Available online www.jsaer.com

Journal of Scientific and Engineering Research, 2018, 5(12):56-61

Research Article

ISSN: 2394-2630
CODEN(USA): JSERBR

Multi-Criteria of Decision-Making Approach by using Fiber Reinforced Polymer in AJM

Abhijeet Gupta[1]*, Rupesh Adiley[2]

[1]Assistant Prof., [2]M. Tech Research Scholar
Dept. of MechanicalEngg, Dr. C. V. Raman University Bilaspur, India

Abstract In the recent year, many multi-criteria decision-making methods have been proposed to evaluate and examine the effectiveness ofdifferent machining process. The aim of this study is to propose a multi-criteria decision making (MCDM) approach tooptimize the machining parameters of Abrasive jet machining (AJM) in the fiber reinforced polymer (CFRP) materials. In AJM, drilling experiment was done on CFRP composite material as the work piece and aluminum oxide (Al_2O_3) as abrasive powder. The effect of Overcut (OC) and Material removal rate (MRR) of this material was finding by using L_9 orthogonal array based on Taguchi design.Selected control parameters are pressure of air and stand-off-distance, and output responses such as MRR and OC was calculated. These responses are contradicting in nature, for eliminating this modification has been converted into single response optimization techniques is known as PCA based grey relation analysis. In this result PCA based GRA means principal component analysis combine with grey relation analysis and simultaneously optimized single quality characteristics know overall quality performance index (OQPI).

Keywords Abrasive Jet Machining, Multi-Criteria Decision Making, Fiber Reinforced Polymer, Principal component analysis, Grey Relation Analysis

Introduction

AJM is also named as abrasive micro blasting, is a nonconventional machining process that carried a high-pressure air stream with small abrasive particles to impinge the work surface through a nozzle for material removal of the work piece [1].

Carbon fiber reinforced polymer (CFRP) composites are used for light-weighting of structural components of an aircraft which in turn leads to an improved fuel economy; reduced emissions and increased payload of aircrafts. Material behavior under conventional machining is different to homogenous metals and alloys. The non-homogeneity, anisotropy, and high abrasiveness and hardness of the reinforcement fibers make the machining of CFRP a difficult task [2]. Carbon fibers are used in composites with a lightweight matrix. Carbon fiber composites are ideally suited to applications where strength, stiffness, lower weight, and outstanding fatigue characteristics are critical requirements [3]. According to Mutavgjic higher the tensile strength of the organic compound the higher is the tenacity of the carbon fiber [4].

Lin and Chen present Drilling of carbon fiber-reinforced composite. And to describe effects of cutting speed as well as other cutting parameters on drilling characteristics, including cutting forces and tool wear when drilling carbon fiber-reinforced composite materials at high speed [5]. Yan et al. [6] investigated the effects of catalyst content, polymerization temperature and time on the viscosity average molar mass and degree of crystallinity. The mechanical properties of the composites with different post-heat treatments were further investigated. Mahabalesh Palleda [7] investigated the influence of the different chemical such as acetone, phosphoric acid and polymer (polyacrylamide) in the ratio of 30% chemicals with 70% of water. Abrasive assisted electrochemical jet machining is a hybrid manufacturing technology coupling erosion and corrosion concurrently to remove metals [8].

This work presents various issues observed in AJM on CFRP composite materials, and the effects of AJM are analyzed in processing these composite materials. Drilling experiment was done on CFRP composite material as the work piece and aluminum oxide (Al_2O_3) as abrasive powder.The two output responses are finding MRR and SR and this response contradicting in nature, for eliminating this variation has been converted into single response optimization techniques is known as PCA based grey relation analysis have been applied.

2. **Conduct of Experiment**

Experimental set up is shown in the Fig. 1. In this experiment nozzle diameter (2 mm), abrasive particle size (50 µm) is kept constant. The machining parameter Stand of Distance (SOD) and Pressure (P) are varying. For calculating initial and final weight electronic balance weight machine (SHINKO DENSHI Co. LTD, JAPAN, Model: DJ 300S.), was used. It has 300 gm. weight capacity and 0.001gm accuracy.

The diameter of hole and nozzle diameter before experiment and nozzle dia. after experiment was measurement by tool maker microscope and optical microscope. In this experiment diameter of drilled hole was calculated by taking of the mean diameters of both the data two microscope. CFRP sample piece is obtained according to the standard dimensions i.e. the sample pieces have square section of 50 mm and thickness of the sample piece is 2mm.

