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Experimental Investigation of Machining Parameter for AJM using Nimonic Alloy 75

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Abstract – In abrasive jet machining (AJM), abrasive specks stay motley by compacted air in a closed chamber and are intensive over the objective surface over a nozzle. The stream of specks coming out of the nozzle through very extraordinary swiftness(175-300m/s) impacts the objective surface and eliminates the material by destruction. Typically for abrasive jet machining brittle work piece or fragile materials are machined more capably. In this project, the highlights are the stimulus of dissimilar progression considerations like Nozzle Diameter(D),Pressure(P),and Nozzle Tip Distance(ND), on the Metal removal (MRR) of Nimonic alloy 75 by Abrasive jet machining. Tungsten carbide nozzles with diameters 2mm, 3mm, 4mm, were deliberated. For this study Al_2o_3 abrasive with partical size of about (40 µm , 60µm) is elected. Other limits contain Pressure (7bars,8bars, 9bars), Nozzle Tip Distance (5mm, 6mm, and 7mm) are considered. Experiments were conducted and the effects were examined, which includes design of experiments (DOE), Taguchi, ANOVA (analysis of variance) and GRA .

Keywords:

AJM, Non Traditional Machining Methods, Nimonic Alloy 75, Al2O3 abrasive spocks

INTRODUCTION

Industries like automobiles, aeronautics, nuclear reactors, ornaments, medicines etc. which hang on on precise great level of technology and engineering, anxieties some individual machine tools and technologies which can justify their need. One of the margins with obsolete machining technique is a step-up in immovability of work materials results in decline in profitable cutting speed. So it became irrepressible to cut newly evolving materials which has better strength. Generation of amalgamated prototypical with subtractive manufacturing is further matter with traditional manufacturing technique. Apart from this, lower tolerances, better finish, micro sizes, and automation of system are certain additional matters in which traditional manufacturing methods are having limitations. The outcomes to these problems arisen as extension of novel non-Traditional machining methods superior known as innovative manufacturing systems. Innovative manufacturing systems currently reached at a stage where machining of tough to cut materials, intricate model, micro level sizes became very easy, proficient and fast. These technique not simply produce, perfect prototypical and manage with stiffer matter but also simply adjustable for automation. In the manufacturing industry, necessities for machining of innovative intricate model, matter and micro level sizes possess arising. Tough to cut materials, Fused material are limited examples where non conventional machining became an obvious essential. Tools used for cutting in unconventional technique are Abrasive jet machines, electron beam, laser beams, infrared beam, electric arc, and plasma cutting and so on dependent on the type of functioning material. These un-conventional techniques are widespread with many progressions and continual for dissimilar exertion atmosphere. So in this study, worth of Abrasive jet machining is investigated for different input parameters.

LITERATURE REVIEW

G.Kandpal Chandra , B., et at[1] (2011) Considered abrasive jet machining process parameters are investigated and analyzed different limits. It excludes several responses of investigates take be present directed by varying nozzle stand off distance, pressure proceeding dissimilar thickness (t) of ceramic and glass plates. It was detected that as nozzle stand off distance rises, material removal rate (MRR) rises. As the pressure upsurges and abrasive particle size surges material removal rate (MRR) is enhanced as we initiate in AJM process..

Tsai. F. C., Et Al[2] (2013) Careful refining on SKD 61 frame steel by SIC with polish layer. The broadsheet observes the abrasive jet refining of electro-discharged machined (EDM) and blight steel samples used 2000 Sic , 3000 or 8000 Sic commercials and several preservative covering clean liquid. The investigation expressions that once the enhancing growth was achieved by 2000 Sic spot with a pure liquid and water was improver it was newcomer that the exterior irregularity is condensed from Ra=1.0 micro meter to 0.08 micro meter within 10 min of SKD 61 exterior perfecting the earth SKD 61 apparent by 3000 Sic adverts through pure aquatic and water polish, the surface lumpiness is originate to decrease from an primary value of Ra=0.36 micro meter to a finishing value of Ra=0.054 m within 60 min. A gas atomization practice is betrothed to idea wax coated 3000 Sic element for educational the enhancing presentation. Next the trialing the effect appearance was that the wax-coated abrasive unit decreases the mending time and completes an superior surface finish.

