Proceedings of 10th International Conference on Precision, Meso, Micro and Nano Engineering (COPEN 10)
December 07 – 09, 2017, Indian Institute of Technology Madras, Chennai – 600 036 INDIA

Experimental Parametric Studies on Hast Alloy Using Abrasive Water Jet Machining

S.Jaya Kishore
***, K.Siva Kumar, Dr.M.Narayana Rao**
Sri Venkateswara College of Engineering, Department of Mechanical Engineering, Tirupati - 517501, INDIA
Narayana College of Engineering, Department of Mechanical Engineering, Nellore-524001, INDIA

Abstract

Abrasive water Jet Machining is mainly used in the aero industries for cutting hard materials and related composits.Its main uses are in machining space craft components,nuclear power plant components etc.Normally the diameter of jet is between 0.04 mm and 0.010 mm.In this paper investigation are made between in put process parameters and the process responses such as MRR,Surface Rouness etc. hardest materials and so many composites.Regression equations were developed to correlate the input parameters and processes responses to Optimize process parameters and predicted by using Integrated Gray relational and Genetic Algorithm Optimization technique's.A optimal level of Processes parameter's Transverse Speed(TS)-70mm/min,Abrasive Flow Rate(AFR)-200gm/min and Stand Off Distance(SOD)-1mm are predicted by using integrated technique.The major contribution of present work is to study effect of process parameters on quality of machined surface in AWJM.

Keywords: Hast Alloy, MRR,Surface Roughness,Kerf width,Taper.

1. INTRODUCTION

Water jets are introduced in USA during 1970's and were utilized merely for machining purposes. As the technology developed to include abrasive water jets, modern material machinings were discoverd. A variety of modern materials (Inconel,Titanium,Incoloy,superalloys,ceramics,composites, heat sensitive alloys etc.,) is shaped for different applications with this processes [1] Although they are many machining techniques available, abrasive water jet machining is widely used to produce proper complicated profile shaped products with zero surface hardening or thermal defects[2].Accurate and good quality of holes are required for some specific applications.Squareness of drilled hole at entry and exit, and taperness are important attributs which influence the quality of a drilled hole in abrasive water jet machining[3],In comparison with conventional type of machining, Abrasive Water jet machining produces minimal forces on the workspecimen, and does not require any specific workholding & tool holding devices. AWJ processes is least harmful[4].In optimizing various processes parameters genetic algorithm has its advantage [5-8](i) Exact solution is cost effective for implementation in manufacturing so that GA offers nearer optimal conditions(ii) Objective functions can easily handled of any complexity with both discrete (integer) and continuous variables; (iii) Non-linear connection in between the inputs and outputs can search automatically(iv) optimizing technique used in GA is simple results we get in a fast manner[9]. For proper study of optimal processes parameters quadratic polynomials were developed for optimal performance characterstics [10]. The literature reveals, it was shown that many researchers have optimized various processes parameters on MRR,Ra and KW using optimization techniques. The main motto of this research paper is to investigate the effect of AWJM process parameters such as TS,AFR and SOD on processes responses such as MRR, Ra,KW & taperness are identified and analyzed using regression model to formulate the optimization fitness function equation.Two optimization techniques GRA& GA are proposed to form the integration system labeled as integrated GRA-GA.

Fig. 1. Abrasive water jet machining during machining of HastelloyC276

2. EXPERIMENTAL SETUP

The specimen material chosen for this experimental work is Hast alloy C276. Ni-Cr-Mo-W alloys,named as Hastalloy & its chemical composition is shown in Table 1.Hastelloy has a nature of heat resistence, good mechanical properties, excellent resistence to corrosion and it is having ability to operate at high elevated temperatures, attracting at nuclear power plants etc.,[11,12].

Microstructures are studied for Hastalloy C276 with magnification lens of 5X.

Table 1

Material	Ni	Fe	Cr	Mo	Cu	Ti	C	Mn	Su	Si
Hastalloy	57	5.5	15.5	16	2.5	2.5	0.01	1	0.03.08	

The internal structure is studied for Hastelloyc276 material with lens magnification of 5x as shown in fig.2.

