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OPTIMIZATION OF ABRASIVE WATER JET MACHINING PARAMETERS USING TAGUCHI TECHNIQUE FOR AL MATERIAL REINFORCED WITH SiC

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ABSTRACT

In this thesis, different experiments are performed on Aluminum Alloy 6061 mixed with SiC by varying machining parameters such as Abrasive Flow Rate, Nozzle distance and pressure (i.e) Nozzle to work piece distance to determine surface Roughness. Optimization is done using L9 orthogonal array by Taguchi technique to determine better parameters to obtain minimum surface roughness. The parameters considered are Abrasive flow rate 200g/min, 300g/min, 400g/min, Nozzle distance 1.5mm, 2mm, 2.5mm and Pressure 30kpsi, 50kpsi, 70kpsi. Optimization of machining parameters using Taguchi Technique is done in Minitab 17.

INTRODUCTION

This novel technology was first initiated by Franz to cut laminated paper tubes in 1968 and was first introduced as a commercial system in 1983. In the 1980s garnet abrasive was added to the water stream and the abrasive jet was born. In the early 1990s, water jet pioneer Dr. John Olsen began to explore the concept of abrasive jet cutting as a practical alternative for traditional machine shops. His end goal was to develop a system that could eliminate the noise, dust and expertise demanded by abrasive jets at that time. In the last two decades, an extensive deal of research and development in AJM is conducted.

PROCESS

In Abrasive jet machining abrasive particles are made to impinge on work material at high velocity. Jet of abrasive particles is carried by carrier gas or air. The high velocity stream of abrasives is generated by converting pressure energy of carrier gas or air to its Kinetic energy and hence high velocity jet. Nozzles direct abrasive jet in a controlled manner onto work material. The high velocity abrasive particles remove the material by micro-cutting action as well as brittle fracture of the work material.

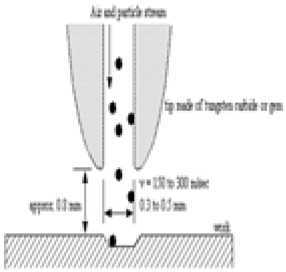

Fig – Principle of Abrasive Jet Machining

INTRODUCTION TO TAGUCHI METH OD

Every experimenter has to plan and conduct experiments to obtain enough and relevant data so that he can infer the science behind the observed phenomenon. He can do so by,

Trial –and - error approach

Performing a series of experiments each of which gives some understanding. This requires making measurements after every experiment so that analysis of observed data will allow him to decide what to do next:

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"Which parameters should be varied and by how much". Many a times such series does not progress much as negative results may discourage or will not allow a selection of parameters which ought to be changed in the next experiment. Therefore, such experimentation usually ends well before the number of experiments reaches a double digit! The data is insufficient to draw any significant conclusions and the main problem (of understanding the science) still remains unsolved.

Design of experiments

A well planned set of experiments, in which all parameters of interest are varied over a specified range, is a much better approach to obtain systematic data. Mathematically speaking, such a complete set of experiments ought to give desired results.

Usually the number of experiments and resources (materials and time) required are prohibitively large. Often the experimenter decides to perform a subset of the complete set of experiments to save on time and money! However, it does not easily lend itself to understanding of science behind the phenomenon. The analysis is not very easy (though it may be easy for the mathematician/statistician) and thus effects of various parameters on the observed data are not readily apparent. In many cases, particularly those in which some optimization is required, the method does not point to the BEST settings of parameters. A classic example illustrating the drawback of design of experiments is found in the planning of a world cup event, say football. While all matches are well arranged with respect to the different teams and different venues on different dates and yet the planning does not care about the result of any match (win or lose)!!!! Obviously, such a strategy is not desirable for conducting scientific experiments (except for coordinating various institutions, committees, people, equipment, materials etc.).

LITERATURE REVIEW

In this review the experimental analysis of Abrasive jet machining is discussed. The experimentations conducted by various researchers by influencing the abrasive jet machining (AJM) process parameters on material removal rate, Surface integrity, kerf are discussed. The parameters like SOD, Carrier gas, Air Pressure, Type of Abrasive, Size, Mixing Ratio etc. are focused.

P. Jankovi´c[1], the research aim was connected with the demands of industry, i.e. the end user. Having in mind that the conventional machining processes are not only lagging behind in terms of quality of cut, or even some requests are not able to meet, but with the advent of composite materials were not able to machine them, because they occurred unacceptable damage (mechanical damage or delamination, fiber pull-out, burning, frayed edges).

Dr. A. K. Paul et al.[2] carried out the effect of the carrier fluid (air) pressure on the MRR and the material removal factor (MRF) have been investigated experimentally on an indigenous AJM set-up developed in the laboratory. Experiments are conducted on Porcelain with silicon carbide as abrasive particles at various air pressures. It was observed that MRR has increased with increase in grain size and increase in nozzle diameter. The dependence of MRR on stand-off distance reveals that MRR increases with increase in SOD at a particular pressure.

