Optimization of process parameters of abrasive water jet machining process for EN4 material

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Abstract
AWJM Being a relatively recent machining technology, abrasive water jet machining (AWJM) uses the impact of an abrasive substance to erode the material of the work piece. An detailed literature review that is included demonstrates the possibilities of this technique. The topic of this dissertation is water jet abrasive machines. Study is now being done to determine how Process parameters such as Stand of Distance (SOD), Traverse speed, and Abrasive flow rate affect Material Removal Rate (MRR) and Surface Roughness (Ra). The strategy was based on Taguchi's process parameter optimization method. When the experiments are finished, we will determine Surface Roughness and MRR.

Keywords: abrasive water jet machiningAWJM, Material Removal Rate (MRR), Surface Roughness

1. Introduction
1.1. Conventional Machining
During conventional machining, a work piece’s shape is often altered by an instrument composed of a harder material. Hard metals and alloys require more time and energy to manufacture using normal methods, which raises prices. In rare circumstances, conventional machining may not be possible. Because conventional machining creates residual tensions during the manufacturing process, it also costs money in terms of tool wear and product quality loss. An increasing number of people are becoming interested in non-traditional machining techniques due to the growing need for manufactured goods made of hard alloys and metals, such as titanium or Inconel 718.

1.2. Non-Conventional Machining
Non-conventional machining makes use of alternative energy sources. Two non-traditional or non-conventional machining technologies are water jet machining (WJM) and abrasive water jet machining (AWJM). They are included in the mechanical category of unconventional processes, which also includes abrasive jet machining (AJM) and ultrasonic machining (USM). The mechanical energy of water and abrasive phases is employed in these procedures (WJM and AJWM) to accomplish material removal or machining.