* Author to whom correspondence should be made, Email: shun@acer.iitm.ernet.in

ISBN: 978-93-80689-28-9

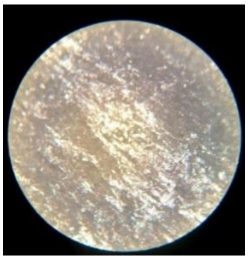

Fig. 2. Hastelloy Specimen Microstructure of of 5X

3. INFORMATION REGARDING SPECIMEN

3.1. Preparation of specimens

Hastelloyc276 workpiece having 100*100*10 mm3 workpieces is used for is machined into 25 work pieces are generated each of 10mm * 10mm.

3.2. Preparation of Machining setup

The experiment starts with constructing a layout of the machining in Autocad-2017 software by using the WCS. Design of all Experiment runs are carried on a CNC AWJM setup available at "EXCEL WATER JET CUTTING", SIDCO Industrial Estate, Thirumazhisai, Chennai -602107, TN, India

Fig. 3. Excel AWJM setup

3.3 Parameter Setting

(i) Transverse speed(TS)-A: The speed of machine tool over the workpiece with which it is machined.
(ii) Abrasive Flow Rate(AFR)-B: the rate of abrasive flow along with Water is given by gm/min.
(iii) Stand of distance(SOD)-C: The distance between the tip of the Nozzle and the workpiece. The processes parameters are in Table 2 are set based upon the DOE.

Table 2

List of Variable processes parameters with their levels.

Parameter	Units	Levels				
		1	2	3	4	5
Transverse Speed-TS-A	mm/min	40	50	60	70	80
Abrasive Flow Rate-AFR-B	gm/min	50	100	150	200	250
Stand Of Distance-SOD-C	Mm	1.0	2.0	3.0	4.0	5.0

A fixture of mildsteel fixture of 100mm has been shaped for quick mounting and proper clamping of workpiece and machining is performed.

3.4 Selection of OA L_{25}

In this research work orthogonal array L_{25} has to be taken based upon processes parameters,levels and Response factors.

DOF for a Control Factor= No.of levels-1

DOF for AB = (No. of Factors in A-1)* (No.of Levels-1) =2*4= 8

Total DOF = 8*No.of factors=8*3=24

The condition for selecting OA is the DOFs for selected OA must be higher than DOFs required for experiment is 24 so, the nearest OA available for satisfying the condition of selecting OA is L_{25}.

3.5 Processes Responses

(i) MRR: To calculate MRR or Single channel, used formulae is:

$$MRR = \frac{Amount of metal removed from the workpiece in mm^3}{Time taken for machining in sec} \quad (1)$$

It is multiplied by density of hastelloy then MRR is later changed to gm/sec.

(ii) Kerf width: $$\frac{side of the machined surface on workpiece (s_1)}{side of the cut piece from the specimen (s_2)} \quad (2)$$

(iii) Surface Roughness: It is tested by using Habson talysurf instrument.

(iv)Holetaper=

$$\frac{(hole entrance dimension) - (hole exit dimension)}{2 * Thickness of the workpiece} \quad (3)$$

Fig. 4. Hastelloy work piece Before & After Machining.

A total of 25 experiments were conducted and, the DOE is designed by using MINITAB, which is a statistical tool and operates to find the sequence of experiments and possible combinations of input parameters, to observe the effect of significant factors at 95% confidence level, the response parameters results are presented through graphs. The processes parameters and processes responses are illustrated in Table 3.

4. RESULTS AND DISCUSSION

4.1. Grey Relational Analysis

GRA is going to perform Grey Analysis and is given in fig.5.

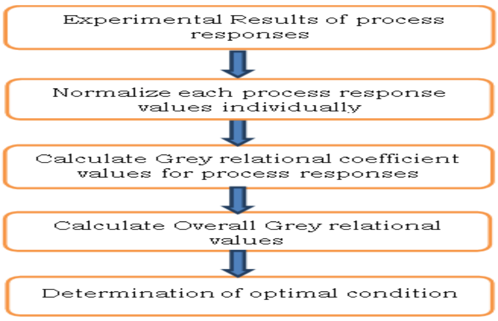

Fig. 5.GRA Processes Flow chart.

