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Experimental Analysis of Mrr and Surface Finish Using Abrasive Water Jet Machining Of Aluminum Alloy 7475

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ABSTRACT

In this thesis, different experiments are performed on Aluminum alloy 7475 by varying various parameters such as Pressure, Sand Feed, Transverse Speed and Standoff Distance (i.e) Nozzle to work piece distance to determine Material Removal rates and surface finish. Optimization is done using L27 orthogonal array by Taguchi technique to determine better parameters to obtain maximum removal rates and minimum surface roughness. Grey relational analysis will be applied to generate grey relational grade to identify the optimum process parameters. These optimum parameters can be adjusted to improve performances of AWJM.

The parameters considered are Transverse Speed 70mm/min, 80 mm/min, 90 mm/min, Standoff Distance 0.5mm 1mm, 1.5mm, and Sand Feed 50 g/min, 100 g/min, 150 g/min, Pressure 160MPa, 240 MPa, 320 MPa.

INTRODUCTION

In AJM, work material is removed by erosion of high velocity abrasive particles by impinging stream of abrasive particles carried by high pressure air or gas through a nozzle on the work surface.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.

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.

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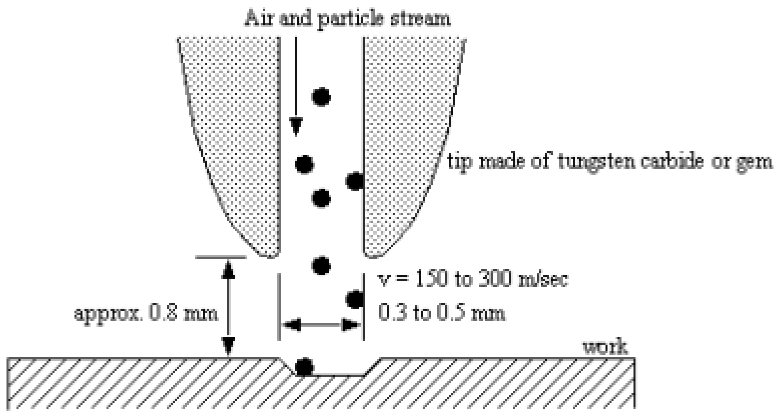

Principle of Abrasive Jet Machining

OPERATIONS ON ABRASIVE WATER JET MACHINING

Based on the applications some of the recent developments in operations using AWJM arelisted below.

1) Straight line cutting
2) Turning
3) Curved and corner cutting
4) Honey comb cutting
5) Segmental turning
6) Small hole drilling
7) Polishing
8) Water slicing

LITERATURE SURVEY

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 behindin terms of quality of cut, or even some requests are not able to meet, but with theadvent of composite materials were not able to machine them, because they occurredunacceptable 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. SreenevasaRao [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-grainedalumina samples. The use of synthetic diamond abrasive is a possible choice if high machining efficiency is desired. However, themachined 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 manyapplications have several problems inherent with traditional abrasive jet equipment. Poor repeatability in pressure feed AJM systemwas 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 machinedchannel.

A. Ghobeity et al. [7] stated that particle distribution can greatly affect the shape and depth of profile. Analytical model hasdeveloped with by considering the particle size distribution. It results that if particle size distributed uniformly it helps to maintainuniform velocity of abrasive jet which causes improvement in MRR.

A. El-Domiaty et al. [8] did the drilling of glass with different thicknesses have been carried out by Abrasive jet Machiningprocess (AJM) in order to determine its machinability under different controlling parameters of the AJM process. The large diameterof the nozzle lead to the more abrasive flow and which lead to more material removal rate and lower size of abrasive particle lead tothe low material removal rete. They have introduced an experimental and theoretical analysis to calculate the material removal rate.