Classification of non-conventional machining process

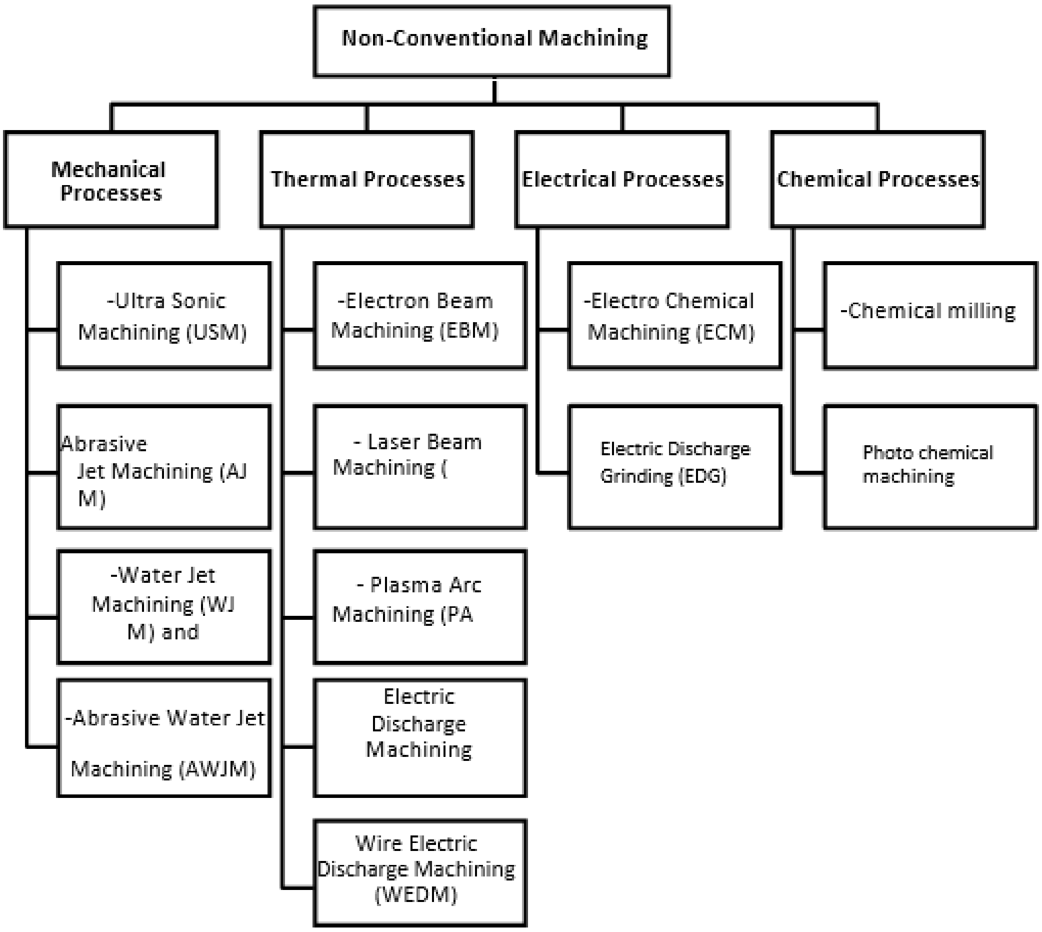

Fig 1 classification of non-conventional machining process

2. Process principal

High pressure water is blasted through a tiny hole onto a concentrated area to cut materials in abrasive water jet cutting. A water pump powers the abrasive water jet cutting machine initially. Pressurized water is pumped to the nozzle from a water tank or other water supply by the water pump. If an abrasive is used, it is typically added at the nozzle, as Figure illustrates.

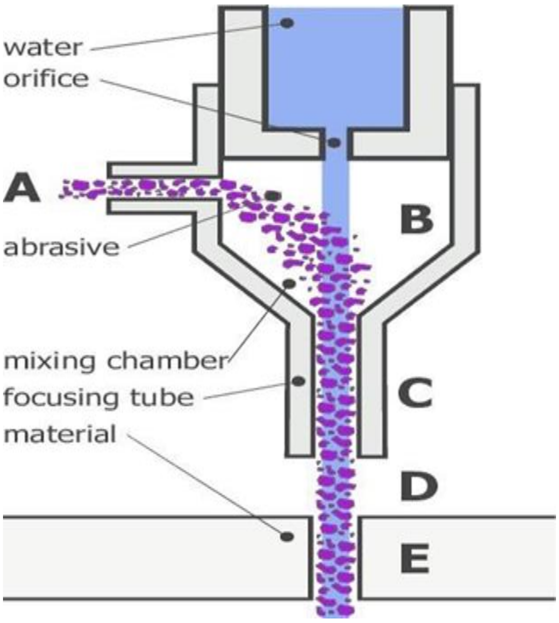

Fig 2 AWJM process

3. Literature review

A.K. Ahsan and M.A. Azmir had studied the glass/epoxy composite laminate abrasive water jet machining technique. To ascertain the impact about machining settings on surface roughness and kerf taper ratio, they employed analyses of variance and Taguchi's design of experiments. It was still able to cut when tougher abrasive materials like silicon carbide and aluminium oxide were used.

The performance of several abrasive materials, such as garnet, silicon carbide, and aluminium oxide, during abrasive water jet machining of glass, was studied by A.A. Khan and M.M. Hague. Utilising a range of parameters, including abrasive flow rate (gm/min), work feed rate (mm/min), and SOD (mm), they examined the average width and taper of cuts made with various abrasive materials. When using abrasive materials such as garnet, aluminium oxide, and silicon carbide, the taper of cut rises with SOD.

UlasCaydas and AhmetHascalik had investigated on the impact of traverse speed on Ti-6Al- 4V alloy abrasive water jet machining. They have employed abrasive water jet (AWJ) machining with traverse speeds ranging from 60, 80, 120, 150, 200, and 250 mm/min. Following machining, scanning electron microscopy (SEM) and surface profilometry were used to analyse the profiles of the machined surfaces, kerf geometries, and microstructural characteristics of the machined surfaces.

When cutting 6063-T6 aluminium alloy, J. John RozarioJegaraj and N. Ramesh Babu developed a strategy for effective and high-quality material cutting utilising abrasive water jets, taking into account variations in aperture and focusing nozzle diameter. Performance has been evaluated using a variety of criteria, including cutting efficiency, material removal rate, and depth of cut. They have experimented with varying orifice sizes and focusing nozzles to achieve variations in cut depth.

Using abrasive water jet machining, MahabaleshPalleda studied the taper angles and material removal rates of drilled holes in various chemical conditions, such as acetone, phosphoric acid, and polymer (polyacrylamide) in a 30% to 70% water ratio. By adjusting S-O-D, MRR is calculated by recording the specimen's initial and final weight and blasting time for twominutes. From there, they discovered a variety of findings maximum material removal was noted at a S O-D of 4.5mm when the slurry contained only water, 4mm when acetone was added, and 3.5mm when phosphoric acid was added. However, compared to the other three slurries with an increase in SOD, the fourth curve-which is the result of the slurry combined with polymer-shows the largest material removal.