Dr. M. Sreenevasa Rao [3] reviewed that Ingulli C. N. (1967) was the first to explain the effect of abrasive flow rate on material removal rate in AJM. Along with Sarkar and Pandey (1976) concluded that the standoff distance increases the MRR and penetration rate increase and on reaching an optimum value it start decreasing. J. Wolak (1977) and K. N. Murthy (1987) investigated that after a threshold pressure, the MRR and penetration rate increase with nozzle pressure. The maximum MRR for brittle and ductile materials are obtained at different impingement angles. For ductile material impingement angle of 15-20 results in maximum MRR and for brittle material normal to surface results maximum MRR.

X. P. Li et al. [4] stated that during cutting of work piece, reinforcement particles made impact on surface of the work which causes wear of work specimen. These particles get dislodged in material surface. It is reported that pressured air approach minimizes the tool wear and also prevent of particles from being embedded in work piece .Experimental tests for cutting of SiC-Al has been carried out with tungsten carbide tool with or without the aid of the pressured air jet are conducted. It shows that pressured air jet method significantly minimize the wear of work piece.

Manabu Wakuda et al. [5] reported that the material response to the abrasive impacts indicates a ductile behavior, which may be due to the elevated temperature during machining. Chipping at the peripheral region of the dimples was found for coarse-grained alumina samples. The use of synthetic diamond abrasive is a possible choice if high machining efficiency is desired. However, the machined surface reveals a relatively rough appearance as a result of large-scale intergranular cracking and subsequent crushing.

A. Ghobeity et al. [6] have experimented on process repeatability in abrasive jet machining. They mentioned that many applications have several problems inherent with traditional abrasive jet equipment. Poor repeatability in pressure feed AJM system was traced to uncontrolled variation in abrasive particle mass flux caused by particle packing and local cavity formation in reservoir. Use of mixing chamber improved the process repeatability. For finding out process repeatability they measured depth of machined channel.

EXPERIMENTAL METHODLOGY

EXPERIMENTAL SET-UP

Experimentation is conducted by machining composite work pieces by varying the process parameters considered Abrasive flow rate nozzle Distance (distance between nozzle and work piece) and pressure and their performance is measured by determining material removal rate and Surface Roughness.

Water is an accelerating medium which is compressed to very high pressures up to 1,00,000 psi or more than that with the help of an Intensifier pump. On this, water will try to escape somewhere because of its incompressible property. This highly pressurized water is directed along high pressure piping through an orifice having very small diameter in between 0.0005 mm to 0.15 mm. The velocity of pressurized water is double the speed of sound. A mixing tube is employed after an orifice. The water create a vacuum that will pull the abrasives from a hopper. So, the jet is ready to cut any material. This prepared jet when comes along the material, it cuts some portion of the material having fine quality. This depends on thickness of material, speed of cut and type of garnet used. The difference between the size of kerf and width of tube orifice is 10 % and kerf is always greater than tube orifice. Nozzle is an important part of AWJM through which the pressurized abrasive water jet comes outside the machine to cut the material. The distance between nozzle tip and work piece surface is called “Stand-off distance”.

WORK PIECE SIZE

Rectangular piece of composite materials i.e. Al 6061 mixed with SiC material are taken

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and machined using water jet machining by varying the process parameters abrasive flow rate, nozzle distance (i.e) distance between nozzle and work piece, Pressure.
Nozzle diameter = 1.1mm
Abrasive size = 80 mesh [garnet]
Orifice = 0.35 mm
Machine guage length = 3×1.5m
Coolant = Ro-purified water

S.NO.	PROCESS PARAMETERS	LEVEL 1	LEVEL 2	LEVEL 3
1	ABRASIVE FLOW RATE (g/min)	200	300	400
2	NOZZLE DISTANCE (mm)	1.5	2	2.5
3	PRESSURE (kpsi)	30	50	70

The parameters are varied as per L9 orthogonal array using Taguchi Technique.

EXPERIMENTATION PHOTOS

Fig – Setting of work piece on the machine

Fig – Garnet Mesh Size

Fig – Cutter at the zero position

OPTIMIZATION OF MACHINING PARAMETERS FOR LESSER SURFACE ROUGHNESS USING MINITAB SOFTWARE

SR

In this project, Taguchi method is used to optimize the process parameters Transverse speed, Abrasive flow rate and Nozzle Standoff Distance for lesser surface roughness. The optimization is done in Minitab 17 software.

