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Optimization of Abrasive Water Jet Machine Process Parameter for AL-6351 using Taguchi Method

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Abstract: Abrasive Water jet (AWJ) Machining is a recent non-traditional machining process. Major part of this technology is a very high-pressure beam of water and abrasives, which is used for machining. Abrasive water jet cutting of material involves the effect of a high pressure velocity jet of water with entrained abrasive particles on to material to be cut. This technology is widely used in industry for cutting difficult-to-machine materials, milling slots, polishing hard materials, cleaning contaminated surfaces, etc. In the present study commercially three different materials AL-6351 is machined with the abrasive water jet machine. Experimental investigations should conduct to assess the influences of Abrasive water jet machining (AWJM) process parameter on surface roughness. The approach is based on Taguchi's method to optimize the AWJM process parameter for effective machining. It was found the process parameters are stand-off-distance from the work surface; work feed rate, jet pressure Abrasive type are effective to evaluate criteria of the work surface roughness. The Experiment will be conducted at "SUNCORE ENGINEERING INDIA" Manjusar G.I.D.C Vadodara. AL-6351 is select as work piece material and will be machined under abrasive water jet machine model DWJ 2030-FB.The effect of various parameters as Traverse Speed, Abrasive flow rate, and standoff distance will be checked on output parameter like surface roughness measured by Surface Roughness Tester TR100. The Taguchi method will be used for designing the experiment and optimum result can be achieved through ANOVA and Compare it With Minitab 16 at the end.

Keywords: Abrasive Water Jet machine, Al-6351, Taguchi Method.

I. Introduction:

Abrasive Water jet (AWJ) Machining is a recent non-conventional machining process. In this technology, a very high-pressure beam of water and Abrasives are used for machining. This technology is widely used in industry as it has many advantages. In this chapter an introduction to Abrasive Water jet (AWJ) Technology is provided. A review of the AWJ history is first carried out to draw a picture of the progress in this technology. Brief descriptions of the schema and the main components of an AWJ system are also given. Advantages and drawbacks of the AWJ technology are then evaluated. There are two types of water jets: pure (or plain) water jet and abrasive water jet. In pure water jet cutting, only a pressurized stream of water is used to cut through materials. This type of cutting is used to cut soft materials such as card board, leather, textiles, fiber plastics, food or thin plates of aluminum. The abrasive particles are accelerated by the water stream and then leave the focusing tube (or the nozzle) with the stream. AWJ cutting is used for cutting harder materials such as stainless steel, glass, ceramics, titanium alloys, composite materials, and so forth consists of four main parts: the water preparation system, the pressure generation system, the jet former, and the abrasive supply system.

Advantages of AWJ Technology

- AWJ can machine a wide range of materials including titanium, stainless steel, aerospace alloys, glass, plastics, ceramics, and so on.
- AWJ can cut net-shape parts and near net-shape parts.
- Only one nozzle can be used for machining.

II. Literature Survey:

Jiuan-Hung Kea, Feng-Che Tsaia, and Jung-Chou Hungb. "Characteristics study of Flexible Magnetic abrasive in Abrasive jet machining". In the present research, they had present a novel hybrid method that self-made magnetic abrasive with elasticity was utilized to investigate machining characteristics in abrasive jet machining. According to Taguchi method and experimental results, flexible magnetic abrasive is adopted in abrasive jet machining not only restrains the abrasive jet direction to enhance more uniform main processing area and material removal rate but also has slip-scratch effect to obtain better surface roughness than traditional machining. With the help of flexible magnetic abrasive we can obtain better surface roughness than traditional machining, and it (flexible magnetic abrasive) is use used for restrains the abrasive jet direction for more uniform processing area and material removal rate. Magnetic field is main factor for surface roughness (Ra), material removal rate (MRR). [1]

M.A Azmir ,A.K Ahsan and A Rahmah, "Investigation on abrasive water jet machining of Kevlar Reinforced Phenolic Composite using Taguchi approach" Experimental investigations were found the influence of Abrasive Water Jet Machining (AWJM) process parameters on surface roughness (Ra) and kerf taper ratio (TR) of aramid fiber reinforced plastics (AFRP) composite. The approach was based on Taguchi's Method and Analysis of Variance (ANOVA) to optimize the AWJM process parameters for effective machining. It was found that traverse rate was considered to be the most significant factor followed by hydraulic pressure in influencing the Ra quality criteria. In case of TR, traverse rate showed the greatest influence by standoff distance. It was also confirmed that increasing the kinetic energy of water jet may produce a better quality of cuts. It was confirmed that determined optimal combination of AWJM parameters satisfy the real need for machining of AFRP composites in practice. They have concluded that Traverse rate is the Most significant factor On surface roughness During AWJM while standoff distances and abrasive mass flow rate are the insignificant control factor on surface roughness (Ra). By applying the optimal setting to the Experiments there are considerable improvement in the process. [2]