MRR is calculated by adjusting S-O-D, noting the first and last specimen while maintaining a 2-minute blasting time, and then obtaining a variety of observations maximum material removal was noted at a S O-D of 4.5mm when the slurry contained only water, 4mm when acetone was added, and 3.5mm when phosphoric acid was added. However, the fourth curve, which results from the polymer-added slurry, has a higher.

4. Literature Review Summery

I was able to identify the gap that many academics focus on by looking at various machine components and parameters through this literature review. I discovered that a lot of factors influence the machining procedure. However, three important factors that have a significant impact on the machining process are the traverse speed (mm/min), the abrasive flow rate (gm/min), and the stand of distance (SOD in mm). I have therefore attempted to determine the goal by working with the many abrasive water jet machine parameters to optimise it. I will work on EN4 content with this task. Three process parameters, including traversal speed (mm/min), stand-off distance (SOD) (mm), and abrasive flow rate (gm/min), have been chosen by me.

5. Methodology

This project's goal is to assess AWJM's performance with EN4 material. Proper setup of the experiment is crucial to achieving this goal.-the methodology's flow chart is displayed in figure Japanese physicist Genichi Taguchi created a method based on open-ended experiments. His method has been widely applied to reduce process parameters in several technical domains. The Taguchi approach allows for the integration of DOE with parametric process optimisation. Taguchi's signal-to-noise ratio and a series of experiments with good balancing are provided by ANOVA. The goal functions for optimisation are (S/N) ratios, which are logarithmic functions representing the desired output. Learning the le parameter space requires a minimal number of experimental runs.

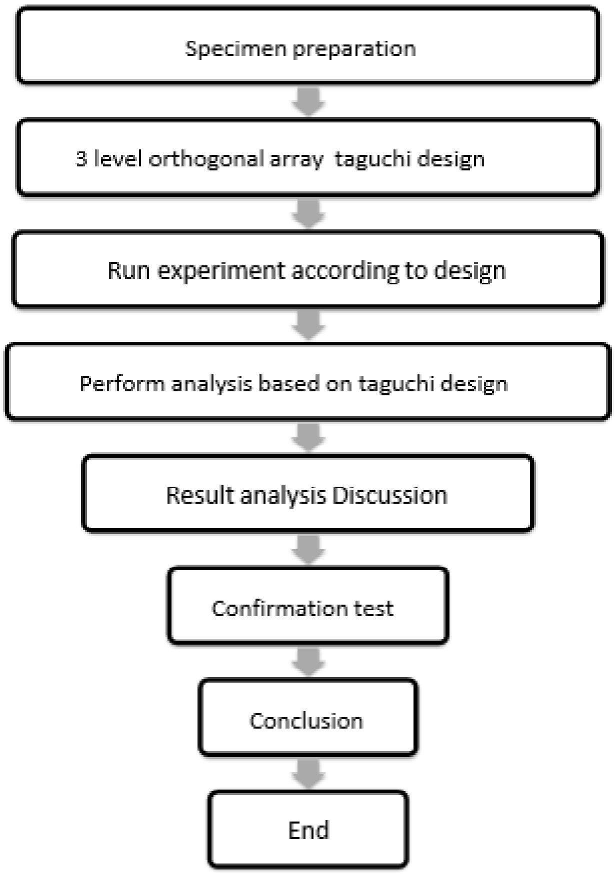

Fig 3: Methodology

6. Experiment set up

A water jet containing abrasive material is known as an abrasive water jet. Typically, the abrasive substance is introduced into the jet stream when the water shoots out of a nozzlequickly. Because the abrasive particles join the rushing water in a similar way to how passengers join a moving train, this phenomenon is frequently referred to as entrainment. As a result, the particles move by the water jet, just like in a train. On the other hand, an abrasive water jet could alternatively be described as a high-speed premature jet of abrasive. Cutting, drilling, twisting, and other machining and finishing tasks are the functions of the abrasive water jet.