4.2. Normalization of results

The first step in Grey-Taguchi analysis is to normalize the experimental results of MRR,R_a,KW and taper.Each response value is normalized in the range of 0 to 1.For normalizing MRR "Higher is the better" is to selecet in Eq.4, R_a,Kw and taper "Smaller is the better" is to select in Eq.5.

$$X_j(v) = \frac{y_j(v) - \min y_j(v)}{\max y_j(v) - \min y_j(v)} \quad (4)$$

$$X_j(v) = \frac{\max y_j(v) - y_j(v)}{\max y_j(v) - \min y_j(v)} \quad (5)$$

Table 3

Plan of processes parameters for experimental setup as per coding and measured responses

Run order	Procsesses Parameters			Processes Responses			
	TS	Afr	Sod	MRR	kw	R_a	Taper
1	40	50	1	1.17	1.921	0.0145	0.116
2	40	100	2	1.20	1.826	0.0135	0.057
3	40	150	3	1.23	1.368	0.013	0.035
4	40	200	4	1.3	1.85	0.0135	0.030
5	40	250	5	1.28	4.69	0.0135	0.18
6	50	50	2	1.15	2.9	0.015	0.069
7	50	100	3	1.11	3.7	0.0145	0.191
8	50	150	4	1.14	4.5	0.0155	0.165
9	50	200	5	1.20	4.9	0.0145	0.006
10	50	250	1	1.11	4.53	0.013	0.034
11	60	50	3	0.97	3.52	0.017	0.264
12	60	100	4	1.07	4.9	0.0155	0.048
13	60	150	5	1.13	6.19	0.014	0.019
14	60	200	1	1.10	4.76	0.0135	0.069
15	60	250	2	1.12	4.84	0.013	0.021
16	70	50	4	1.1	5.71	0.0135	0.104
17	70	100	5	1.12	6.63	0.017	0.009
18	70	150	1	1.06	7.02	0.015	0.005
19	70	200	2	1.17	6.75	0.016	0.046
20	70	250	3	1.17	6.574	0.0135	0.009
21	80	50	5	1.06	5.53	0.0145	0.157
22	80	100	1	1.04	5.69	0.015	0.001
23	80	150	2	1.11	7.57	0.0135	0.011
24	80	200	3	1.13	7.037	0.013	0.011
25	80	250	4	1.16	8.087	0.015	0.029

4.3. Grey Relational coefficient

The grey relational coefficient $\varepsilon_j(v)$ can be calculated by using Eq.6 this grey relational coefficient value is used to get grey order. Grey relational grade can be calculated by using Eq.7. a Higher grade indicates the best higher order value.

$$\varepsilon_j(v) = \frac{\Delta_{\min} + \phi\Delta_{\max}}{\Delta_{oj}(v) + \phi\Delta_{\max}} \quad (6), \qquad \gamma_j = \frac{1}{n}\sum_{v=1}^{n} \varepsilon j(k) \quad (7).$$

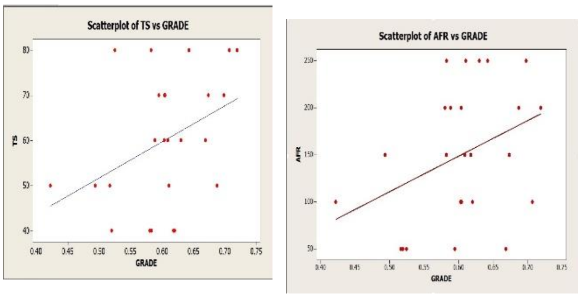

Fig.6 Transverse speed Vs Grade & AFR Vs Grade.

Transverse Speed is increases then grey grade is increases hence we can get better machining as shown in fig.6. If AFR as it increases then grey grade incrases hence better machining is obtained as sod is small then we get better machining in fig.7.

