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Parameter Optimization of Abrasive Water Jet Machining in Aluminium 6061 Material

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Abstract:
Abrasive Water jet (AWJ) machining is an emerging technology for material processing with the distinct advantages the absence of no thermal distortion, high machining versatility, high flexibility and small cutting forces. Moreover, the need of advanced machining technique like AWJM is inevitable to produce complex components in the field of automobile, aerospace, marine, chemical and power plant industries. Several components have been produced using aluminium with many intrinsic features for many applications. However, the influence of various parameters of AWJ machining technology on material performance are found to be scanty, the performance of aluminium on AWJ machining process has not been explored. Taking all these aspects into account, the current project formulates a study of the AWJ machining performance of aluminium plate with respect to varying factors. A study of aluminium plate was made with special references to the Taguchi's method for optimizing the cutting parameters of AWJM for minimizing the surface roughness. An L9 (34) orthogonal array was selected for conducting the experiment with the identified significant parameters namely, Feed rate, Pressure, Standoff distance and Abrasive Method. The significance of the cutting parameters was analyzed with the help of ANOVA. The optimum process parameters were identified with the help of signal to noise ratio (SN).

I. INTRODUCTION

Aluminium 6061 Materials

6061 Aluminium plate is a precipitation-hardened aluminium alloy containing magnesium and silicon as its major alloying elements. 6061 aluminium plate is one of the most versatile of the heat-treatable alloys. 6061 is popular for its medium to high strength requirements, good toughness and excellent corrosion resistance.

Features

- Good Mach inability and weld ability
- Most common alloy of aluminium for general purpose use

Applications

- Transportation Components
- Aircraft and marine fittings
- Machine processing equipment
- Recreation Products

II. MACHINING OF ALUMINIUM MATERIALS

The diversity of applications using Aluminium needs the attention of machinability studies, for a better understanding of the cutting processes, regarding accuracy and efficiency for improved quality products. The machining of Aluminium is a relatively difficult task, due to their constitutional heterogeneity, anisotropy and heat sensitivity. The conventional cutting of Aluminium materials presents problems that include extensive delamination, splintering, and short Work piece MRR caused by the abrasive nature of the Aluminium materials. However, obtaining a complex shape component is necessary for the performance of some specific tasks in different applications. This has been achieved through a proper selection of non-traditional machining processes.

Parts of Abrasive Water jet Machine

(a) Air Compressor
(b) Chiller Plant
(c) RO Plant
(d) Rooster Pump
(e) Stabilizer
(f) Abrasive feeder
(g) Nozzle

Abrasive water jet Machining

The abrasive water jet machine (Figure 3.2) used for this study was supplied by the Innovative International Ltd. (Model: DWJ1313-FB), ekkattuthangal, Chennai, India. The nozzle set of AWJ machining with clamped aluminium plate. The 3-axis AWJ machine was equipped with an ultra-high pressure pump (Model: DIPS6-2230) and an auto abrasive delivery system which had a 170-litre abrasive storage capacity, with ability to supply abrasives for a continuous operation of 500–800 min. In this study, the same working principles of AWJ machining were followed as described is have been observed. Garnets (80 mesh, 120mesh) of various sizes were used as abrasive particles. In this work, common parameters such as diameter of focusing nozzle and abrasive flow rate were considered as 0.76mm and 125.234 m3/s respectively. The other varying control factors were P, Sd, Vf. However, the output characteristics of specific target material were dependent on the machining parameters. All the cutting operations were performed using single pass cutting, and that was directed along the longitudinal direction of plate as indicated in Figure. For the same machining condition, three slots were cut with the length of 50mm, and the average value was taken for the measurement of kerf taper as well as surface roughness.

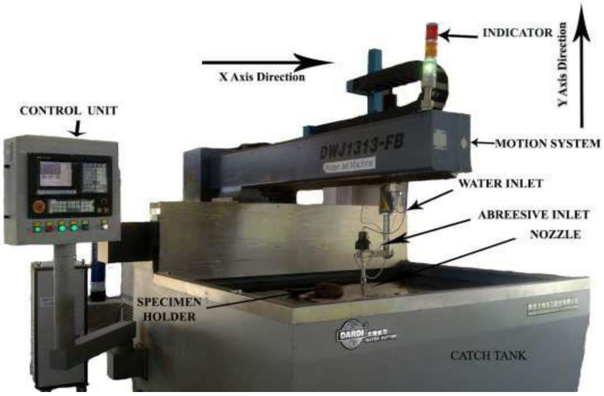


Figure.1. Experimental Setup of Water jet Machining

III. DESIGN OF EXPERIMENT

Introduction of DOE

The word experiment is used in a quite precise sense to mean an investigation where the system under study is under the control of the investigator. This means that experiment is the process in which purposeful changes are made to the input variables of processor systems so that we may observe and identify the reasons for changes that may be observed in the output response. For investigate or discovers something about any process there are number of experiments are required for finding response of desire output in condition of large input. Therefore to reduce the number of Experiments and to obtain good quality of investigation the term named Design of experiments (DOE) is highly useable method in all over the world.