Job No.	Abrasive Flow Rate (g/min)	Nozzle Distance (mm)	Pressure (MPa)	Surface Finish Values R_a µm
1	200	1.5	30	2.77
2	200	2.0	50	3.47
3	200	2.5	70	2.97
4	300	1.5	50	3.75
5	300	2.0	70	3.05
6	300	2.5	30	2.09
7	400	1.5	70	3.43
8	400	2.0	30	3.00
9	400	2.5	50	3.92

Table – Measured Surface Roughness values for experimental data

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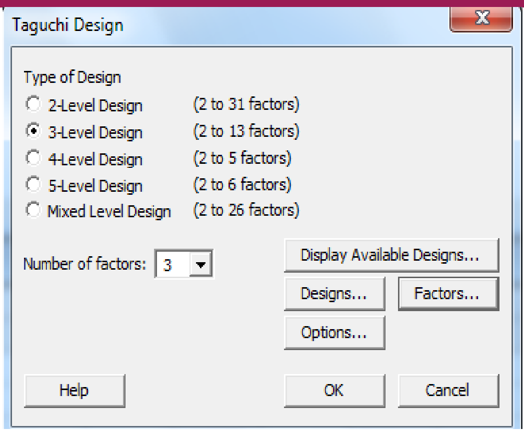

Fig – 3-Level Design 3 Factors

Select Design

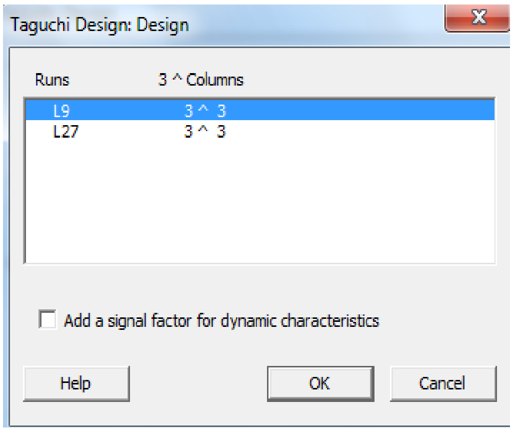

Fig – Selecting L9 (9*9)

Select Factors - Enter Factors and their respective values

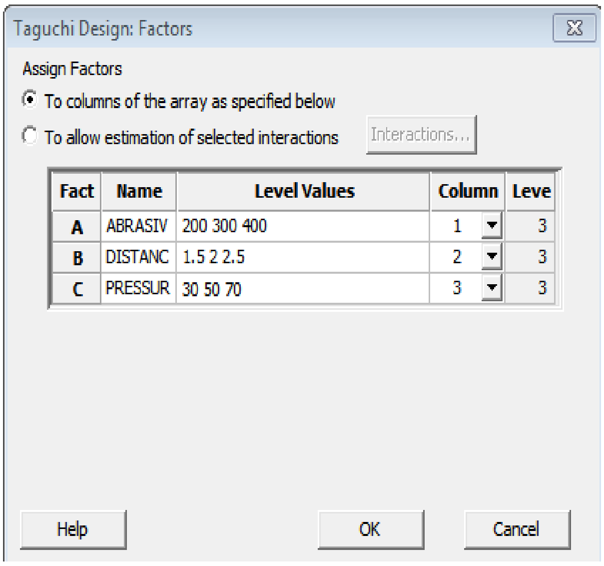

Fig – Considered parameters with their values

In the above fig, it explains that the input parameters which are taken for the machining process, as this data is available from the machining. As the range of the data is taken from the references which are mentioned below and even according to the material properties, here in this thesis we have considered abrasive flow rate, nozzle distance and pressure of the machine

AJM nozzle AJM nozzle is usually made of tungsten carbide or sapphire (usually life – 300 hours for sapphire, 20 to 30 hours for WC) which has resistance to wear. The nozzle is made of either circular or rectangular cross section and head can be head can be straight, or at a right angle. It is so designed that loss of pressure due to the bends, friction etc is minimum possible. With increase in wear of a nozzle, the divergence of jet stream increases resulting in more stray cutting and high inaccuracy.

Enter Surface Roughness Values in the table

Worksheet 1 ***

↓	C1	C2	C3	C4
	ABRASIVE FLOW RATE	DISTANCE OF NOZLE	PRESSURE	SURFACE ROUGHNESS
1	200	1.5	30	2.77
2	200	2.0	50	3.47
3	200	2.5	70	2.97
4	300	1.5	50	3.75
5	300	2.0	70	3.05
6	300	2.5	30	2.09
7	400	1.5	70	3.43
8	400	2.0	30	3.00
9	400	2.5	50	3.92

Fig – Observed Surface Roughness values from experimentation

Now after entering the surface roughness values in the worksheet, here we have to give the set of conditions in the taguchi method. Here the response data should be selected as the surface roughness, as we have to analyze SR from the obtained testing reports