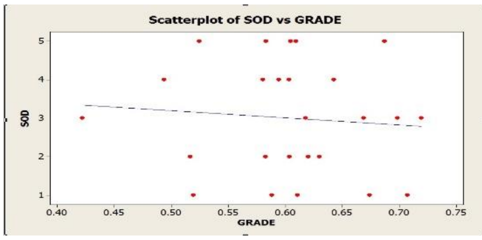

Fig.7 Stand of Distance Vs Grade.

Influence of Transverse Speed is in Fig.8. The raise in Transverse speed leads to raise in the machining linearly up to level 70mm/min-A4 it improves MRR and then if still we increased improper machining should takes place MRR is also reduced as in Fig.6.

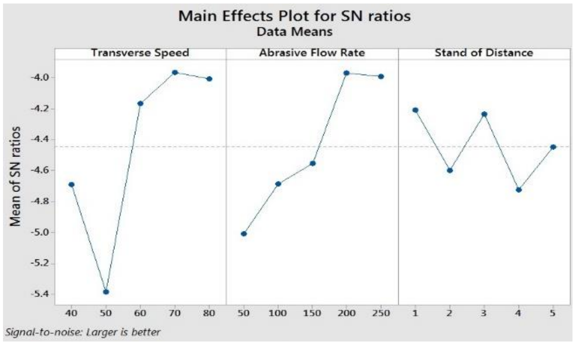

Fig.8 Main effect plot S/N Ratio for Grey Relational vs Grade.

The influence of AFR is as in Fig.8. Increase in AFR leads to raise in the machining linearly up to level 200 mm/min-B4 it maximize surface finish and then if still we increased surface finish is reduced place as shown in Fig.6.

Influence of stand off diatance is as shown in Fig.8. The sod will be minimum such that better cuts are takesplace if SOD leads to increases taperness of hole is takes place 1 mm -C1 in Fig.8.

4.4 Genetic Algorithm

Here we have to search the processes parameters that led to a maximize value of machining performance.Value of experimental data & regression modeling to estimate the optimal processes parameter values that has to be with in the range of maximum and minimum processes parameter results of experimental design.

Advantages:

1. Fast and simple optimization technique.
2. It estimates the current populational potential minimum value for machining performance with optimal processes parameters.

The minimum predicted performance value at the optimal solution was estimated as Equ 8.

$GA= R_a =C\, V^q P^r h^s$ ------Non linear equation (8)

$\ln R_a=\ln(C)+q \ln(V)+r\ln(p)+s\ln(h)$-------Linear Equation (9)

GA must be iterated many times in order to produce a usable result for a non-trial problem.

4.5 Regression Equation

Regression equation is generated by Minitab-17 software for each processes responses can be expressed as

$\ln(MRR) = -2.87- 0.106 \ln(ts)+0.053 \ln(afr)+0.161 \ln(sod)$ (10)

$\ln(SR) = 1.458 - 0.019 \ln(ts)-0.0492 \ln(afr)-0.0208 \ln(sod)$ (11)

$\ln(KW) = 0.36 - 0.305 \ln(ts)+0.069 \ln(afr)+0.217 \ln(sod)$ (12)

$\ln(Taper) = 9.65-2.265 \ln(ts)-0.880 \ln(afr)+0.516 \ln(sod)$ (13)

FitnessFunction, $Y=W_1MRR+W_2R_a^{-1}+ W_3KW^{-1}+W_4Taper^{-1}$ (14)

Where, W_1, W_2, W_3& W_4 are weights of responses.

W_1=0.039, W_2=0.071, W3=0.076, W4=0.814.

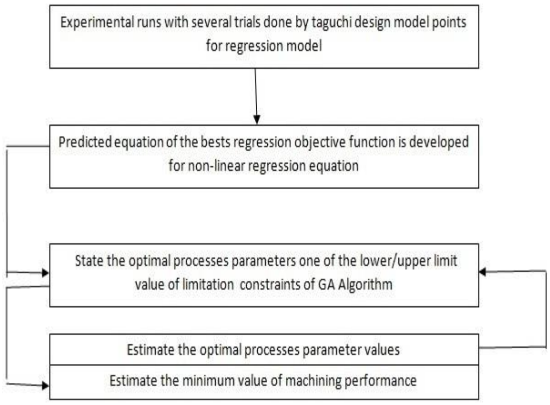

Fig.9 The flow of the proposed GA optimization.