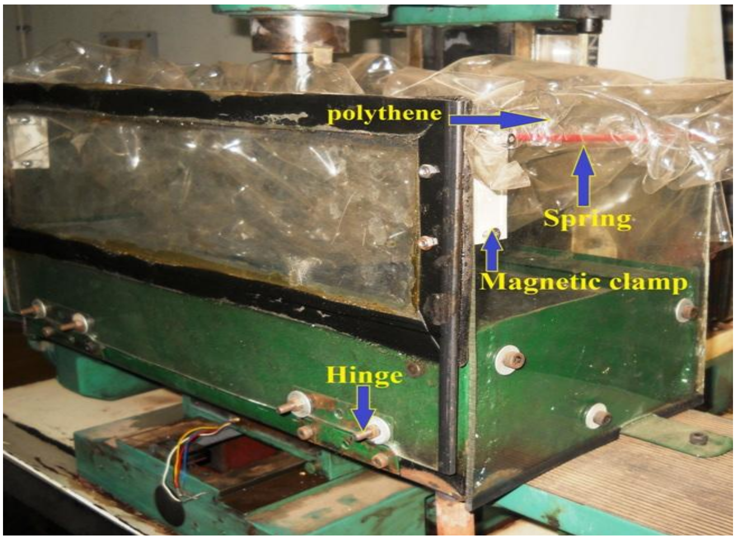

Figure 1: Tool and work-piece of abrasive jet machining

3. Machining parameters and their selection

In this experiment, a two factor and three levels setup (Table 1) is chosen with a total of nine numbers of experiments to be conducted and hence L_9 Orthogonal Array (OA) was chosen. Machining parameters and their level are presented below, and other parameters are kept constant during this experiment. The observed value of MRR and Overcut are presented in Table 2.

Table 1: Control Parameters and their levels

Factor	Symbol	Unit	Levels		
			Level 1	**Level 2**	**Level 3**
Stand of distance	(SOD)	mm	0.6	0.8	1.0
Pressure	(P)	bar	2	4	6

Table 2: Experimental observed value

Run no	**SOD (mm)**	**P (bar)**	**Weight of Composite material (gm)**		**Over Cut (mm)**	**MRR (mm^3/min)**
			Initial weight	**Final weight**		
1	0.6	2	65.679	65.675	0.1325	1.667
2	0.6	4	65.674	65.665	0.1825	3.750
3	0.6	6	65.665	65.648	0.4375	7.083
4	0.8	2	65.729	65.723	0.1450	2.500
5	0.8	4	65.723	65.709	0.3065	5.833
6	0.8	6	65.709	65.684	0.5075	10.417
7	1.0	2	65.764	65.759	0.1600	2.083
8	1.0	4	65.759	65.748	0.2065	4.583
9	1.0	6	65.748	65.729	0.4575	7.917

4. Influence of machining parameters on MRR and OC

During the process of AJM, the influence of machining parameter like SOD and pressure has significant effect on MRR on composite material as shown in main effect plot for MRR in Fig. 2. The pressure (p) is directly proportional to MRR in the range of 2 to 6 bar.

This is expected because an increase pressure produces strong kinetic energy which produces the higher temperature, causing more material to erode from the work piece [9]. The other factor SOD does not influence much as compared to pressure. It is clearly indicated from the above figure 2 at SOD 0.8mm the MRR was maximum. It decreases with increase in SOD and decreases with decrease in SOD. It suggests that the effect of one factor is dependent upon another factor.