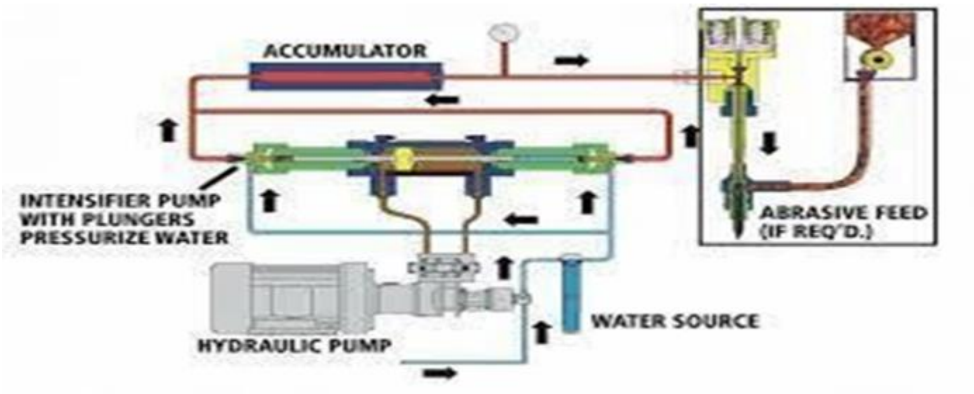

Fig 4: Working system of AWJM

The abrasive water jet's machining and finishing applications rely on the idea that the material it strikes will erode. Both the water and the abrasive substance, which make up the jet, have distinct functions in addition to supporting one another. The abrasive material in the jet stream is primarily there to supply the erosive forces. The jet's main function is to transfer the abrasive material to the work piece so that erosion can occur. The abrasive material is nonetheless also accelerated by the jet to a speed at which its impact and change in momentum might be effective. Furthermore, it serves a second purpose**.**

Table 1 factor's value

Factors	**Level1**	**Level2**	**Level3**
Traversespeed(mm/min)	50	55	60
Abrasiveflowrate(gm/min)	250	300	350
Standofdistance(mm)	2	4	6

Table 2: Result of MRR and surface roughness

Ex.No.	Process parameters			MRR(gm/min)	Surfaceroughness(µm)
	Traverse speed (mm/min)	Abrasive flow rate (gm/min)	Stand of distance(mm)		
1	50	250	2	**3.28**	**2.78**
2	50	300	4	**3.53**	**2.96**
3	50	350	6	**3.66**	**3.23**
4	55	250	2	**3.62**	**2.99**
5	55	300	4	**3.64**	**3.40**
6	55	350	6	**3.72**	**3.60**
7	60	250	2	**4.00**	**3.30**
8	60	300	4	**4.13**	**3.62**
9	60	350	6	**3.96**	**3.77**

Table 3:S N ratio for MRR and SR

Exp. No	MRR(gm/min)	SNRatio for MRR(gm/min)	Surface Roughness(µm)	SNRatioFor SurfaceRoughness
1	3.28	10.32	2.78	-8.88
2	3.53	10.96	2.96	-9.43
3	3.66	11.27	3.23	-10.18
4	3.62	11.17	2.99	-9.48
5	3.64	11.22	3.40	-10.63
6	3.72	11.41	3.60	-11.15
7	4.00	12.04	3.30	-10.34
8	4.13	12.32	3.62	-11.17
9	3.96	11.95	3.77	-11.53

7. Optimum control parameter level

The significant factor is provided by the desired response ANOVA. Consequently, the level with the highest SN Ratio is the ideal level of a significant control component. By choosingthe important control factor at its optimal level, the output parameter can be optimised. Non- significant control factors can be applied at any level.

Table 4 optimum results

Response	Traverse speed (mm/min)	Abrasiveflowrate(gm/min)	Standofdistance(mm)
MRR	60	300	4
Surface Roughness	50	250	2

8. Conclusion

Parametric analysis has been done for MRR and surface roughness on EN4 material in the current work. Using a L9 Orthogonal array, experiments are conducted with different stand- of-distance, traverse speed, and abrasive mass flow rate for EN4 material. The software Minitab 21 was utilised to examine the experimental data. Following examination, the following results were reached.

1. The effects of process parameters vary depending on the response. The behaviour of the parameter with the objective response affects the significant parameters and their percentage contribution.
2. As traversal speed increases, MRR increases as well as surface roughness increases. The most important control factor for both surface roughness and MRR during AWJM is traverse speed.
3. A higher flow rate of abrasives results in a higher MRR and less impact on surface roughness. The current investigation shows that both the abrasive mass flow rate and the abrasive flow rate have little effect on surface roughness and MRR, respectively.
4. Up to a certain point, MRR rises as SOD increases; above that point, SOD increases cause MRR to decline and Surface Roughness to increase along with SOD.The most important controlling element for surface roughness is SOD.
5. The most important control component for MRR is traverse speed; SOD and abrasive flow rate are also important controls for MRR. The most important controlling element for surface roughness is SOD.
6. An increase in the mixing ratio is accompanied by an increase in the MRR and the Surface Roughness value, which is expressed in Ra.
7. One of the most important controlling factors for Surface Roughness and MRR is the mixing ratio.

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