C.Nagdeve. L, et al [3] (2012) the research method, Taguchi process is practical to invention optimal method parameters for Rasping Abrasive Water Jet Machining(AWJM) .The objective of investigational analysis is near conduct research of machining factors control on MRR and SR of slog bit of Al 7075. The system remained created on Taguchi's method, enquiry of difference and signal to noise ratio [SN Ratio] to progress the Grainy Water Jet Machining development bounds for running machining and to think the peak select for both AWJM restriction such as Abrasive flow rate, Navigate speed, Abrasive grit size and Stalemate distance. This paper also presents analysis of several considerations and on the source of investigational outcomes, examination of change (ANOVA), F-test and SN Ratio.

Balasubramaniam. R., et, al [4] (1997) During the development of AJM method is an investigation is accompanied through recognize a conclusion several limitations of AJM similar to angle of impingement besides jet height refusing method. The example of stainless steel is used experimental procedure depend on the Taguchi technique, profile protector measure the amount of worth and also a graphical easements examined through investigate the practical distraction .The sample effects are also inspect by ANOVA process. Then the investigation particular decisions are available.

El-Domiaty. A., et al [5](2009) Intelligent report of this method , Drilling of glass through disparate thicknesses consume delivered by AJM method. Now directive to control ,its machinability beneath diverse directorial limits of the AJM method. Here two investigational and practical evaluates remained obtainable. Through blur elimination is inflated through limitations Jet height and Range of impingement.

Pandey, et, al (1980) and Bhattacharya [6](1976) In this report gives the possessions of grainy flow rate and material removal rate stand -off distance on the. They seeming that MRR extents an optimal rate with the growing in AFR and SOD, and then falls with the growth in these factors.

S.Rajendra Prasad, K.Ravindranath and M.L.S. Devakumar [7] (2018) Considered abrasive jet machining process of Nickel 233 alloy, it involves the compared with multi objective optimization on the Weighted Aggregated Sum Product Assessment (WASPAS) and ratio analysis (MOORA) to analyzed the different responses i.e material removal rate(MRR), surface roughness (Ra) and taper angle (Ta).

S.Rajendra Prasad, K.Ravindranath and M.L.S. Devakumar [8] (2016) This research concluded that AJM parameters, like pressure, Nozzle size and shape, abrasive mass flow rate can be effect the output responses.

EXPERIMENTATION

For execution the investigational effort on nimonic alloy 75 is used as a sample. Producing of a hole in nimonic alloy 75 using AJM is finished on the sample. The trials take by accompanied on the Abrasive Jet Machining . Several contribution constraints was diverse in AJM process, like pressure (7bars,8bars,9bars), Nozzle stand-off distance (5mm, 6 mm, 7mm), nozzle diameter (2mm, 3mm,4mm). Each issue takes its individual influence on the yield of response physiognomies i.e. material removal rate(MRR) and surface roughness(SR). Table. 1 displays the materials used and specification of AJM machine.

Table 1: Nomenclature of Machining Unit and Their Specifications

Nomenclature	Specifications
Sample material	NIMONIC ALLOY75
Size of work piece material (mm)	40 x 40
Thickness (mm)	0.75
Nozzle material	Tungsten Carbide
Nozzle diameter sizes (mm)	2,3,4
Abrasive	Al2O3
Abrasive sizes(µm)	40 & 60
Pressure (bars)	7,8,9
Stand Off Distance (mm)	5,6,7
No of experiment	27

Fig. 1: Machining of Nimonic alloy 75 Using AJM

The experimental setup consists of the following major components are.

Mixing chamber: Through mixing progression, the abrasive specks are gradually augmented due to allocation of force from the jet, When the jet finally leaves the focusing nozzle.

Air filter : It cleans the air or gas earlier incoming the compressor.It is shown in figure 2.

Air compressor : It pressures the air or gas up to mandatory level. It is shown in figure 3.

Fig.2 Fig.3

Nozzle: It is prepared of stiff and resistant material similar tungsten carbide and abrasive jet strike on the sample through nozzle. It is shown in figure 4.