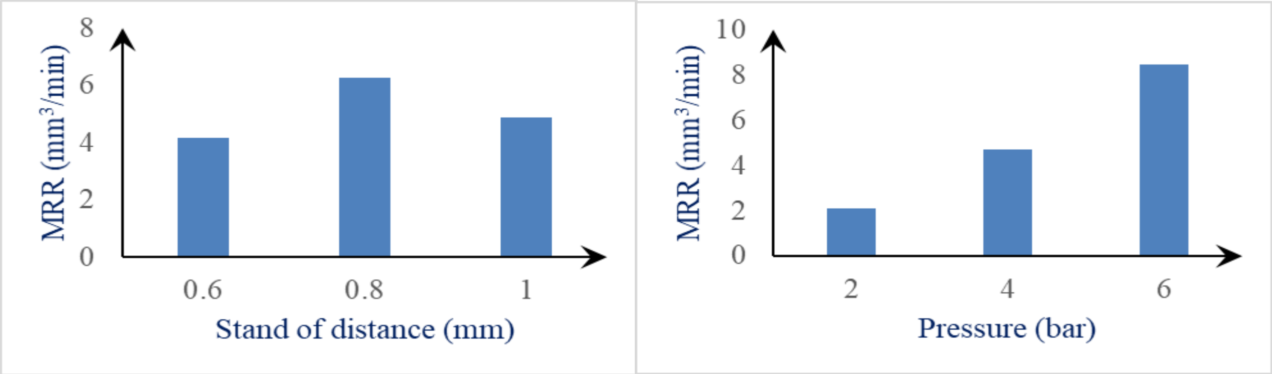

Figure 2: Main effect plot for mean of MRR

During the process of AJM, the influence of machining parameter like SOD and pressure has significant effect on OC, as shown in main effect plot for OC that is Fig. 3. The pressure (p) is directly proportional to OC in the range of 2 to 6 bar.

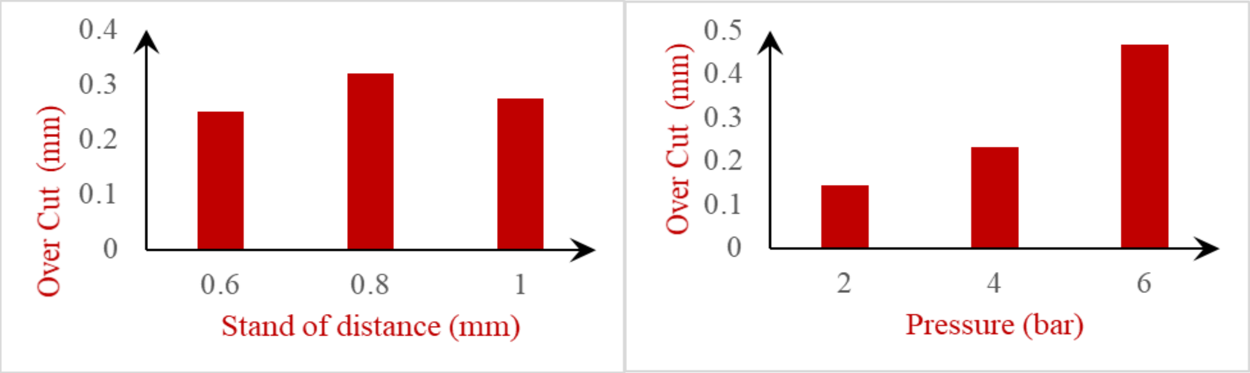

Figure 3: Main effect plot of mean for OC

This is expected because an increase pressure produces strong kinetic energy which produces the higher temperature, causing more material to erode from the work piece and make OC higher.

The other factor SOD also influences on the OC. It is clearly indicated from the above figure at SOD 0.8mm the OC was maximum. It decreases with increase in SOD and decreases with decrease in SOD.

5. PCA- based GRA method

PCA based GRA method is used to convert multiple responses into a single characteristic index known as overall quality performance index (OQPI) [10]. For calculation of optimal OQPI value involves following steps:

- Converting the experimental data into S/N ratio.
- Calculating the principal component scores (PCS).
- Obtaining normalized PCSs.
- Calculating the grey relation coefficient using principal component score.

5.1. Calculating OQPI

At first, the experimental values of MRR and OC are converted into S/N ratio. According to this method, the three types of S/N ratios are categorized into lower-the-better (LTB), higher-the-better (HTB), and the nominal-the-better (NTB). The S/N ratio with LTB and HTB represented following equation 1 and 2 for MRR and OC respectively [11-12].

LTB response variable

$$\eta_{ij} = -10\log\left[\frac{1}{n}\sum_{i=1}^{n} y_i^{-2}\right] \quad (1)$$

HTB response variable

$$\eta_{ij} = -10\log\left[\frac{1}{n}\sum_{i=1}^{n} y_i^{2}\right] \quad (2)$$

Where η_{ij} denotes the S/N ratios calculated from observed i^{th} experiment and j^{th} response) values, $y_i$represents the experimentally observed value of the i^{th} experiment and n=1 is the repeated number of each experiment in L_9 OA is conducted.

