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Surface Roughness analysis of drilling on GFRP composites by experimental investigation and predictive modeling

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Abstract: Glass Fiber Reinforced Plastics composites have an increased application in recent days, due to its enhanced structural properties, Mechanical and thermal properties. Drilling of holes in GFRP becomes almost unavoidable in fabrication. The heterogeneous nature of this kind of materials makes complications during machining operation. However, drilling is a common machining practice for assembly of components. The quality of holes produced in the GFRP material is severely affected by surface roughness, Circularity and Delamination . The objective of the study is to apply the full factorial design, ANOVA and Fuzzy logic model to achieve an improved hole quality considering the minimum surface roughness through proper selection of drilling parameters. The regression method is employed in the Experimental investigation and Mathematical modelling of drilling of GFRP material using HSS drill bits and the fuzzy logic model for the validation of the mathematical model.

Index terms: GFRP, ANOVA, Fuzzy logic, aircraft fuselage, Full factorial Method, Drilling, Surface Roughness.

I. INTRODUCTION

Glass fiber Reinforced Plastics (GFRP) are widely being used in the automotive, machine tool industry, aerospace components, sporting equipment's [1] because of their particular mechanical and physical properties such as specific strength and high specific stiffness. An aircraft fuselage structure around 100,000 holes is required for joining purpose [2, 3]. About 60% of the rejections are happening in aircraft industry due to the defects in the holes [4]. Many of these problems are due to the use of non-optimal cutting tool designs, rapid tool wear and cutting parameters [5, 6]. Among the defects caused by drilling with tool wear, Delamination appears to be the most critical [7].The surface finish of the work piece is an important attribute of hole quality in any drilling operation. During machining many factors affect the surface finish. Many theoretical models have concluded that the effect of spindle speed on surface roughness is minimal [8]. In practice, however spindle speed has been found to be an important factor [9]. The quality of drilling surfaces depends on the cutting parameters and tool wear, while changing the cutting parameters causes to tool wear [10].Researchers have attempted to model the surface roughness prediction using multiple regression, mathematical modeling based on physics of process, fuzzy logic [11].Machining operation being highly nonlinear in nature, soft computing techniques have been found to be very effective for modeling [12].The influence of process parameters such as spindle speed, lubrication and feed rate on surface finish were investigated during the experimentation of Metal matrix composites. The experiments were conducted according to the full factorial design .The percentage of contribution of highest influential factors can be determined using analysis of variance(ANOVA) a statistical tool, used in design of experiments[13,14]. Fuzzy logic is a mathematical formalism for representing human knowledge involving vague concepts and a natural but effective method for systematically formulating cost effective solutions of complex problems [15]. A model was developed for surface roughness on drilling of GFRP composites using fuzzy logic [16]. The primary objective of this study is to quantify the influence of process input parameters on surface roughness by formulating a mathematical model and validating using Fuzzy logic model.

II. DESIGN OF EXPERIMENT

Design of experiment is the design of all information - gathering exercises where variation is present, whether under the full control experimenter or not. The cutting speed, feed rate and thickness of GFRP plate are the three parameters under investigation in the present study. A full factorial experimental design with a total number of 27 holes drilled into the GFRP specimen to investigate the hole quality on Surface Roughness. The full factorial design is the most efficient way of conducting the experiment for that three factors and each factor at three levels of experiments is used. Hence as per $Levels^{factor}$ (factors to power of levels) formula = $Levels^{factors}$,$N = 3^3 = 27$, N- number of experiments.

Table 1:Assignment levels for process parameters

Factors	Levels		
	1	2	3
Speed,s(rpm)	280	900	1800
Feed,f(mm/rev)	0.18	0.71	1.40
GFRP Plate thickness,t(mm)	5	10	15

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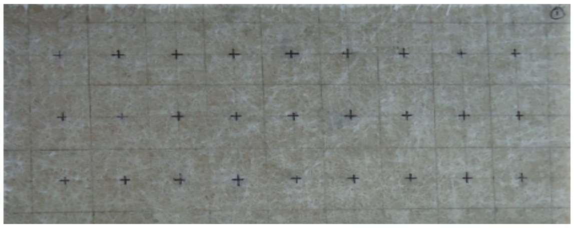
Fig 1: Fabricated GFRP plate