Fig.4

Air Pressure Gauge : It is used to control the level of pressure. It is shown in figure 5.

Air Pressure regulator: It controls the stream level of abrasive jet. It is shown in figure 6.

Fig.5

Fig.6

Grey Relational Analysis (GRA) :

When the objective significance of inventive series is immeasurable, then the expectancy becomes "higher the better" and when the physiognomies of the inventive series becomes "lower the better", the problem becomes different. The presence vital to be used for normalization of the data is different for the former state than that of the second. The basic methodology for normalizing the original sequence is by dividing the values of the inventive series by the first value of the series. In the present work the output responses namely material removal rate should be of greater value and surface roughness should be of smallest value. Hence the expectancy is lower the better. When the condition is "lower the better", the equation is expressed as

$$x_i^*(K)= \frac{\max x\mathrm{i}\,(K) - x\mathrm{i}(K)}{\max x\mathrm{i}\,(K) - min x\,\mathrm{i}(K)} \quad \ldots\ldots\ldots\ldots(1)$$

Where i=1….m; k = 1,....,n. m is the quantity of investigational data pieces and n is the number of limits. xi *(k)* indicates the innovative series, *xi*(k)* is the series later data pre processing, max x0i*(k)* is the largest value of x0i*(k)*, min x0i*(k)* is the least value of *x*i*(k)* .When the requirement is "higher the better", the equation is expressed as

$$x_i^*(K)= \frac{Y\mathrm{ij} - \max Y\mathrm{ij}}{\max x\mathrm{i}\,(K) - minY\,\mathrm{ij}} \quad \ldots\ldots\ldots\ldots (2)$$

Grey Relational Coefficient:

Once the pre-processing of the data has been found out, the Grey Relational Coefficient (GRC) ,has to be deliberate to definite the construction among the ideal and normalized definite tentative outcomes. The grey relational coefficient(GRC) is expressed as

$$\text{Grey Relational Coefficient} = \frac{\triangle\min \ + wi\triangle max}{|\,xi - xij\,| + wi\triangle max} \text{ ………(3)}$$

Grey Relational Grade:

The comparison among the several grey relational coefficients becomes weighty due to the variance in numbers and variation. Further reduction is made easy by finding the average value among the coefficients. That is to translate each arrangement into its mean. This mean is also called as grey relational grade(GRG).

Grey relational grade,αj = 1\N ∑ Yij ………(4)

Where αj is the grey relational grade(GRG) for the *jth* trial and N is the total performance physiognomies. In this work, the GRG signifies the level of connection among the reference arrangement and the comparability order. When there is an identical coincidence among two sequences, then the value of GRG is equal to 1.

Taguchi design:

It was exposed by Dr. Genichi Taguchi of japan. Taguchi design is a statistical technique. This is a tough parameter design, for designing trials to estimate how dissimilar parameters disturb the mean and variance of a procedure presentation characteristics.

It is essentially converging on curtailing distinction and sensitivity to noise. It offers an effective technique for conniving products and procedure that runs efficiently, steadily and optimal finished a variation of situations. These approaches involve two, three, four, five and mixed-level fractional factorial designs. To decide which aspects greatest disturb product excellence, it permits only the congregation of the essential data hence valid time and means. Taguchi provides orthogonal array design which decreases the experimentation trails.

The investigational data are analysed in the Taguchi technique and to discovery the finest response beneath optimum state. It is used for guessing the single factor participation and besides their collaboration in the progression response. It makes and analysis the main effect plot and collaboration plot for signal to noise ratio, standard deviations, and means. It also generates residual plot on histogram, normal plot, and residual versus order, residual versus fits.

In this trial, (Table2) is preferred with a total of twenty seven quantities of trials to be accompanied and hence L_{27} Orthogonal Array (OA) was taken.