Vaibhav.j.Limbachiya, Prof Dhaval.M.Patel. "An investigation of Different Material on Abrasive water jet machine". Theoretical MRR found equal to the experimental MRR. In this paper investigation for three different materials like en8, acrylic and aluminum is carried out using Taguchi design of experiment method. Experiments are carried out using L25 Orthogonal array by varying Material traverse speed and abrasive mass flow rate for each material respectively. Anova carried out for identifies significant parameters. Both factor, Traverse speed and Abrasive mass flow rate are affecting MRR of each material. Clearly define that increasing Traverse speed and abrasive mass floe rate, will directly increasing MRR. [3].

D.K.Shanmugam, S.H.Masood. "Investigation on Kerf characteristic in abrasive water jet cutting of layered composite." Layered composites are "difficult-to-machine" materials as it is inhomogeneous due to the matrix properties, fibre orientation, and relative volume fraction of matrix. Abrasive water jet cutting has proven to be a viable technique to machine such materials compared to conventional machining. This paper presents an investigation on the kerf taper angle, an important cutting performance measure, generated by abrasive water jet (AWJ) technique to machine two types of composites: epoxy pre-impregnated graphite woven fabric and glass epoxy. This paper presents the investigated results on machining of two types of composite 1) Epoxy pre-impregnated graphite woven fabric 2) Glass epoxy on CNC abrasive water jet machine. The effects of the different parameters Abrasive flow rate (g/s), Standoff distances(mm), Traverse Speed(mm/s), Water pressure (Mpa) on the response characteristics Kerf taper angle are explained. Recommended condition is to maintain high water pressure (Mpa), low traverse speed (mm/s) & low standoff distance (mm) to minimize kerf taper angle. [4]

Ahmet Hascalik, Ulas Cayds, Hakan Gurun, "Effect of Traverse speed on Abrasive in Abrasive jet machining of Ti-6Al-4V alloy". In the presented study, Ti–6Al–4V alloy, known as one of the difficult-to-machine materials using conventional machining processes, was machined under varying traverse speeds of 60, 80, 120, 150, 200, and 250 mm/min by abrasive water jet (AWJ) machining. After machining, the profiles of machined surfaces, kerf geometries and micro structural features of the machined surfaces were examined using surface profilometry and scanning electron microscopy. The aim of this study is to investigate experimentally the profiles of machined surfaces, kerf geometries and micro structural features of the machined surfaces in terms of traverse speed in AWJ-machined Ti–6Al–4V alloy. In fact Higher Traverse speed or increasing gradually in AWJM gives narrower kerf width with grater kerf taper ratio. Surface roughness is approximately constant. [5]

III. Summary and Discussion:

Very few researcher has used the AL-6351 material for study on Abrasive water jet machining process. So now we will doing experimental work with using AL-6351 material by adopting Taguchi experimental design.

IV. Material and Method:

Aluminum alloys tend to lose their strength when they are exposed to temperatures of about 200-250°C. However, their strength increases at subzero temperatures. They have high corrosion resistance. AL-6351 is commonly used for Aircraft parts like wings, fuelslage. AL-6061 has Tensile strength 96.5Mpa, Tensile Yield strength 250 Mpa and Hardness is 90. It is highly resistant to weather conditions. It is suitable for most of Marine application and piping and tubing for industrial work.

Table 1 Physical Properties of AL-6351

Density (g/cm^3)	Ultimate tensile Strength (Mpa)	Elasticity of Moduls (Gpa)	Machinability %	Use Temp(C^o)
2.6-2.8	250	70 - 80	50	180

A methodology for the design of an experiment is proposed in order to find as many schemes as possible with the maximum number of factors with different levels for the smallest number of experimental runs. The abilities in generation of the largest groups of orthogonal arrays were analyzed for experimental runs of 4, 6, 8, 9, 10, 12, 14, 15, and 16. The results show that the proposed method permits the construction of the largest groups of orthogonal arrays with the maximum number of factors. The orthogonal arrays used by the Taguchi approach allow the study of the simultaneous effect of several factors efficiently, providing better results in smaller number of experiment.