III. SPECIMEN PREPARATION

The Glass fiber reinforced composite used is fabricated using hand lay-up technique [12]. The composition type is Glass fibers (fiber length=20-30mm) reinforced with isopathalic resin with 30% reinforcement .The material was fabricated and then cut into pieces of 22cm x 11cm for all the three thicknesses of plate (Fig.1)

A. Methodology

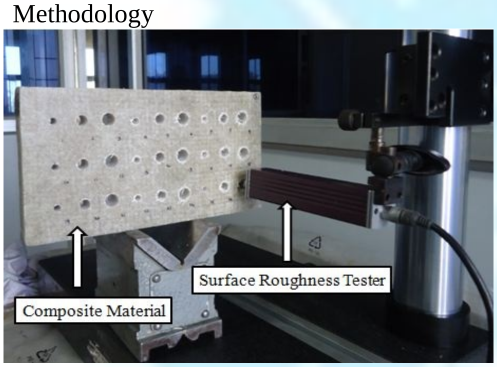

Fig 2: Surface Roughness Tester

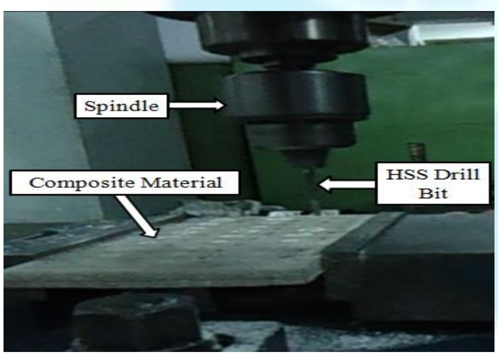

Fig 3: Experimental Setup

Experiments were carried out in high speed radial drilling machine using HSS drill of 10mm diameter. Experiments were carried out according to full factorial design. It provide a powerful and efficient method for designing processes that operate consistently and optimally over a variety of conditions. The selected levels of process parameters were given in Table 1.Fig. 3 shows the photographic view of the experimental setup. Further, the hole quality characteristics surface roughness measured using roughness tester [Mitutoyo TR-200].Fig. 2 shows the measurement of hole quality characteristics using roughness tester. Point angle was measured before every drill for 27 experiments using Digital Profile Projector [OPTOMECH, 10x magnification].

IV . RESULTS AND DISCUSSION

A. ANOVA

The Analysis of variance is extensively used to analyze the experimental results. ANOVA tests the significance of group difference between two or more groups. The normal probability plot represents that all the points on the normal plot lie close to the straight line (main line) or not. Versus fits plots represents that how far deviation occur from the normal distribution. An interaction plot is occurs when the change in response from the one level of a factor to another level differs from change in response at the same two level second factor. A main effect plot is present when different levels of an input affect the responses directly.

B. ANOVA FOR SURFACE ROUGHNESS

Fig.4 Represent that all the points lie closer to the regression line, this implies that the data are fairly normal and there is a no deviation from the normal. Histogram graph shows the skewness. The Equation No. 1 represents that feed has much effect on Ra. The main effect plot for Surface Roughness has been shown in the Fig 5. The plot shows that Ra decrease with low cutting speed and low feed rate for 15 mm plate, as well as the initial (without wear in drill bit) point angle has less effect on Ra. Table 2 Shows that the analysis of variance of second order model with 95% confidence interval for the Surface roughness experiments. Parameter A gives 44.2% contribution to the Ra.