The second steps conduct PCA on the S/N ratios to obtain uncorrelated PCSs corresponding to each experimental run, in the form of PCS_{il}it can be obtained by follows:

$$PCS_{il} = a_{l1}\eta_{i1} + a_{l2}\eta_{i2} + \dots\dots\dots + a_{lj}\eta_{ij} \quad (3)$$

Where $a^2_{l1}+a^2_{l2}\dots\dots+a^2_{lj} = 1$. The a_{l1}, $a_{l2}\dots\dots a_{lj}$are the elements of eigenvector corresponding to the l^{th} eigenvalue of response variables. It can be calculated by MINITAB software. The eigenvalue and eigenvector are shown in Table 3. The third steps normalized the PCSs value by using equation 4.

$$X_{il} = \frac{PCS_{il} - PCS_{il}^{\min}}{PCS_{il}^{\max} - PCS_{il}^{\min}} \quad (4)$$

Where X_{il} and PCS_{il} are normalized and observed data, respectively for i^{th} experiment using l^{th} principal component score. The smallest and largest values of PCS_{il} for the l^{th} PCS are min PCS_{il}^{min} and max PCS_{il}^{max} respectively.

Table 3: Eigen analysis of the correlation matrix

Variable	Eigen vectors		Eigen value	Proportion
	PC1	**PC2**		
SN-MRR	-0.707	-0.707	1.9578	0.979
SN-OC	0.707	-0.707	0.0422	0.021

Then next step is to calculate the grey relation coefficient (GRC) of normalized PCSs data with the help of equation 5.

$$\gamma = \frac{1}{n}\sum_{i=1}^{n} W_l \zeta_{ij} \qquad (5)$$

$$\zeta_{ij} = \frac{\Delta_{\min} + \zeta\Delta_{\max}}{\Delta_{il} + \zeta\Delta_{\max}} \qquad (6)$$

Where Δ_{il} = $|1-X_{il}|$. ζ_{ij} is the GRC of i^{th}experiment using j^{th}response, Δ_{max} and Δ_{min} are the global maximum and global minimum values in the different data series, respectively. The distinguishing coefficient varies between 0 and 1, which is to expand or compress the range of GRC. After calculating the GRCs, for l no. of PCS, the final steps OQPI (γ) can be calculated using equation 6

Where w_l is the proportion of variance explained by i^{th} principal component and The magnitude of γ imitates the overall degree of standardised deviation of the i^{th}experimental run. In general, a scale item with a high value of γ indicates that the respondents have a high degree of favourable consensus on the particular item. The OQPI values of i^{th}experimental run is tabulated in Table 4.

Table 4: Steps for Calculation of PCA based GRA

Run no	SN-MRR	SN-OC	PCS-1	PCS-2	GRC 1	GRC 2	OQPI
1	4.4387	17.5557	9.2737	-15.5500	0.9352	1.0000	0.9365
2	11.4806	14.7747	2.3289	-18.5625	0.5692	0.3665	0.5649
3	17.0043	7.1804	-6.9455	-17.0986	0.3738	0.5295	0.3771
4	7.9588	16.7726	6.2314	-17.4851	0.7296	0.4739	0.7243
5	15.3178	10.2714	-3.5678	-18.0916	0.4272	0.4068	0.4268
6	20.3549	5.8913	-10.2257	-18.5560	0.3333	0.3670	0.3340
7	6.3738	15.9176	6.7475	-15.7600	0.7579	0.8925	0.7607
8	13.2230	13.7016	0.3384	-19.0357	0.5118	0.3333	0.5080
9	17.9712	6.7922	-7.9036	-17.5077	0.3610	0.4710	0.3633

5.2. Analysis of OQPI

The higher value of OQPI means comparability sequence has a stronger correlation to the reference sequence. Fig.4 represents main effect plots for OQPI and this graph depicts that the optimal machining parameters setting is Stand of distance 0.6 mm and Pressure 2 bar which would simultaneously ensure better Productivity in terms of maximum value of MRR and better quality in terms of minimum value for OC.