AlirezaMoridi et al. [9] has presented an experimental study to understand the effect of process parameters (like nozzlediameter, air pressure, abrasive mass flow rate, jet impact angle and nozzle traverse speed) on the cutting performance measures (likegroove depth and width, kerf taper angle and roughness of the groove bottom surface) in abrasive jet micro-grooving of quartzcrystals. Groove depth increase by increasing the abrasive mass flow rate which lead to more particles impinging the target surfaceand gives more material removal. However, excessive abrasive flow-rate increases inter-particle collision which reduces the averageremoval rate per particle.

Mr. Bhaskar Chandra [10] Studied the variation in Material Removal Rate according to change in Gas pressure and Holediameter according to change in NTD. Various experiments were conducted on work piece material- glass using abrasive materialalumina.

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JuktiPrasadnPadhy [11] carried the drilling experiment on glass work piece using aluminum oxide as abrasive powder.Experimental work was done by considering stand-off distance (SOD) and pressure as machining parameter to study material removalrate (MRR) and overcut (OC). The effect of observed value of MRR and OC was analyzed by Taguchi design. From analysis it wasconcluded that the pressure and SOD both are significant for MRR and only pressure is significant for OC. Individual optimal settingsof parameters are carried out to minimize the OC and maximize the MRR.

OPTIMIZATION OF MACHINING PARAMETERS FOR HIGHER MATERIAL REMOVAL RATES AND LESSER SURFACE ROUGHNESS USING MINITAB SOFTWARE

Factors and levels of experiments

Factors	Units	Level 1	Level 2	Level 3
Pressure	MPa	160	240	320
Transverse speed	mm/min	70	80	90
Sand feed	g/min	50	100	150
Standoff distance	Mm	0.5	1	1.5

Experimental input parameters

JOB NO.	Pressure (MPa)	Transverse speed (mm/min)	Sand feed (g/min)	Standoff distance (mm)
1	160	70	50	0.5
2	160	70	100	1.0
3	160	70	150	1.5
4	160	80	50	1.0
5	160	80	100	1.5
6	160	80	150	0.5
7	160	90	50	1.5
8	160	90	100	0.5
9	160	90	150	1.0
10	240	70	50	0.5
11	240	70	100	1.0

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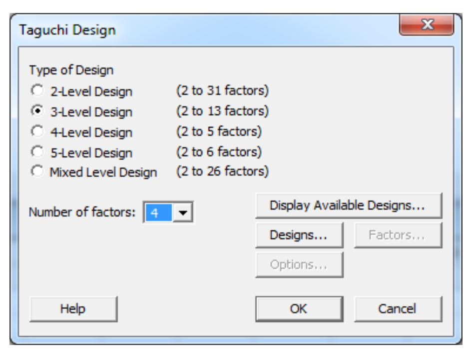
12	240	70	150	1.5
13	240	80	50	1.0
14	240	80	100	1.5
15	240	80	150	0.5
16	240	90	50	1.5
17	240	90	100	0.5
18	240	90	150	1.0
19	320	70	50	0.5
20	320	70	100	1.0
21	320	70	150	1.5
22	320	80	50	1.0
23	320	80	100	1.5
24	320	80	150	0.5
25	320	90	50	1.5
26	320	90	100	0.5
27	320	90	150	1.0

DESIGN OF ORTHOGONAL ARRAY

First Taguchi Orthogonal Array is designed in Minitab17 to calculate S/N ratio which is given below
3-Level Design and No. of factors - 4



