International Journal For Technological Research In Engineering
Volume 5, Issue 7, March-2018 *ISSN (Online): 2347 - 4718*

INVESTIGATION OF SURFACE ROUGHNESS, MATERIAL REMOVAL RATE AND KERF WIDTH ON ABRASIVE WATER JET MACHINING USING MULTI CRITERIA DECISION MAKING METHOD

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ABSTRACT: Abrasive water jet machining is a non-traditional machining Process that offers a productive alternative to traditional technique. Process parameters of machining are optimized for maximum material removal rate using Genetic Algorithm Technique. GA is a relatively new and powerful method for optimization and which is used to obtain optimum solution in given circumferences. This research work attempts to achieve maximum metal removal rate in abrasive water jet machining under all constraints which are for different process parameters such that stand off distance, Jet Pressure, Abrasive material grain size, Abrasive material . Obtained results are better than other optimization technique.
Key words: AWJM, Genetic Algorithm, MRR, Surface Roughness, Kerf Width

I. INTRODUCTION

Abrasive water jet Machining is a novel machining process capable of processing wide range of hard-to-cut materials. The cutting power is obtained by means of a transformation of a hydrostatic energy into a jet of anample kinetic energy to disintegrate the material. The required energy for cutting materials is obtained by pressurizing water to ultrahigh pressure and forming an intense cutting stream by focusing high-speed water through a small orifice. The use of the AWJM is based on the principle of erosion of the material by the impact of jets. Each of the two components of the jet, i.e. the water and the abrasive material has a specific purpose. The primary purpose of the abrasive material within the jet stream is to provide the erosive Forces. Abrasive water jet process is similar to AJM excluding that in this case water is used as a carrier fluid in place of gas. These processes offer merit of cutting electrically non conductive as well as difficult to machine materials comparatively more rapidly and efficiently than other processes. Figure 1 shows the cutting head of AWJM which includes mainly orifice abrasive mixer, focussing tube, and nozzle.

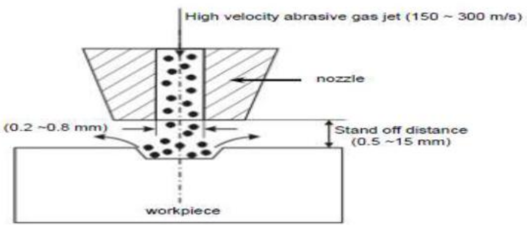

Figure 1. Cutting Mechanism of AWJM

Choi et al. (1996) it was developed the power function relationship between acoustic impression (AE) Energy and process parameter for statistical material removal rate and it validated by experimental acoustic impression (AE) Energy is higher change in the process parameter.S. Paul et al.(1998) MRR take place in AWJM of polycrystalline into two zone. In first zone material is removed by micro cutting and facturd where as the second zone material remove by plastic deformation and facturd . It was also found that experimental and model predicted data having a good correlation. Pal et al. (2014) it was found that increased in pressure material removal rate and depth increased because high kinetic energy of the jet also it was found that small compared to the large because small particle generate small unregulated of machine surface. Kartal et al. (2016)it was found that the high surface quality is achieved provision of cold machining conditions, cutting by erosion and elimination of tool wear issue have increased the quality of the surface being machined. Vasanth et al. (2016) in the present study abrasive flow rate and stand of distance has the most significant role on determining surface quality ,high abrasive flow and high stand of distance produces high surface roughness. Miao et al. (2017) it can be conclude that experimental and simulation model result shows that exit velocity reduce 50% as compare to that inlet velocity. Also simulation result shows that exit velocity 30 to 21% higher than experimental data. The comparison between two method made under the different abrasive contents. Abrasive particle transformation is more close to the experimental value.The nozzle used in the experiment, the simulation model of the nozzle is established and the internal flow field simulation is carried out. The simulation results show that the exit velocity is reduced by about 50% compared to the inlet velocity. Babu et al. (2017) it was found that decreasing in feed rate surface roughness reduced 51% angle and kerf angle 78% as compared to inter settings. Also development mathematical method R2 value found 91% It is so that sufficient to ancient the surface roughness and Kerf angle.Thus the work established with the developed mathematical model and optimal values can be employed to manufacturing industries where a tough circumstance arise and accurate profile is required in cutting mild steel Prasad et al. (2017)by the experiment work, conclude that nozzle diameter has most significant effect on the Material Removal Rate and Stand of distance has most significant effect on kerf accuracy.Maximum MRR achieve at 8 bar Air pressure, 6mm SOD, 4mm Nozzle diameter and minimum kerf