Table 2 AJM Input Parameters

Factor	Symbol	Unit	Levels		
			Level 1	Level 2	Level 3
Pressure	(P)	Bar	7	8	9
Stand of distance	(SOD)	Mm	4	5	6
Nozzle diameter	(ND)	Mm	`2	3	4

Machined work pieces with variable nozzle diameters 2mm, 3mm and 4mm it shown in fig.7,fig8 and fig.9

Fig.7

Fig.8

Fig.9

*Analysis of Variance (ANOVA)***:**

Analysis of Variance is an analytical tool in discovery the mean and variance among the responses. It is used to find out the percentage involvement of each factor and comparative consequence of each factor there by finding out the greatest significant factor. Based on F-value (Significance factor value) important parameters can be identified. By ANOVA we can novelty Degree of freedom (DF), Probability (P), Significant Factor ratio (F Ratio), Mean squares (MS), and Sum of Squares (SS), calculated percentage contribution.

RESULTS AND DISCUSSIONS **:**

The conclusion of machining limits pressure, stand off distance and nozzle diameter is calculated by ANOVA. Three reiterations for every of 3 tribunals were finished in the situation of variable nozzle diameter thus as to quantity MRR, SR and similarly later Signal to Noise ratio is assessed by the Minitab software.

Taguchi Analysis: MRR versus Pressure, Stand off distance, Nozzle diameter

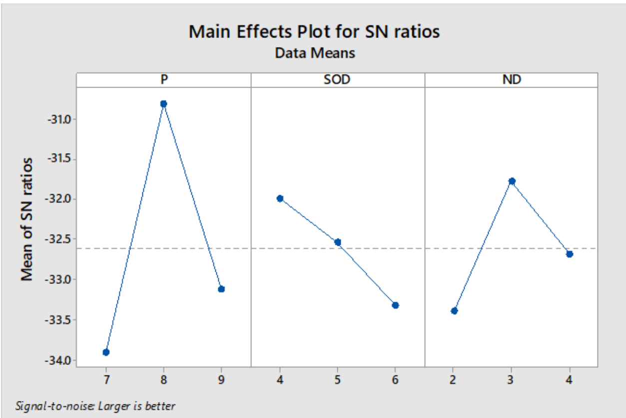

Fig.10. Main effects plot for SN ratios of MRR

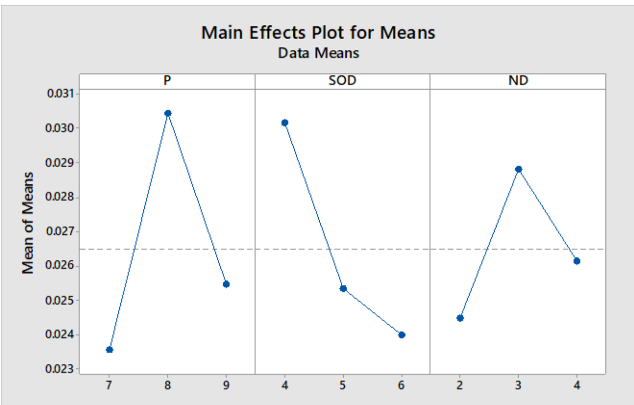

Fig.11 Main effects plot for Means of MRR

In Figure 10 shows main effects plot for SN ratios and means , the graphs are plotted among mean of MRR and several parameters. These two graphs are displays effect of several factors on the mean of S/N ratio and means of material elimination rate plotted exploiting the machining effects acquired. It is perceived from the plot displays similar trend as exposed by plot of mean of MRR. This auxiliary validates the effects and outcomes of parameters.

Response Table for Signal to Noise Ratios

'Larger is better'

Level	Pressure	SOD	ND
1	-33.91	-31.99	-33.39
2	-30.80	-32.53	-31.77
3	-33.12	-33.32	-32.68
Delta	3.12	1.33	1.62
Rank	1	3	2

Response Table for Means

Level	Pressure	SOD	ND
1	0.02357	0.03016	0.02449
2	0.03044	0.02533	0.02883
3	0.02547	0.02398	0.02616
Delta	0.00687	0.00617	0.00433
Rank	1	2	3