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Options – Smaller is better

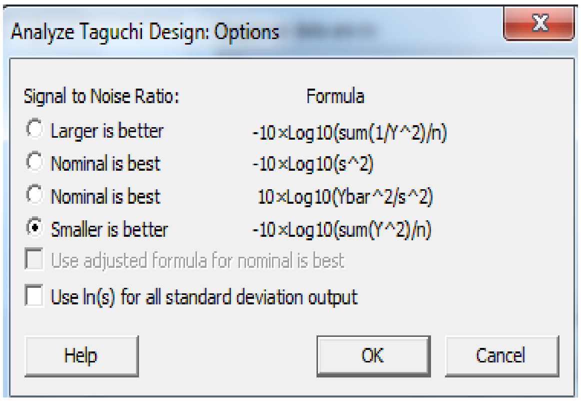

Fig – Surface Roughness to be calculated as Smaller is better

A signal-to-noise ratio is a measure of robustness, which can be used to identify the control factor settings that minimize the effect of noise on the response. Minitab calculates a separate signal-to-noise (S/N) ratio for each combination of control factor levels in the design.

You can choose from different S/N ratios, depending on the goal of your experiment. In all cases, you want to maximize the S/N ratio.

Results Table

Worksheet 1 ***

↓	C1	C2	C3	C4	C5
	ABRASIVE FLOW RATE	DISTANCE OF NOZLE	PRESSURE	SURFACE ROUGHNESS	SNRA1
1	200	1.5	30	2.77	-8.8496
2	200	2.0	50	3.47	-10.8066
3	200	2.5	70	2.97	-9.4551
4	300	1.5	50	3.75	-11.4806
5	300	2.0	70	3.05	-9.6860
6	300	2.5	30	2.09	-6.4029
7	400	1.5	70	3.43	-10.7059
8	400	2.0	30	3.00	-9.5424
9	400	2.5	50	3.92	-11.8657

Table – Calculated Signal to Noise Ratios for Smaller is better

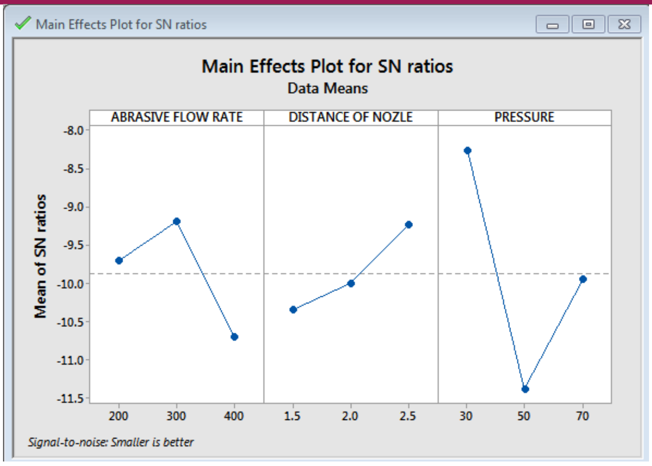

Fig - Effect of machining parameters on Surface Roughness for S/N ratio for Smaller is better

RESULTS

Taguchi method stresses the importance of studying the response variation using the signal–to–noise (S/N) ratio, resulting in minimization of quality characteristic variation due to uncontrollable parameter. The Surface Roughness is considered as the quality characteristic with the concept of "the smaller-the-better".

Analysis and Discussion

Regardless of the category of the performance characteristics, a greater S/N value corresponds to a better performance. Therefore, the optimal level of the machining parameters is the level with the greatest value.

Abrasive flow rate: - The effect of parameter Abrasive flow rate on SR is shown above figure S/N ratio. So the optimum Abrasive flow rate is 300g/min.

Standoff Distance: - The effect of parameter Standoff Distance on SR is shown above figure S/N ratio. So the optimum Standoff Distance is2.5mm

Pressure: - The effect of parameter Pressure on SR is shown above figure S/N ratio. So the optimum Pressure is 30MPa.

CONCLUSION

Experimentation is conducted by machining composite work pieces Al 6061 SiC [7.5%] by varying the process parameters considered Abrasive flow rate nozzle Distance (distance between nozzle and work piece) and pressure and their performance is measured by determining Hardness and Surface Roughness.

In this thesis, different experiments are performed on Aluminum alloy 6061 + 7.5% SiC powered work piece by varying various parameters to determine Hardness and Surface Roughness. The parameters considered are Abrasive flow rate 200g/min, 300 g/min, 400 g/min, Nozzle Distance 1.5mm, 2mm and 2.5mm; and Pressure as 30MPa, 50MPa and 70MPa.

Optimization is done using L09 orthogonal array by Taguchi technique method to determine better parameters to obtain lesser surface roughness values.

From the Taguchi technique For Minimum Surface Roughness, the optimum Abrasive Flow Rate is 300g/min and the optimum Nozzle Distance is 2.5mm and the optimum Pressure is 30MPa.

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