accuracy achieve at 10 bar air pressure, 3mm SOD, 3mm Nozzle diameter. Ti-6Al-4V is effectively machined on abrasive jet machine and effect of their process parameters on the material removal rate is analyzed by using Taguchi and ANOVA. By the experimental work, it is noted and concluded that, nozzle diameter has the most significant effect on the metal removal rate.
In optimizing the machining process parameters, the selection of machining process parameters is a very crucial part in order for the machine operations to be successful.

II. SOLUTION METHODOLOGY

In many industries of manufacturing, the parameter setting is made based on the skill and experience of the machinist or based on the handbook recommendations. However, due to this, optimum parameter setting is not achieved which leads towards poor quality, reduced production, and increased cost of product. Input Parameter of AWJM considered in this study such stand off distance, Jet Pressure, Abrasive material grain size, Abrasive material and Output Parameter selected as Kerf width, Material Removal Rate, Surface Roughness.
Objective functions:

$$MRR = \frac{W_b - W_a}{\rho T} \qquad (1)$$

Where, W_a = Weight after Experiment
W_b = Weight before Experiment
T= Time taken to cut.
ρ= Density of material 2.825* 10^{-3} g/mm^3
Surface Roughness Measurement:
Surface of machined side of workpiece measured by the Surface Tester.
Kerf width:
It is the width of material that is removed by a cutting Process. Kerf width is measured by Traveling microscope.
Genetic Algorithm Genetic algorithm is based on the strategy of model development base on genetic evolution mechanism based on Darwinian Theory for selection procedure to explore a given search space. The algorithm is provided with a set of possible solutions which is represented by chromosomes termed a population. Solution from one population is taken and used to form a new population. This is motivated by a hope that the new population will better than its predecessor generation. Solutions chosen to form new solutions are selected based on their fitness. The more suitable they are, the better their chances of being reproduced. This process of selection will repeat till some predetermined condition based on, the number of populations or for instance, is satisfied. Procedure for solving the discrete optimization problem mentioned using GA is illustrated in Figure.

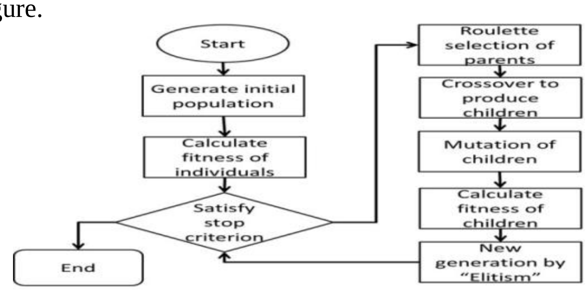

Figure 2: Flow chart of GA

Function preparation:
Function prepared for multi objective optimization problem by normalizing and combining the function. Function is normalized by weighted average normalizing method.

There are three objective functions Material Removal Rate (MRR), Surface Roughness (SR), Kerf Width (KW). This objective is also conflict each other because MRR is maximizing function and surface roughness and kerf width is minimizing function. So this MRR, SR and KW is normalized and combined as per weighted average normalizing method as per below,

$$\text{Normalized function } Y = W1\frac{MRR}{min.MRR} + W2\frac{max.SR}{SR} + W3\frac{max.KW}{KW} \qquad (2)$$

Where Weight (W1+W2+W3) = 1
Here W1=W2=W3=1/3

Normalized function Y is maximizing problem for MATLAB it must be converted to minimization problem. For convert maximization problem to minimization problem the function is inverted.

$$\text{Combined objective function } y = \frac{1}{combined\ \ normalized\ \ function\ \ Y} \qquad (3)$$

III. PROBLEM DEFINITION

Material removal rate maximization in AWJM and kerf width, surface roughness minimization in AWJM. Process parameters such as stand off distance, Jet Pressure, Abrasive material grain size, Abrasive material are to be used for this work. Al+ Al_2O_3 is work material and abrasive particle is SiC, Garnet, Al_2O_3.