Y=((0.071*(0.0566*X^-0.106*Y^0.053*Z^0.161)
+(0.039*0.01356*X^-0.019*Y^-0.0492*Z^-0.0208)^-1)+
(0.076*(1.4333*X^-0.305*Y^(0.069)*(Z)^(0.217))^-1))+
0.814*(15521.788*X^-2.265*Y^-0.880*)^(0.516))^-1); (15)

Simple fitness function=@simple_fitness;

The GA repeatedly modifies a population of individual solutions at each step, the GA operates by selecting individuals from population at random as parents and generates children for next generation. The minimized fitness function value of Eq.(15) subjected to limitation constraints. The lower and higher processes parameters of experimental design are used to define the GA optimization constraint as follows:

$40\leq V\leq 80$ (16)

$50\leq P\leq 250$ (17)

$1.0\leq h\leq 5.0$ (18)

Basically,to obtain optimal solutions,some criteria must be considered in GA as listed in Table 4.matlab toolbox is applied to get the minimum values.

Table 4. Optimal solution is obtained by GA parameter combination

S.No	Parameters	Setting value / Function type
1	Population Size	100
2	Scaling Function	Rank
3	Selection Function	Rollete wheel
4	Cross over function	Heuristic
5	Cross over rate	0.8
6	Mutation function	Adaptive feasible

The set values of optimal processes parameters that lead maximumze Mrr,Minimize R_a,Kerf width and taper for Transverse Speed(TS)-70.00085mm/min moving nozzle speed, AFR-210.9605gm/min,SOD- 1.0826mm. It is also indicate that the optimal solution is obtained at 51st generation mean fitness is 90.85613.

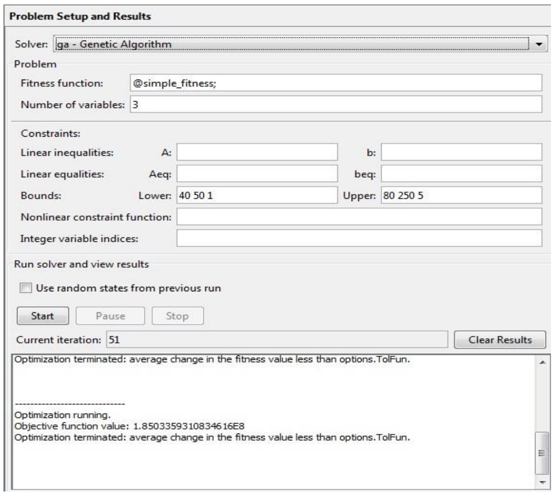

Fig.10 Optimal solution for GA.

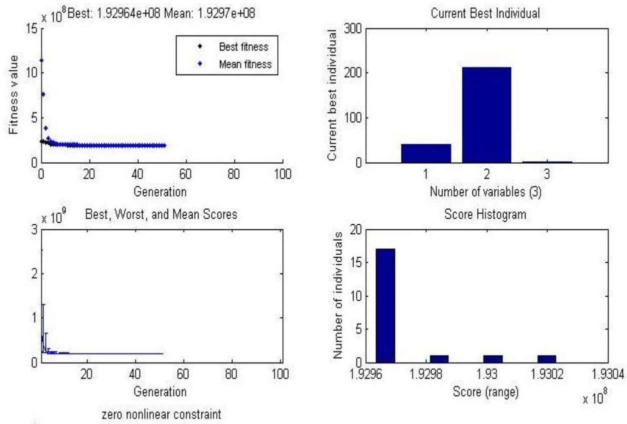

Fig.11 Fitness function plot for GA.

The best fitness improves slowly in later generation, whose populations are closer to optimal global point, but the 51st generation is found to give the global optimal point.