3-Level Design 4 Factors

GRAPH OF SN RATIO FOR MRR

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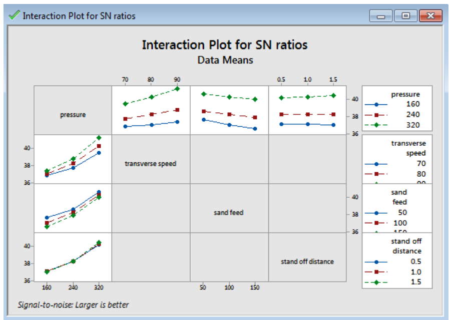
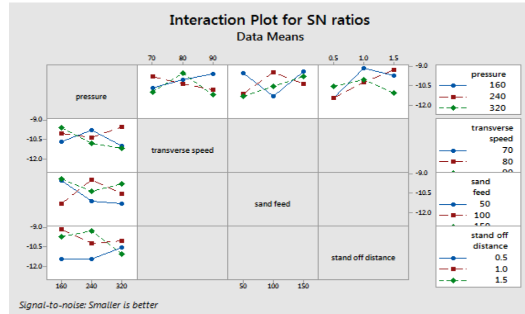
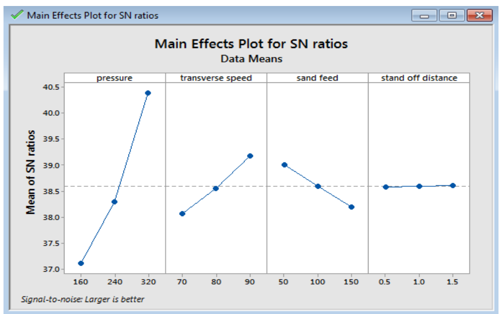


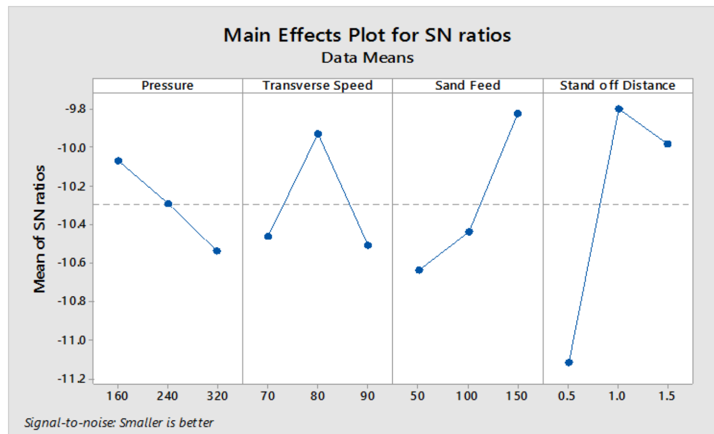
Interaction Plot for SN Ratio



Interaction Plot for SN Ratio



Effect of machining parameters on MRR for S/N ratio for Larger is better



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

GRAPH OF SN RATIO FOR SURFACE ROUGHNESS

To optimize parameters using ANOVA, first the arrangement of L27 orthogonal array is done in Taguchi Method.

Enter Surface Roughness values and MRR values in the table

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↓	C1	C2	C3	C4	C5	C6
	pressure	transverse speed	sand feed	stand off distance	surface roughness	MRR
1	160	70	50	0.5	4.756	75.000
2	160	70	100	1.0	3.749	69.387
3	160	70	150	1.5	2.230	65.641
4	160	80	50	1.0	1.975	76.024
5	160	80	100	1.5	4.442	71.083
6	160	80	150	0.5	3.622	67.346
7	160	90	50	1.5	2.840	77.988
8	160	90	100	0.5	2.986	73.906
9	160	90	150	1.0	3.169	70.122
10	240	70	50	0.5	4.341	81.011
11	240	70	100	1.0	2.346	77.511
12	240	70	150	1.5	2.852	73.651
13	240	80	50	1.0	3.721	85.276
14	240	80	100	1.5	2.988	82.243
15	240	80	150	0.5	3.165	78.260
16	240	90	50	1.5	2.860	90.605
17	240	90	100	0.5	3.724	88.275
18	240	90	150	1.0	3.910	84.121
19	320	70	50	0.5	4.030	97.385
20	320	70	100	1.0	2.957	95.836
21	320	70	150	1.5	3.690	91.457
22	320	80	50	1.0	3.304	105.879
23	320	80	100	1.5	3.293	105.230
24	320	80	150	0.5	2.413	100.567
25	320	90	50	1.5	3.714	123.853
26	320	90	100	0.5	3.928	112.850
27	320	90	150	1.0	3.269	111.835