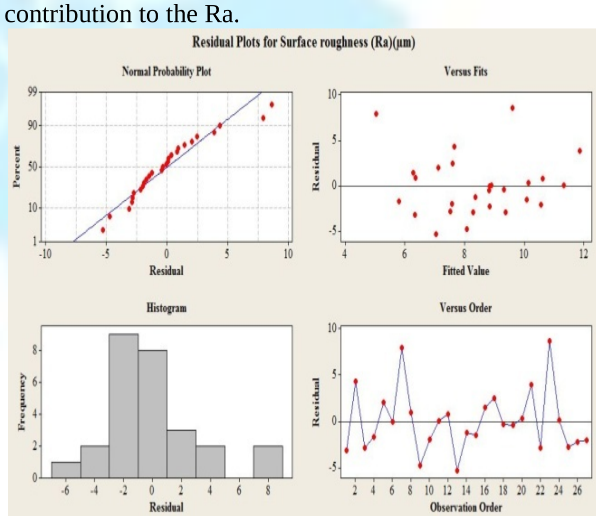

Fig.4 Residual plot for Ra

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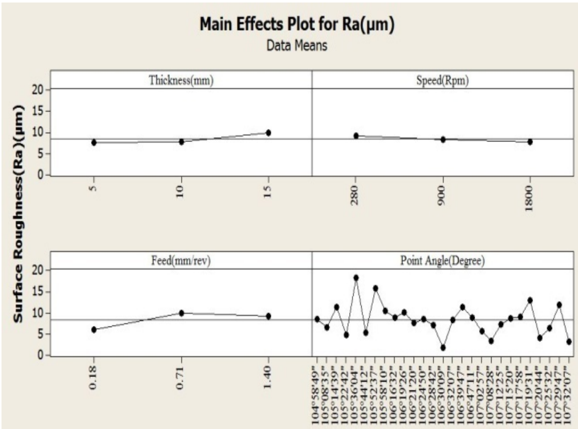

Fig 5 Main Effects plot for Ra

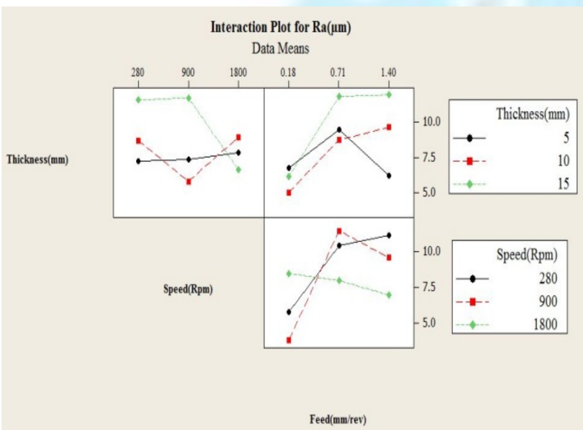

Fig 6 :Interaction plot for Ra

C. Mathematical model for Surface Roughness

The models were based on the Box-Behnkn design method. The developed second order mathematical model for surface roughness.
Surface Roughness
= 4.87 - 0.00086 (s) + 2.49 (f) + 0.249 (t)-------(1)

Table 2 : Analysis of variance

Predictors	Coef	SE Coef	T	P
Constant	4.873	2.352	2.07	0.05
S	8.56e-4	1.09e-3	-0.78	0.442
F	2.494	1.367	1.49	0.151
T	0.2487	0.1673	2.07	0.017

S = 3.54808 R-Sq = 21.1% R-Sq(adj) = 10.8%

Source	DF	SS	MS	F	P
Regression	3	77.44	25.81	2.05	0.135
Residual Error	23	289.54	12.59		
Total	26	366.99			

Fig.6 Represent that high feed rate and low speed have less effect on Ra while drilling on 5mm thickness plate. When drilling on 10mm thickness of plate with cutting parameters of low speed and feed rate shows surface roughness is minimized. For 15mm plate high speed and high feed rate has less effect on Ra. From Fig.5 shows that when decreasing the point angle , the effect of surface roughness is increased . Decreasing the point angle causes tool wear . Fig 7 shows the predicted and measured hole characteristics at different drilling process parameter conditions. The result significantly shows that the values relatively follow the similar trend pattern of the measured value and predicted values from the developed regression model.

V. FUZZY LOGIC MODEL

Fuzzy logic refers to a logical system that generalizes the classical two-value logic for reasoning under uncertainty. It is a system of computing and approximate reasoning based on a collection of theories and technologies that employ fuzzy sets, which are classes of objects without sharp boundaries. Fuzzy logic is the best in capturing the ambiguity in input. Fuzzy logic has become popular in the recent years, due to the fact that it is possible to add human expertise to the process. Nevertheless, in the case where the nonlinear model and all the parameters of a process are known, a fuzzy system may be used.