Taguchi method for single objective optimization:

Taguchi's methods of experimental design provide a simple, efficient, and systematic approach for the optimization of experimental designs for performance quality and cost. The main purpose of Taguchi method is reducing the variation in a Process through robust design of experiments

Control Factors and Their Range of Setting for the Experiment

Control Variable	Pressure (MPa)	Standoff Distance (mm)	Abrasive flow rate(g/s)
Level-I	40	1	7
Level-II	60	2	8
Level-III	80	3	9

4 Experiment design with expected range

SL. NO	Pressure (MPa)	Standoff Distance (mm)	Abrasive flow rate(g/s)
1	40	1	7
2	40	2	8
3	40	3	9
4	60	1	8
5	60	2	9
6	60	3	7
7	80	1	9
8	80	2	7
9	80	3	8

5. EXPERIMENTATION

The equipment used for machining the samples is DWJ Flying Arm CNC abrasive water jet cutting machine equipped with KMT model of water jet pump with the designed pressure of 3800 bar (55000psi) and rated discharge of 2.3l/min. The machine is equipped with a gravity feed type of abrasive hopper, an abrasive feeder system, a pneumatically controlled valve and a work table with dimension of 1600mm×2100mm. For the nozzle assembly, it has an orifice of 0.25mm diameter of sapphire jewel. The abrasives were delivered using compressed air from a hopper to the mixing chamber and were regulated using a metering disc. All the cutting experiments were performed on INCONEL 718 material and are single pass experiments conducted by choosing standoff distance of 3mm and the jet impact angle of 900. Granite sand abrasives were used as abrasives. The surface roughness was measured with the profile projector of magnification x10 and a least count of 0.02 mm. surface roughness of each cut was measured at three different places for accurate evaluation and the specimen is weighed before and after the experimentation.

$$\therefore MRR_{ductile} = 0.5\frac{M_g U^2}{H}$$

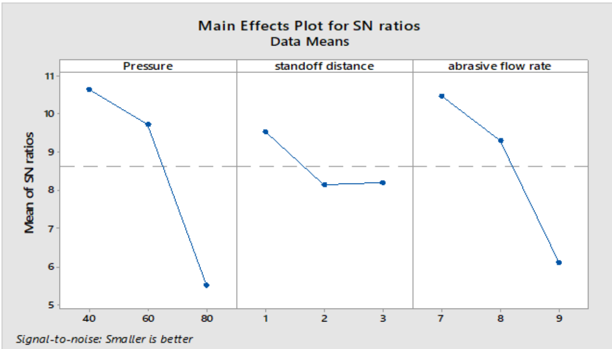
- U = Velocity of abrasive jet at the point of impact.
- H = Flow strength or hardness of the work material.
- M_g = Mass flow rate of abrasive particles.
- ρ_g = Density of each abrasive particle.

Response for the input parameters

S.No	Pressure (MPa)	Standoff Distance (mm)	Abrasive flow rate(g/s)	MRR(mm3 /min)	Ra (µm)
1	40	1	7	**2224**	**0.20**
2	40	2	8	**2526**	**0.31**
3	40	3	9	**2940**	**0.41**
4	60	1	8	**2400**	**0.27**
5	60	2	9	**2700**	**0.43**
6	60	3	7	**2100**	**0.30**
7	80	1	9	**2654**	**0.69**
8	80	2	7	**2015**	**0.45**
9	80	3	8	**2327**	**0.48**

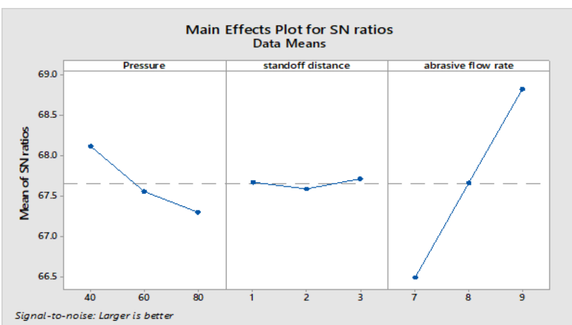
S/N ratio calculation of SR

Ex. NO	**S/N ratio of SR**
1	13.9794
2	10.1728
3	7.7443
4	11.3727
5	7.3306
6	10.4576
7	3.2230
8	6.9357
9	6.3752



4 S/N ratio calculation of MRR

Ex. NO	S/N ratio of MRR
1	66.9427
2	68.0487
3	69.3669
4	67.6042
5	68.6273
6	66.4444
7	68.4780
8	66.0855
9	67.3359



IV. RESULT

Optimization results of orthogonal array Vs Grey theory design

	Orthogonal Array	Grey Theory Design	Percentage Deviation
Response /Level	A1B1C1	A1B1C3	
Surface roughness	0.2	0.14	3.33%
Metal removal rate	2224	2170	0.92%

V. CONCLUSION

The following conclusions can be drawn from the results of the present work:

- The optimal parameter values are abrasive flow rate at 9 gm/sec, pressure at 40 Mpa and standoff distance at 3mm. At these parameters the values of MRR and surface roughness are 2940 mm3 /min and 0.41µm respectively.
- It is shown that the performance characteristics of the AWJM process, namely water jet pressure, abrasive flow rate and standoff distance are improved together by using Taguchi single objective analysis and Grey Relational Analysis.
- From ANOVA it is found that water jet pressure has more significant effect on surface roughness and MRR rather than abrasive flow rate and standoff distance.
- The predicted S/N ratio is nearest to the conformation test S/N ratio; this explains that the DOE process adopted for optimization of parameters is accurate.

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