. Although investigators have contributed in several directions, much more work needs to be done. Such as incorporating other performance metrics or exploring alternative statistical methods for optimization.

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