A .Development of fuzzy logic model

The surface roughness and circularity error in drilling of GFRP is assumed as a function of three input variables viz.plate thickness, spindle speed, and feed rate. The Fuzzy logic prediction model is developed using Fuzzy Logic Toolbox available in Matlab version 7.10(R2010a).In this work Mamdani type Fuzzy Inference Systems(FIS) is used for modeling. The steps followed in developing The fuzzy logic model are described below.

B. Fuzzification of I/O variables:

The input and output variables are fuzzified into different fuzzy sets. The triangular membership function is used for simplicity yet computationally efficient. It is easy to use and requires only three parameters to define.The input variables plate thickness [5-15 mm] ,spindle speed [280-1800 rpm] and

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feed rate [0.18-1.4 mm/rev] are fuzzified into three fuzzy sets viz.Low (L),Medium(M),and High(H) as shown in the Fig.11 (a,b,c).The output variable i.e. The surface roughness and circularity error are divided into nine fuzzy sets as Very Very Low(VVL),VeryLow(VL),Low(L),Medium1(M1),Medium2 (M2), Medium3 (M3),High (H),Very High (VH),Very Very High (VVH) as shown in Fig.11 (d) to increase the resolution and accuracy of prediction.

C . Evaluation of IF-THEN rule

The three input variables are fuzzified into three fuzzy sets each, the size of rule base becomes 27(3x3x3).For generating the Fuzzy rules, the level of the variable having more membership grade on a particular fuzzy set is considered. With appropriate level of all the input variables representing the corresponding fuzzy set, the surface roughness values are used for 27 data sets of fuzzy rule base. Since all the parts in the antecedents are compulsory for getting the response value, the AND (min) operator is used to combine antecedents parts of each rule.

The implication method min is used to correlate the rule consequent with its antecedent. For example, the first rule of the FIS can be written as

Rule 1: 'if Thickness is Low and Speed is Low and Feed rate is Low then surface roughness is Very Very low (VVL)'.

D .Aggregation of Rules

The aggregation of all the rule outputs is implemented using max method, the commonly used method for combining the effect of all the rules. In this method the output of each rule is combined into single fuzzy set whose membership function value is used to clip the output membership function. It returns the highest value of the membership functions of all the rules.

E .Defuzzification

The aggregate output of all the rules which is in the form of fuzzy set is converted into a numerical value (crisp number) that represents the response variable for the given data sets. In the present work, the centroid defuzzification method is used for this purpose. It is the most popular method used in most of the fuzzy logic applications. It is based on the centroid calculation and returns center of area under the curve.The predicted values of surface roughness are compared with the experimental output, prediction model output and fuzzy output. The comparison of prediction performance in fuzzy logic output, prediction model output with the experimental results is given in the Table 3.

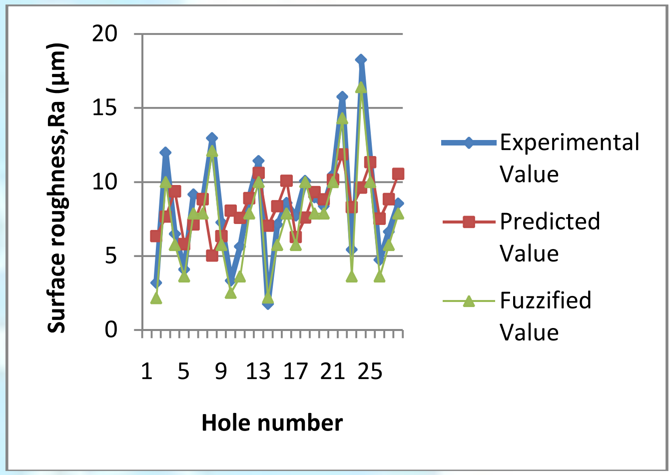

Fig.9 Correlation between Experimental Ra with predicted Ra and Fuzzified Ra

Fig.9 indicates that the outputs from the experiments, Prediction model, Fuzzy are in good correlation with each other.