Table 5. Optimum processes parameters and processes responses values

S. No	OT	TS	AFR	SOD	MRR	R_a	KW	Taper

1	GRA	70	200	1.0	0.047	0.009638	0.56	0.0097
2	GA	70	210.960	1.0286	0.048	0.009607	0.56	0.0093

During validation of results compare between GRA and GA MRR is better to 0.733% , R_a reduced to 0.321%,kerfwidth reduced to 0.3670%,taperness is reduced to 3.295% by optimize processes parameters by using GA method then GRA optimization technique.

5 CONCLUSIONS

In this paper, AWJM is used for machining hastelloy C276. 25 holes of square shape were machined to investigate the effects of processes parameters (i.e, Transverse spee, abrasive flow rate and stand of distance) on quality of machined workpieces such as Metal Removal Rate (MRR),Kerf width(kw),Taperness and Surface Roughness (R_a) conclusions are drawn based on Grey Taguchi Technique & Genetic Algorithm integrated technique.

1. The increase in Transverse speed by GRA leads to rise in the machining capabilities linearly up to level 70mm/min-A4 and the GA optimum value we get is 70mm/min.
2. The rise in AFR by GRA leads to increase in the machining linearly up to level 200gm/min-B by GA and the optimum value we get is 210.960 gm/min.
3. The SOD will be minimum such that better cuts takeplace.
4. The comparison between GRA and GA and MRR is 0.733 %,minimum R_a value is 0.321%,taperness is reduced to 3.295% and kerf width is minimizes to 0.3670%.The searching time for optimized solution can be made faster by using the proposed integration system.

References

[1] Divyansh patel, Puneet tendon., Experimental investigations of thermally enhanced abrasive water jet machning of hard-to-machine metals, CIRP Journal of Manufacturing Science and Technology,(2015) 92-101.

[2] M.Uthhayakumar, M.Adam khan,S.Thirumalai kumaran,Adam slota and Jerzy zajac. Machinability of nickel-based super alloy by abrasive water jet machining.Materials and Manufacturing processes 2016, 31(13), 1733-1739.

[3] P.Rajesh,U.Nagaraju,G.HarinathGowd,T.Vishnu vardhan., Experimetal and Parametric Studies of Nd:YAG laser drilling on austenitic stainless steel , *International Journal of Advanced manufacturing Technology,* 08 (2015) 103-111.

[4] Rajkamal shukla and Dinesh singh., Experimentation investigation of abrasive water jet machining parameter using taguchi and evolutionary optimization techniques., Swarm and Evolutionary computation, (2016) 123-147.

[5] Mukherjee,P.k.Ray,A review of optimization techniques in metal cutting processes,Computer and industrial Engineering 50(2006) 15-34.

[6] D.A.Manolas,T.P.Gialamas,C.A.Frangopoulos, D.T.Tshalis, A genetic algorithm for operation optimization of an industrial cogeneration system, computers and chemical engineering 20(1996) 1107-1112.

[7] F.Cus,J.Balic,Optimization of cutting process by GA approach, Robotic and Computer Intergrated Manufacturing 19(2003) 113-121.

[8] Azlan Mohd Zain,Habibollah Haron,Safian Sharif, Optimization of processes parameters in the abrasive water jet machining using integrated SA-GA11(2011) 5350-5359 .

[9] Sruthi,B.,Kilari,N.,Kishore.J.S,Experimental investigation of Abrasive Water jet machining processes parameters & its Effects on processes responses using grey taguchi optimization technique 2(2016) 13-19.

[10] Duradundi SSawant Badkar,Krishna Shankar pandey,G.Buvanashekaran, Development of RSM-and ANN-based models to predict and analyze the effects of process parameters of laser-hardened commercially pure titanium on heat input and tensile strength(2013) 65:1319-1338.

[11] Singh VB,Gupta A.2000.The electrochemical corrosion and passivation behavior of Monel 400 in concentrated acids and their mixtures.Trans.JWRI,34,19-23.

[12] Haynes Hastelloy C-22HS Standard Product Catalogue.2007.Haynes International:Indiana.p. 2-16.