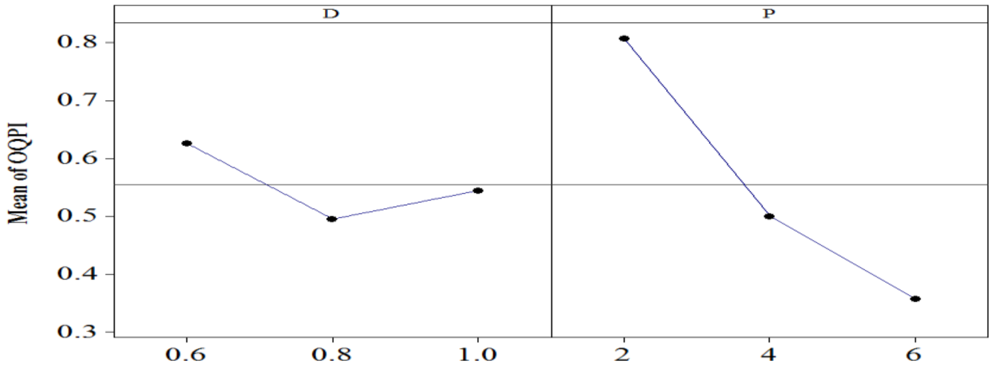

Figure 4: Overall quality performance index values

6. Conclusions

The AJM is can be used for drilling operation of composite fiber reinforced polymer material. Experimental work was done by considering SOD and Pressure are machining parameter to study MRR and OC. For MRR both SOD and pressure are significant factor and for OC only pressure is significant. MRR is increases with increase in pressure. For increase in SOD firstly MRR increases then it is remaining constant after that it is decreases.

For multi-objective optimization using PCA based grey relation analysis, optimal machining parameters setting was finding to Stand of distance 0.6 mm and Pressure 2 bar which would simultaneously ensure better Productivity in terms of maximum value of material removal rate and better quality in terms of minimum value for overcut of fiber reinforced polymer material.

References

[1]. Nouhi, J.K. Spelta,, M. Papini (2018) Abrasive jet turning of glass and PMMA rods and the micro-machining of helical channels, Precision Engineering, Under Press.

[2]. H. Hocheng, C.C. Tsao (2005) The path towards elamination-free drilling of composite materials. International Forum on the Advances in Materials Processing technology, Glasgow, Scotland, 2:51-64.

[3]. M. El-Hofya,, M. O. Helmyb, G. Escobar-Palafoxa, K. Kerrigana, R. Scaife (2018) Abrasive Water Jet Machining of Multidirectional CFRP Laminates, 19th CIRP Conference on Electro Physical and Chemical Machining, 23-27 April 2018, Bilbao, Spain, Procedia CIRP 68: 535 -540.

[4]. V. Mutavgjic, I. G Kovačića, Jadranovo, Z. Jurkovic, M. Franulovic, M. Sekulić, (2017) Experimental investigation of surface roughness obtained by abrasive water jet machining, in: 15th International Research/expert Conference Trends in the Development of Machinery and Associated Technology TMT Prague, Czech Republic, 73-76.

[5]. S.C. Lin and IK. Chen (1996) Drilling carbon fiber reinforced composite material at highspeed' Wear 194: 156-162.

[6]. Chun Yan, Hongzhou Li, Xiaoqing Zhang, Yingdan Zhu, Xinyu Fan and Liping Yu, (2013). Preparation and Properties of Continuous Glass Fiber Reinforced Anionic Polyamide-6 Thermoplastic Composites, Materials and Design, Vol. 46: 688–695.

[7]. Mahabalesh Palleda, (2007) A study of taper angles and material removal rates of drilled holes in the abrasive water jet machining process "Journal of Materials Processing Technology 18: 292– 295.

[8]. Zhuang Liua, ChangshuiGaoa,, Kai Zhaoa, Chao Guob (2018) An empirical model for controlling characteristics of micro channel machined using abrasive assisted electrochemical jet machining. 19th CIRP Conference on Electro Physical and Chemical Machining, Bilbao, Spain. Procedia CIRP 68: 719 – 724.

[9]. J. P. Padhy, S. Dewangan and C. K. Biswas (2014) Optimization of Multi-Objective Optimization of Machining Parameters of AJM using Quality Loss Function, International Journal of Current Engineering and Technology, ISSN 2277 – 4106, 1 (3) : pp.225-257.

[10]. S. Dewangan, C. K. Biswas and S. Gangopadhyay (2015) Multi-Response Optimization of Surface Integrity Characteristics of EDM Process using Grey-Fuzzy Logic-based Hybrid Approach Engineering science and technology an international journal. 18, ISSN 2215-0986: 361-368.

[11]. S. K. Dewangan, C. Tiger, N. Nayak (2018) Optimization of EDM Process Parameters by using PCA based Grey Relation Analysis, International Journal of Mechanical and Production Engineering, 6 (2), ISSN(p): 2320-2092, ISSN(e): 2321-2071:1-4.

[12]. J. P. Padhy, S. Dewangan and G. Talla (2014) Optimization of Abrasive Jet Machining Process using Taguchi's Quality Loss Function" International Conference on Design, Manufacturing and Mechatronics, Trinity College of Engineering and Research, Pune, Jan. 9-10: 581-585.