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Table 3: Surface roughness values for Experimental output, Predicted output and Fuzzy output

S. No	*Plate thickness t (mm)*	*Speed s(rpm)*	*Feed f(mm/rev)*	*Point angle θ (◦)*	*Surface Roughness, Ra (µm)*		
					Experimental output	*Predicted output*	*Fuzzy output*
1	5	280	0.18	107º32'07"	3.19	6.3224	2.15
2	5	280	0.71	107º29'47"	11.98	7.6421	10.00
3	5	280	1.40	107º25'32"	6.49	9.3602	5.75
4	5	900	0.18	107º20'44"	4.09	5.7892	3.62
5	5	900	0.71	107º17'58"	9.16	7.1089	7.87
6	5	900	1.40	107º15'20"	8.79	8.8270	7.87
7	5	1800	0.18	107º19'31"	12.96	5.0152	12.1
8	5	1800	0.71	107º12'25"	7.27	6.3349	5.75
9	5	1800	1.40	107º08'28"	3.33	8.0530	2.50
10	10	280	0.18	107º02'57"	5.64	7.5674	3.62
11	10	280	0.71	106º47'11"	8.98	8.8871	7.87
12	10	280	1.40	106º39'47"	11.42	10.6052	10.00
13	10	900	0.18	106º30'09"	1.76	7.0342	2.19
14	10	900	0.71	106º28'42"	7.12	8.3539	5.75
15	10	900	1.40	106º24'50"	8.58	10.0720	7.87
16	10	1800	0.18	106º21'20"	7.72	6.2602	5.75
17	10	1800	0.71	106º19'26"	10.07	7.5799	10.00
18	10	1800	1.40	106º16'32"	8.97	9.2980	7.87
19	15	280	0.18	106º32'07"	8.37	8.8124	7.87
20	15	280	0.71	105º58'10"	10.48	10.1321	10.00
21	15	280	1.40	105º52'37"	15.75	11.8502	14.30
22	15	900	0.18	105º44'12"	5.43	8.2792	3.62
23	15	900	0.71	105º36'04"	18.25	9.5989	16.4
24	15	900	1.40	105º14'39"	11.43	11.3170	10.00
25	15	1800	0.18	105º22'42"	4.74	7.5052	3.62
26	15	1800	0.71	105º08'35"	6.64	8.8249	5.75
27	15	1800	1.40	104º58'49"	8.55	10.5430	7.87

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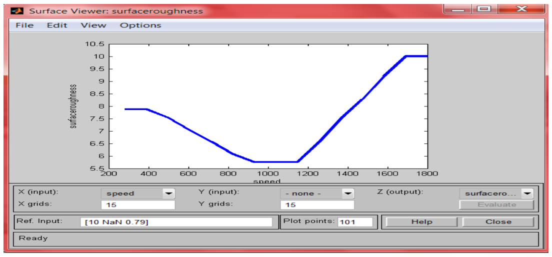


Fig 10 :Surface roughness vs Speed

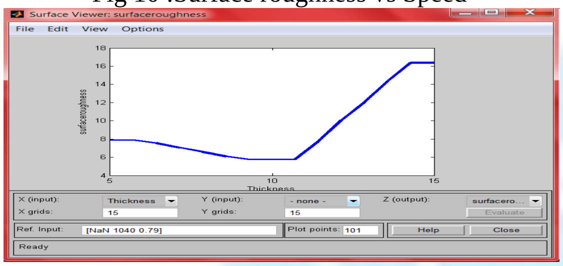


Fig 11 :Surface roughness vs Thickness

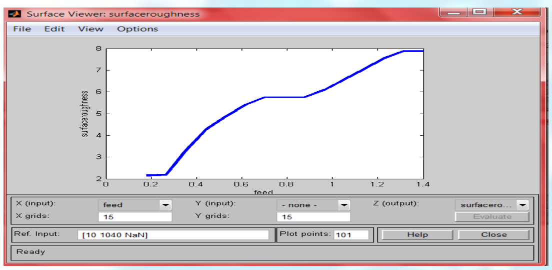


Fig 12:Surface roughness vs Feed rate

The variation of surface roughness with different combinations of input variables is studied using the output surface FIS. Fig 10,11 12 shows the Functional dependence of surface roughness(Ra) with Plate thickness ,feed rate and Spindle speed .It can be observed that the surface roughness increase with increase in plate thickness or increase in spindle speed or increase in feed rate. And it is also observed that surface roughness is decreases with small plate thickness, medium spindle speed and small feed rate.