Observed Surface Roughness and MRR Values

SURFACE ROUGHNESS GRAPHS

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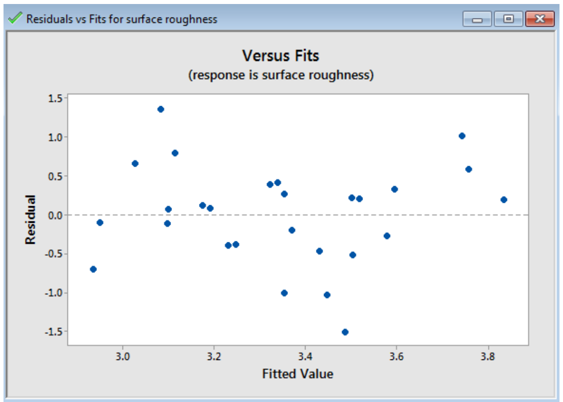
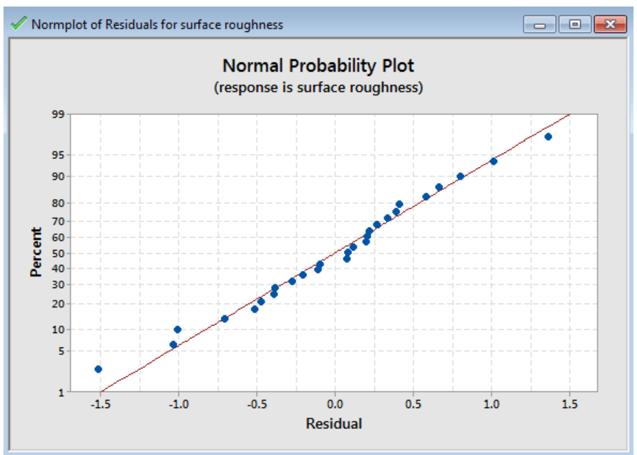
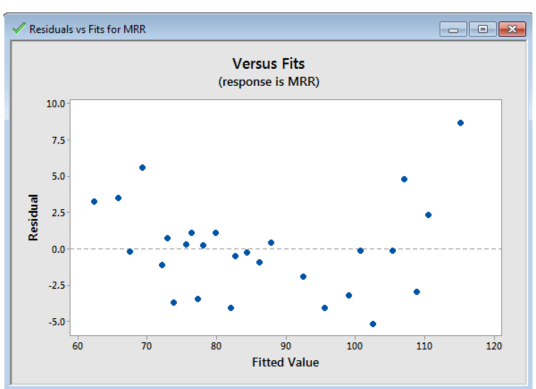


Residual Vs Fits for Surface Roughness

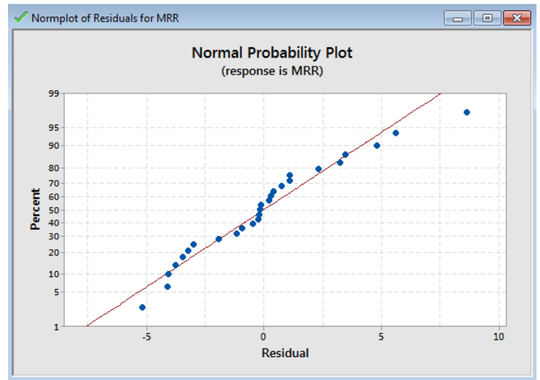


Normal Plot of Residuals for Surface Roughness

MRR GRAPHS



Residual Vs Fits for MRR



Normal Plot of Residuals for MRR

OPTIMIZATION OF MULTIPLE PERFORMANCE CHARACTERISTICS WITH GREY RELATIONAL ANALYSIS

The optimization of parameters considering multiple performancecharacteristics of the Abrasive Jet machining process for Titanium alloy 2 using the GRA is presented.Performance characteristics including MRR,and Surface Roughness (SR) are chosen toevaluate the machining effects. Those process parameters that are closelycorrelated with the selected performance characteristics in this project are the Transverse speed, Abrasive flow rate and Nozzle Standoff Distance. Experiments based on the appropriate L9 OAare conducted first. The normalized experimental results of the performancecharacteristics are then introduced to calculate the coefficient and gradesaccording to GRA.