Steps in Taguchi Method

1. Problem Identification
2. Brainstorming Session (Identify: Factors, Factor settings, Possible interaction, Objectives)
3. Experimental Design (Choose orthogonal array, Design experiment)
4. Run Experiments
5. Analyze Results
6. Confirmation Runs

Table 2 : Level of Experiment

Factor	**Column**	**Level 1**	**Level 2**	**Level 3**
Traverse Speed (mm/min)	A	300	400	500
Abrasive Flow Rate (gm/min)	B	200	300	400
Stand of Distance (mm)	C	2	3	4

Table 3: L9 Orthonogonal array (Experiment)

Experiment no.	**Cutting Speed(mm/min)**	**Abrasive Flow Rate(gm/min)**	**Stand of Distance(mm)**
1	300	200	2
2	300	300	3
3	300	400	4
4	400	200	3
5	400	300	4
6	400	400	2
7	500	200	4
8	500	300	2
9	500	400	3

Figure 1 Specimens after Machining for AL-6351

V. Analysis of Result:

Table 4: Result table

Experiment no.	Cutting Speed(mm/min)	Abrasive Flow Rate(gm/min)	Stand of Distance(mm)	SR(µm)_AL-6351
1	300	200	2	6.302
2	300	300	3	7.048
3	300	400	4	6.284
4	400	200	3	4.934
5	400	300	4	6.222
6	400	400	2	4.894
7	500	200	4	6.006
8	500	300	2	4.746
9	500	400	3	5.262

In design of experiment the results are analyzed due to one or more of the following three objectives.

1. To establish the best or the optimum condition for a product or a process.
2. To estimate the contribution of individual factors.
3. To estimate the response under the optimum conditions.

The optimum condition is identified by studying the main effects of each of the factors. The main effects indicate the general trends of the influence of the factors. Knowing the characteristics, i.e., whether a higher or lower value produces the preferred results, the level of the factors which are expected to produce the best results can be predicted. The knowledge of the contribution of individual factors is a key to deciding the nature of the control to be established on a production process.

VI. Analysis of variance (ANOVA) Terms & Notations:

n = numbers of trails
C.F. = correction factor e = Error
F = variance ratio
f = Degree of freedom
fe = Degree of freedom of error
r = Number of repetition
P = Percent contribution
T = Total of results
S = Sum of squares
S‟= Pure sum of squares
V = Mean squares (variance)
f t = Total degree of freedom
Σ yi = sum of all output values

Table 5: Response Table for Signal to Noise Ratios (Smaller is better)

Level	A	B	C
1	-16.30	-15.14	-14.44
2	-14.51	-15.46	-1508
3	-14.51	-14.73	-15.81
Delta	1.80	0.73	1.37
Rank	1	3	2

- Analysis of Variance tables for the effect of parameter on Surface roughness. Minitab software significant parameters can be easily identified and also find the rank order. Traverse speed hasp-value almost <0.05, hence it is significant parameter. Traverse speed affect for response -surface roughness. Abrasive flow rate has little effect over the surface roughness.
- Stand off distance is also significant parameter but not as much as traverse speed.
- Rank order as per the significance level is that Traverse speed, Standoff Distance and Abrasive Flow rate. The requirement of the optimum level can be decide by SN ratio plot.
- Here, the maximum % contribution in all three parameter is of Traverse Speed 56 %.

VII. Effect of Traverse speed, Abrasive mass flow rate and SOD on Surface Roughness:

In the investigation on the effect of Traverse speed during AWJM of AL-6351, it found from the analysis plot that when the Traverse speed increases the Surface roughness of AL-6351 material Reduces, an increase in Traverse speed and abrasive flow rate leads to a little reduce in the Surface roughness, and Increase in Standoff Distance increase Surface Roughness little. Shown in figure no.2

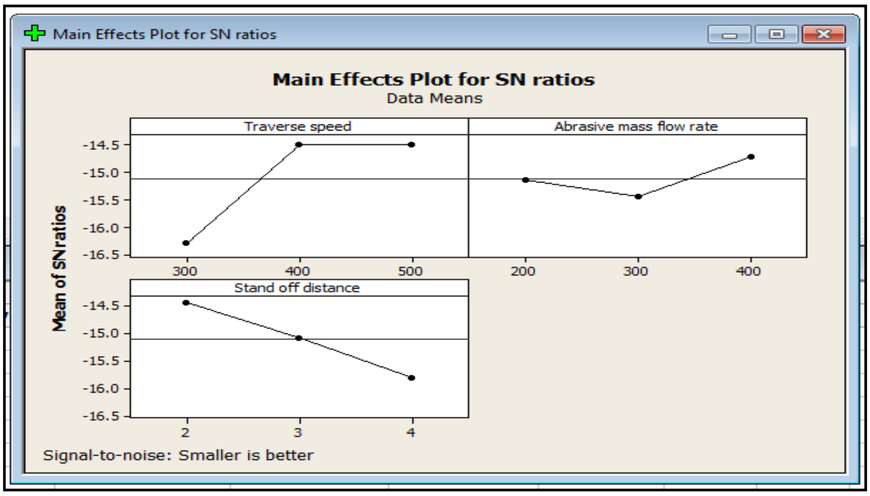

Figure:2 Effect of Traverse speed, abrasive mass flow rate and Stand off distance Vs Surface Roughness for AL-6351