VI .CONCLUSION

This experimental investigation presents the surface roughness characteristics of drilling on GFRP composites. A simple regression prediction model was developed based on the function of process variables and the following conclusions were made

1)Surface Roughness was analyzed as a function of process input variables. Validation was done with a developed fuzzy –rule based model. The results obtained from experiments, Prediction model and the fuzzy model are in good correlation with each other.

2)From analysis of variance and from the fuzzy model, the results indicated that low feed rate, high spindle speed and 5mm thickness of GFRP plate gives better Surface Roughness.

3)It was observed that the surface roughness increases with the decreasing of point angle.

4)Further investigations are needed to enhance the hole quality characteristics considering different tool materials and tool diameters, considering machine vibration, etc during drilling of GFRP composites.

REFERENCES

[1] Park, J. N., Cho, G. J.A Study of the Cutting Characteristics of the Glass Fiber Reinforced Plastics by Drill Tools, International Journal of Precision Engineering and Manufacturing, vol. 8 (2007) 11-15

[2] VijayanKrishnaraj, Member, IAENG, Effects of Drill Points on Glass Fiber Reinforced Plastic Composite While Drilling at High Speed, Proceedings of the World Congress on Engineering 2008 Vol II, WCEE 2008, July 2-4(2008) London.

[3] Sonbatry El, Khashaba U.A, Machaly T, Factors affecting the machinability of GFRP/epoxy composites, Comp Structures, 63 (2004) 329-338.

[4] Montgomery, D.C.,. Design and Analysis of Experiments: RSM and Designs. John Wiley and Sons. New York, USA, 2005.

[5] Konig W, WulfCh, Graß P and Willercheid H, Machining of fiber reinforced plastics, Annals CIRP, 34 (2) (1985) 537-548.

[6] Komaduri R, Machining of fiber-reinforced Composites, Mechanical Engineering, 115 (4), (1993) 58-66.

[7] A.M. Abrao et.al,. Drilling of fiber reinforced plastics: A review, Journal of Materials Processing Technology 186 (2007) 1–7.

[8] Abrao A M, Faria PE, Campus Rubio J., C., Reis P, PauloDavim J Drilling of fiber reinforced plastics: A Review. J Materl. Process Technology 186 (2007)

[9] CaprinoG, Tagliaferi V Damage development in drilling glass fiber reinforced plastics. Int J Mach tools Manuf (6): (1995) 817-829.

[10]Hocheng, H.and H. Puw. On drilling characteristic fiber reinforced Thermoset &Thermoplastics. Int J Mach tools Manuf ,32 (1992)583-592.

[11]M.Chandrasekaran, M.Muralidhar, C.M.Krishna and U.S.Dixit, Application of soft computing techniques in machining performance prediction and optimization:a literature review,Int J Adv Manuf Technol,Vol.46(2010) 445-464.