COMPUTING THE GREY RELATIONAL COEFFICIENT AND THE GREY RELATIONAL GRADE

After data pre-processing is carried out, a grey relational coefficient can be calculated with the pre-processed sequence. It expresses the relationship between the ideal and actual normalized experimental results. The grey relational coefficient is defined as follows:

	Grey Relational Coefficient		Grey Relational Grade γ_i	Rank
Job No.	SR $\xi_i(1)$	MRR $\xi_i(2)$		
1	0.5	0.3734	0.4367	23
2	0.4395	0.3483	0.3939	26
3	0.8451	0.3334	0.5893	7
4	1	0.3783	0.6892	2
5	0.3605	0.3555	0.358	27
6	0.4578	0.34	0.3989	25
7	0.6165	0.3882	0.5024	14
8	0.5791	0.3682	0.4737	17
9	0.5381	0.3514	0.4448	21
10	0.9078	0.4045	0.6562	5
11	0.7894	0.3858	0.5876	8
12	0.6132	0.37	0.4916	16
13	0.4434	0.43	0.4367	22
14	0.5785	0.4116	0.4951	15
15	0.5389	0.3897	0.4643	18
16	0.6111	0.4668	0.53895	13
17	0.4429	0.45	0.67145	3
18	0.41813	0.4224	0.4203	24
19	0.4036	0.5237	0.4637	19
20	0.5861	0.5096	0.5479	12
21	0.4478	0.4732	04605	20
22	0.5108	0.6182	0.5645	10
23	0.5134	0.6098	0.5616	11
24	0.7605	0.556	0.6583	4
25	0.4443	1	0.7222	4

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26	0.4159	0.7257	0.5708	9
27	0.51798	0.7077	0.6128	6

The calculated grey relational grade and its order in the optimization process

GREY RELATION GRADE RANKING

Machining Parameters	Grey Relational Grade			Main Effect (max-min)	Rank
	Level 1	Level 2	Level 3		
Pressure	0.4763	0.5291	0.5736	0.0973	1
Transverse speed	0.5142	0.5141	0.5508	0.0367	3
Sand feed	0.5568	0.5178	0.5045	0.0523	2
Stand off Distance	0.5327	0.522	0.5244	0.0107	4

Grey Relation Grade Ranking

CONCLUSION

In this thesis, different experiments are performed on Aluminum alloy 7475 work piece by varying various parameters to determine Material Removal rates and Surface Roughness. The parameters considered are Transverse Speed 70mm/min, 80mm/min, 90mm/min, Standoff Distance 0.5mm 1mm, 1.5mm, and Sand Feed 50g/min, 100g/min, 150g/min, Pressure 160MPa, 240MPa, 320MPa.

Optimization is done using L27 orthogonal array by Taguchi technique to determine better parameters to obtain maximum material removal rates and lesser surface roughness values.

From the experimental results and the Taguchi method, the following results can be obtained:

i. The effect of Pressure on MRR and Stand Off Distance on Surface Roughness are more.
ii. For Minimum Surface Roughness, the optimum Pressure is 160MPa, Transverse Speed is 80mm/min, the optimum Sand Feed is 150g/min and the optimum Standoff Distance is 1mm.
iii. For Maximum MRR, the optimum Pressure is 320MPa, Transverse Speed is 90mm/min, the optimum Sand Feed is 50g/min and the optimum Standoff Distance is 1mm.

From the Grey Relational Analysis, the optimum machining parameters are Pressure 20MPa, Transverse Speed – 90mm/min, Sand Feed 50g/min, Standoff Distance 0.5mm.

Further by using Taguchi grey relational analysis (TGRA) responses such as Material removal rate and Surface roughness are developed. Error analysis (ANOVA F test) is also carried out and the models developed are found to be significant.

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