Taguchi Analysis: SR versus Pressure, Stand off distance, Nozzle diameter

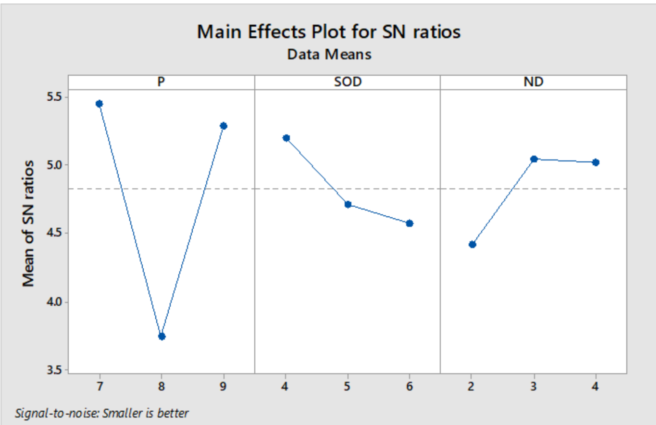

Fig.12 Main effects plot for SN ratios of SR

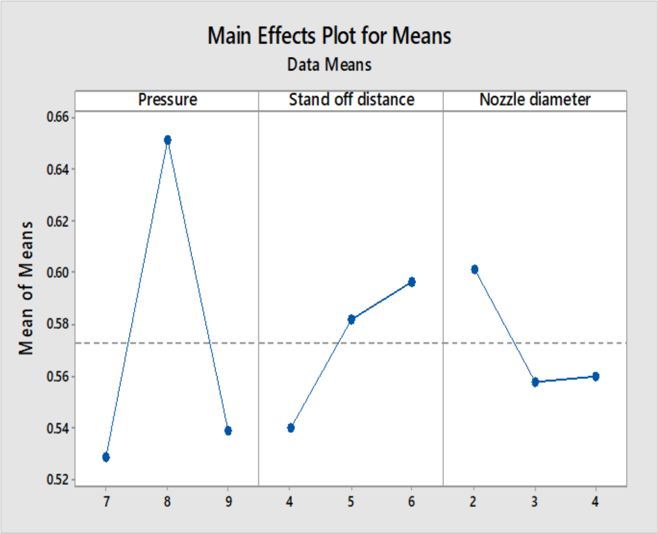

Fig.13 Main effects plot for Means of SR

In Figure 12 and 13 the graphs are plotted among mean of Surface roughness and various parameters. And Figures are displays effect of dissimilar factors proceeding the mean of S/N ratio of material deduction rate plotted developing the machining results attained. It is detected from the plot displays reverse trend as displayed by plot of mean of Surface roughness. Reverse inclination is owed to element that response for signal to noise ratios is engaged as"Smaller is Better". This additional validates the possessions and results of factors.

Response Table for Signal to Noise Ratios

Smaller is better

Level	Pressure	SOD	ND
1	5.447	5.196	4.421
2	3.745	4.709	5.042
3	5.288	4.575	5.016
Delta	1.702	0.620	0.621
Rank	1	3	2

Response Table for Means

Level	Pressure	SOD	ND
1	0.5290	0.5401	0.6012
2	0.6511	0.5822	0.5578
3	0.5389	0.5967	0.5600
Delta	0.1221	0.0566	0.0434
Rank	3	2	1

Grey Relational Analysis (GRA) Results:

Table 2: Results after AJM at Various Responses

S. N	MRR	Ra	Normalized MRR	Normalized SR	Weighted Normalized MRR	Weighted Normalized SR	QL MRR	QL SR	GRC MRR	GRC SR	GRCGD	RANK
1	0.0317	0.52	-0.5327	0.6053	-0.2664	0.3026	0.734	0.697	0.469	0.695	0.58172	L9
2	0.0304	0.40	-0.9065	0.9211	-0.4533	0.4605	0.547	0.539	0.623	0.815	0.71862	L2
3	0.0131	0.69	0.0000	0.1553	0.0000	0.0776	1.000	0.922	0.347	0.574	0.46044	L26
4	0.0268	0.50	-0.5950	0.6579	-0.2975	0.3289	0.702	0.671	0.489	0.712	0.60052	L7
5	0.0308	0.55	-0.4393	0.5263	-0.2196	0.2632	0.780	0.737	0.441	0.670	0.55575	L12
6	0.0192	0.59	-0.3146	0.4211	-0.1573	0.2105	0.843	0.789	0.410	0.640	0.52471	L16
7	**0.0128**	0.46	-0.7196	0.7632	-0.3598	0.3816	0.640	0.618	0.535	0.750	0.64236	L3
8	0.0267	0.48	-0.6573	0.7105	-0.3287	0.3553	0.671	0.645	0.511	0.731	0.62068	L5
9	0.0207	0.57	-0.3770	0.4737	-0.1885	0.2368	0.812	0.763	0.425	0.655	0.53976	L14
10	0.0244	0.60	-0.2835	0.3947	-0.1417	0.1974	0.858	0.803	0.402	0.633	0.51752	L17
11	0.0375	0.63	-0.1900	0.3158	-0.0950	0.1579	0.905	0.842	0.382	0.612	0.49712	L20
12	**0.0454**	0.47	-0.6885	0.7368	-0.3442	0.3684	0.656	0.632	0.523	0.740	0.63132	L4
13	0.0307	0.61	-0.2523	0.3684	-0.1262	0.1842	0.874	0.816	0.395	0.626	0.51053	L18
14	0.0252	0.68	-0.0343	0.1842	-0.0171	0.0921	0.983	0.908	0.353	0.581	0.46663	L22
15	0.0303	0.69	-0.0031	0.1579	-0.0016	0.0789	0.998	0.921	0.347	0.575	0.46099	L24
16	0.0243	0.70	0.0280	0.1316	0.0140	0.0658	0.986	0.934	0.351	0.569	0.46025	L27
17	0.0319	**0.75**	0.1838	0.0000	0.0919	0.0000	0.908	1.000	0.381	0.542	0.46134	L23
18	0.0243	0.73	0.1215	0.0526	0.0607	0.0263	0.939	0.974	0.369	0.552	0.46046	L25
19	0.0379	0.53	-0.5016	0.5789	-0.2508	0.2895	0.749	0.711	0.459	0.686	0.57278	L10
20	0.0331	**0.37**	-1.0000	1.0000	-0.5000	0.5000	0.500	0.500	0.678	0.851	**0.76483**	L1
21	0.0180	0.65	-0.1277	0.2632	-0.0639	0.1316	0.936	0.868	0.370	0.599	0.48444	L21
22	0.0225	0.62	-0.2212	0.3421	-0.1106	0.1711	0.889	0.829	0.389	0.619	0.50373	L19
23	0.0280	0.49	-0.6262	0.6842	-0.3131	0.3421	0.687	0.658	0.500	0.721	0.61042	L6
24	0.0144	0.51	-0.5639	0.6316	-0.2819	0.3158	0.718	0.684	0.479	0.703	0.59096	L8
25	0.0160	0.56	-0.4081	0.5000	-0.2041	0.2500	0.796	0.750	0.433	0.662	0.54763	L13
26	0.0293	0.54	-0.4704	0.5526	-0.2352	0.2763	0.765	0.724	0.450	0.678	0.56413	L11
27	0.0300	0.58	-0.3458	0.4474	-0.1729	0.2237	0.827	0.776	0.417	0.647	0.53212	L15

Conclusion:

This paper concludes that the variations between the single and multi optimization techniques are:

- Higher MRR is measured 0.02440 gm/s at 8bars pressure, stand off distance 4mm and nozzle diameter 2mm. It is detected that the optimal parameters for greater MRR at 8bar pressure, 4mm stand off distance and 3mm nozzle diameter.
- Smallest surface roughness is considered 0.46mm at 7 bars pressure, 6 mm stand off distance and 4mm nozzle diameter. It is detected that the finest factors for lesser surface roughness are 8bars pressure, 5mm stand off distance and 4mm nozzle diameter.

- In GRA Higher MRR is measured 0.045385 gm/s at 8bars pressure, 4mm nozzle tip distance and 2mm nozzle diameter. It is detected that the optimal parameters for greater material removal rate (MRR) are 8bar pressure, 4mm stand off distance and 3mm nozzle diameter.
- In GRA Smallest surface roughness is measured 0.37 mm at 9 bars pressure, 4 mm stand off distance and 4 mm nozzle diameter. . It is detected that the finest factors for lesser surface roughness 8bars pressure, 6 mm stand off distance and 2 mm nozzle diameter.

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