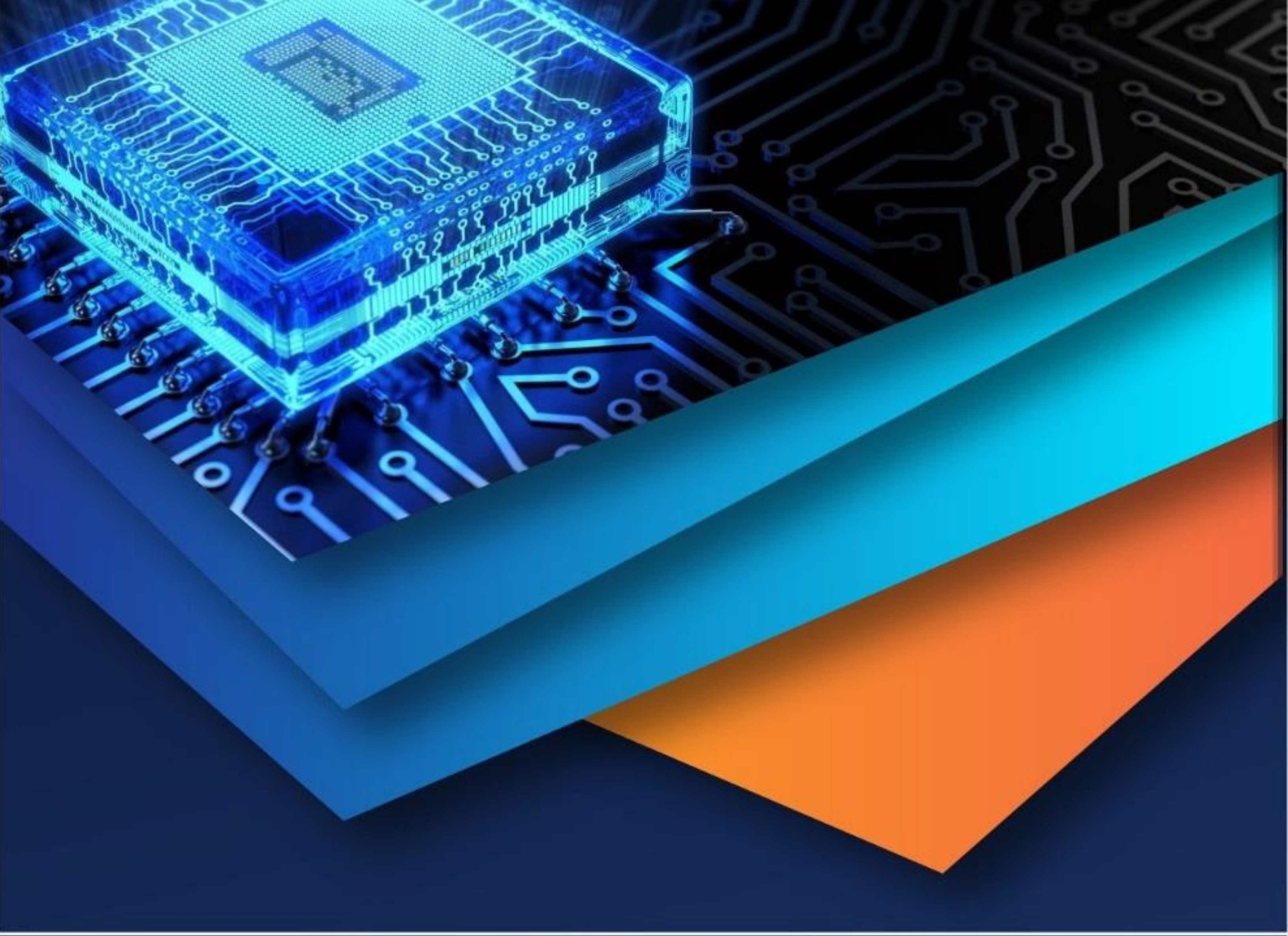
[12]M.Chandrasekaran and D.Devarasiddappa ,Development of Predictive Model For Surface Roughness in End Milling of Al-SiC Metal matrix Composites using Fuzzy logic, Engineering and Technology 68 (2012) 1271-1276

[13] C.Y.Hsu,C.S.Chen,C.C.Tsao,Free abrasive wire saw machining of ceramics, Int J Adv Manuf Technology 40 (2009) 503-511.

[14] Bala Murugan Gopalsamy,Biswanath Mondal,Sukamal Ghosh,Optimisation of machining parameters for hard machining:grey relational theory approach and ANOVA,The International journal of Advanced Manufacturing Technology 45 (2009) 1068-1086.

[15]Vikram Banerjee et.al,Design space exploration of mamdani and sugeno inference systemsfor fuzzy logic based illumination controller, International journal of VLSI and Embedded system-IJVES (2012) 97-101.

[16]B.latha and B.S.Senthilkumar, Modeling and Analysis of Surface Roughness Parameters in Drilling GFRP Composites Using Fuzzy Logic, Materials and Manufacturing Processes 25 (8) (2010) 817-827.



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