Table 1 shows the Machine Specification and Range

Table1 Specifications of FLOW MACH2 Machine

Specifications	
Parameters	Range
Pump Pressure	60,000 psi
Cutting Area	1.3m x 1.3m (4ft x 4ft) to 4m x 2m (13ft x 6.5ft)
Accuracy	±0.127 mm per 1m (0.005 in per 3ft)
Cutting Speed	101.6 mm/min
Rapid Traverse maximum Speed	10 m/min
Axis of Rotation	2 Axis rotated Automatically (X-Axis, Y-Axis) 1 Axis rotated Manually (Z-Axis)
Abrasive Material	Garnet, Aluminum Oxide, Silicon Carbide

Table 2 shows different parameters which are to be considered as control parameters with its ranges.

Table 2 Parameters with range

Factors	Unit	Level		
Stand off Distance (A)	[mm]	2	4	6
Jet Pressure (B)	[N/mm²]	344	358	372
Abrasive Material Grain Size (C)	[Mesh]	2	4	6
Abrasive Material (D)	-	Garnet	Aluminum Oxide	Silicon Carbide

IV. RESULT AND DISCUSSION

Following optimum solution was obtained from following,

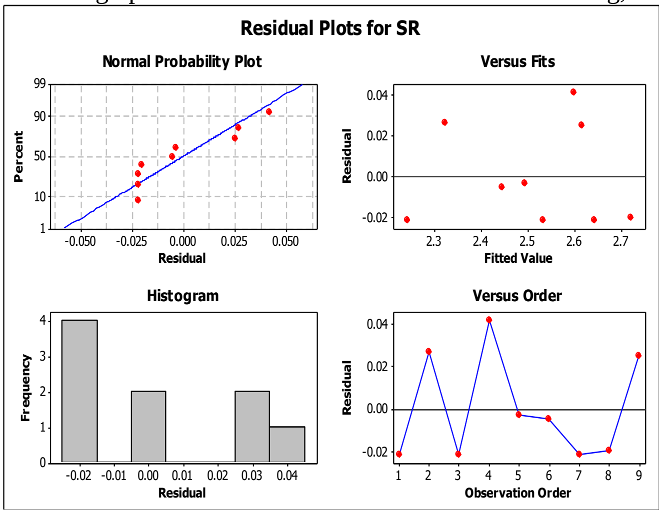

Figure 2: Residual Plots for Surface Roughness

Here R-square value of regression is 97.50 % that means mathematical model derive by regression is 97.50 % agree with the experimentation result.

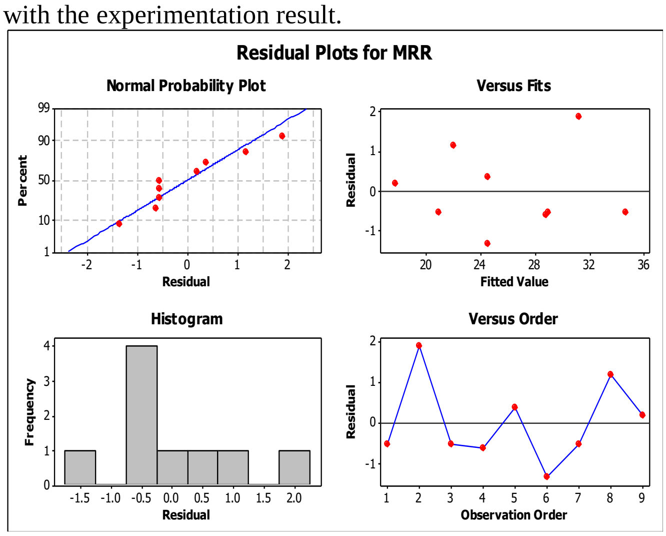

Figure 3: Residual Plots for MRR

Here R-square value of modeling is 96.62 % it means that mathematical modeling derived is 96.62 % agree with experimentation results.