On the basis of experimental results, analysis of variance (ANOVA) and the effect of machining parameters on Surface Roughness the conclusions can be drawn for effective machining of AL-6351 by AWJM process as follows:

1. Increasing the Traverse speed improve Surface Roughness of machining performance.
2. Optimize process parameter can be seen from graph are Traverse speed 400mm/min, Abrasive flow rate 400 gm/min, and SOD 2 mm.

VIII. Regression Analysis:

The regression equation is surface roughness of
AL-6351 = 6.71 - 0.00445 Traverse speed - 0.00133 Abrasive flow rate
+ 0.429 Stand off distance
The Parameter R2 describes the amount of variation observed in cutting force is explained by the input factors. R2 = 60.0 % indicate that the model is able to predict the response with high accuracy. Adjusted R2 is a modified R2 that has been adjusted for the number of terms in the model. If unnecessary terms are included in the model, R2 can be artificially high but adjusted R2(=35.9 %.) may get smaller. The standard deviation of errors in the modelling, S= 0.6502. Comparing the p-value to commonly used α-level = 0.05, it is found that if the p-value is less than or equal to α, it can be concluded that the effect is significant, otherwise it is not significant. So it can be said that Except Surface Roughness, all parameters are significant.

IX. Conclusion:

In the present study a parametric analysis carried out for Surface roughness for the AL-6351 material. The experiments were conducted under various parameters setting. L9 Orthogonal Array based on Taguchi design was performed. Minitab 16 software was used for analyze the result and theses responses were partially validated experimentally. Following conclusion drawn after analysis. Process parameters affect the response in different ways. Hence need to set parameter based on requirement.

1) The type of Traverse Speed is the most significant control factor for Surface Roughness (Ra) of Al-6351 on AWJM. Meanwhile Abrasive Flow rate (mm/s) and SOD (mm) are less significant.
2) Optimize process parameter of Al-6351 can be seen from graph are Traverse speed 400mm/min, Abrasive flow rate 400 gm/min, and SOD 2 mm.

REFERENCES

1) Jiuan-Hung Kea, Feng-Che Tsaia, and Jung-Chou Hungb "**Characteristics study of Flexible Magnetic abrasive in Abrasive jet machining**" Science direct (2012).

2) M.A Azmir,A.K Ahsan, A Rahmah "**Investigation on Abrasive water jet machining of Kevlar reinforced phenolic composite using Taguchi approach**" International conferences on mechanical engineering (2007)

3) Vaibhav.j.limbachiya, Prof Dhaval.M.Patel "**An Investigation of Different Material on Abrasive Water jet Machine**" International Journal of Engineering Science and Technology (IJEST)(2011)

4) D.K. Shanmugama, S.H. Masoodb "**An investigation on kerf characteristics in abrasive water jet cutting of layered composites**" Journal of materials processing technology 2 0 9 (2 0 0 9) 3887–3893

5) Ahmet Hascalik, Ulas caydas, Hakan Gurun "**Effect of traverse speed on abrasive water jet machining of Ti-6Al-4V alloy**" Science Direct.Com,Material and Design 28 (2007) 1953-1957

WEBSITES

6) http://www.waterjet.co.in

7) http://www.stal.com.cn/pdffile/316316l317317l.pdf

8) http://www.suppliersonline.com/propertypages/316.asp

9) http://www.azom.com/article.aspx?ArticleID=6648

10) http://www.sadhanafibre.com/fiber-glass-sheet.html

11) http://www.sadhanafibre.com/fiber-glass-sheet.html

12) http://en.wikipedia.org/wiki/SAE_steel_grades

13) www.sciencedirect.com

BOOKS

14) Ranjit K. Roy**, "Design of experiments using the Taguchi approach: 16 steps to product & process improvement"**, Jony wiley and sons. Inc 2001

15) P.K.Mishra, "**Non conventional machining**"

16) "**Design Of Experiments**" JMP, A Business Unit of SAS SAS Campus Drive Cary, NC 27513

17) "MINITAB 16" software