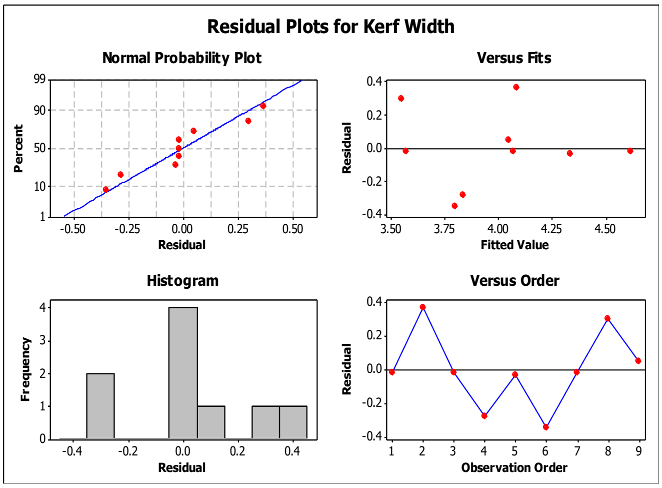

Figure 5.5: Residual Plots for Kerf Width

Here R-square value of the mathematical model is 69.03 % it means that mathematical model derived is 69.03 % agree with the experimentation result.

Signal to Noise Ratio & Analysis of Variance (ANOVA)

- Signal to noise ratio is define the term signal represents the desirable value (mean) for the output characteristic and the term noise represents the undesirable value for the output characteristic.
- Higher is better

$$S/N_{lb} = -10\log_{10}\left(\frac{1}{r}\sum_{i=1}^{n}\frac{1}{y_i^2}\right)$$

Smaller is better

$$S/N_{sb} = -10\log_{10}\left(\frac{1}{r}\sum_{i=1}^{n}y_i^2\right)$$

Table 5: Optimal Condition for MRR, SR and KW from SN Ratio

Material Removal Rate (mm³/min) Larger is Better Surface Roughness (μm) and Kerf Width (mm) Smaller is Better				
Output	Stand -off Distance (mm)	Jet Pressure (N/mm²)	Abrasive Material Grain Size (Mesh)	Abrasive Material
MRR	2	358	6	Sic
SR	2	372	6	Al2O3
KW	4	372	2	Sic

V. CONCLUSION

- Genetic Algorithm is powerful optimization technique, used for optimizing the MRR, kerf width, surface roughness of Abrasive water jet machining.
- Better solution was found in each iteration and after no. of iteration it's become steady.
- Results obtained by Genetic Algorithm is better than other optimization technique.

Appendix A : MT Lab Code For Genetic Algorithm Equation

y_{Garnet} =1./((0.6144).*((41.364 -(2.85833.*x1)-(0.0215476.*x2)+(0.375.*x3))./17.28)+(0.2682).*(2.70./(4.5

4643+(0.055.*x1)-(0.00559524.*x2)-(0.045.*x3))+(0.1172).*(4.60/(3.54286+(0.0416667.*x1)-(0.00119048.*x2)+(0.175.*x3)));

y_{Al2O3}=1./((0.6144).*((43.1074 -(2.85833.*x1)-(0.0215476.*x2)+(0.375.*x3))./17.28)+(0.2682).*(2.70./(4.39643+(0.055.*x1)-(0.00559524.*x2)-(0.045.*x3))+(0.1172).*(4.60/(3.72619+(0.0416667.*x1)-(0.00119048.*x2)+(0.175.*x3)));

y_{SiC}=1./((0.6144).*((46.1074 -(2.85833.*x1)-(0.0215476.*x2)+(0.375.*x3))./17.28)+(0.2682).*(2.70./(4.4831+(0.055.*x1)-(0.00559524.*x2)-(0.045.*x3))+(0.1172).*(4.60/(3.37619+(0.0416667.*x1)-(0.00119048.*x2)+(0.175.*x3)));

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