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PREDICTION OF VIBRATION AMPLITUDE AND SURFACE ROUGHNESS IN MACHINING OF AL6061 METAL MATRIX COMPOSITES BY RESPONSE SURFACE METHODOLOGY

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ABSTRACT

In this work, the Prediction of acceleration amplitude and surface roughness of Aluminium alloy (Al6061), reinforced with 15% Silicon Carbide particle (SiC_p) metal matrix composites, has been made in the end milling process considering various machining parameters. The MMC was considered the difficult to machining due its reinforcement hardness and nature of abrasive element and the prediction of the amplitude and surface roughness are determined by conducting experiments on it. The experimental observations are used in a statistical method (RSM) and the mathematical prediction model is developed such that the Acceleration amplitude (φ_a) and surface roughness (R_a) are the response functions and the machining parameters, spindle speed (s), feed rate (f), depth of cut (d) and nose radius (r) are the design variables. The prediction model is used to determine the objective functions at different machining conditions and to analyses the effect of machining parameters on surface roughness and acceleration amplitude. The results of the model compared with the experimental results and found to be good agreement with them. The output of prediction model helps in selection of process parameters that reduce vibration and surface roughness, which ensures quality of milling process.

Keywords: Acceleration amplitude, Surface finish, Al6061, MMC, RSM.

1. INTRODUCTION

The modern years, use of the MMCs are increasing and they are used as alternatives for conventional materials. The engineering applications of the MMC are most widely found in aerospace and automobile industries. MMCs have higher specific modulus, strength and wear resistance than convention alloys (Quan and Ye, 2003). The important engineering applications of MMC are in automobile components like pistons, piston rings, cylinder liners, electrical sliding contacts, turbocharger connecting rods etc., Aluminium, Magnesium and Titanium are generally used like a matrix material and SiC and Al_2O_3 are most popular reinforcement (Ding et al., 2005). Many researchers have been focused on the effect of cutting force on conventional alloys and very few researches have been focused the effect of surface roughness and acceleration amplitude in the composite materials. The extensive tool wear is the major problem with machining MMC and this because of hardness and abrasive reinforcements of the MMC. Chatter vibrations of the machining operation will damage the cutting tool, when it may source early failure of tool and detroit the surface finish. The machine tool components are focused to wide range of loads, due to the modification in cutter geometry work piece, speed, feed and depth of cuts determination of machine tool vibration of the is of great important and instrumental in increasing the quality of machining. To predict the factors of a vibration and tool life and to ensure the quality of surface finish a machine tool monitoring system is needed. Ciftci et al. (2004) investigated the 2014Al alloy reinforced with SiCp MMC, through the results of SiC volume fraction and its size jointly in the machining were analyzed and they identified that the coated cutting tool performances were superior to the uncoated tools such that the uncoated tools created enhanced surface finish even at low cutting speed. Alaneme (2012) conducted heat treating and cold rolling processes on the SiCp reinforced Aluminium 6063 composites with premixed borex and the results of the experiments indicated that the reduction of porosity levels, uniform distribution of reinforcement and the tensile and fracture toughness properties were found to be improved.

TamerOzben et al. (2008) studied the Aluminium reinforced with silicon carbide particle (SiCp) MMC and proved that the mechanical properties also the results on tool wear and surface finish of machining parameters for different volume fraction. Superior mechanical properties like hardness and impact toughness were achieved with the increase in reinforcement. The high reinforcement of SiCp created a higher tool wear and the feed rate and cutting speed were significantly affected the surface finish. Ndaliman et al. (2011) investigated machining o Parameters of the Cu-TaC electrode during electrical discharge machining on surface composition, topography and surface roughness of the machined surface. The experiments were indicated that the topography and surface roughness were affected by the machining conditions of peak current and pulse duration. Zamri et al. (2011) studied the sliding wear behavior of the potential of palm oil clinker as reinforcement in composite based aluminium. The reinforcement made in order to improve wear resistance of aluminium in tribological applications. Palanikumar and Karthikeyan

(2007) investigated the surface roughness on the machining of Al/SiC composites and observed the minimum surface roughness attained by response table, response graph, normal probability graph and ANOVA technique.

Sureshkumarreddy et al. (2008) experimented the Al/SiC composite material instituted the superiority of parts by milling. From the result they demonstrated that the occurrence of the reinforcement improved the characteristics of machinability in terms of both surface finish and lower propensity to obstruct the cutting tool, when evaluated to a conventional aluminium alloy. It has been indicated by them that the PMMCs are expected to lead technological and economical gains when used with Al/SiC PMMC in many engineering applications instead of AL alloys. Pramanik et al. (2006) presented a mathematical model to determine the forces during machining of ceramic reinforced MMC based aluminium alloy. From the studies they proved that the force various generated from chip formation was much more than the force of plowing and particle fracture. SureshkumarReddy and Vengateshwararao (2005) developed a prediction model based on the results of experiments to obtain the surface roughness and also analyzed the effect of cutting speed, feed, radial rake angle and nose radius on surface roughness. The model was used in genetic algorithm to optimize the machining parameters and the results were validation made by the comparison of conditions of machining obtained from experiments.

Davim et al. (2007) made investigation on the performance on milling of aluminium alloy L65 with different helix angles and cutting forces also they measured concaveness and surface roughness of a plane surface after machining. They also studied effects of spindle speed, depth of cut and feed rate on cutting force and surface roughness and proved that there was no significant difference between up milling and down milling with regards to the cutting force. A vibration model was developed by Chelladurai et al. (2008) to create an empirical model using artificial neural network model and the model based on full factorial experimental design to analyze the effect of various cutting speed, depth of cut, feed rate and flank tool wear. They showed that the vibration increases tool wear and hence it influences the quality of the machining components. The manufacturing in a position to improve quality machined parts to satisfy the demands and necessarily include the cause of machining-vibration to (Maass et al., 2008) create an empirical/analytical model. Multi- frequency analysis (Zatarain et al., 2009) gives the better results at constant cutting force direction belongs to very low directional factors for end milling process. Zhang and Chen (2008) proposed and demonstrated a tool condition monitoring method for end milling with respect to the vibration measurement appeared through micro controlled data acquisition system. Rahim et al. (2009) fabricated a unit for measuring vibration with help of micro electromechanical based accelerometer. Experimental observations were made to characterize the device and initial tests showed that the measurement was ability to sense, measure and monitor the condition. Nakagawa et al. (2008) developed a method to find chatter vibration of hardened steels in end milling and found that the variations in frequencies of vibration occurred at minimum and maximum cutting speeds.

Murmu (2011) conducted the wear test on SiCp reinforced aluminium 6061alloy composites and the experimental results were used to develop the two prediction models based on generalized regression neural network (GRNN) and response surface methodology (RSM). It was observed that the investigation the GRNN was better than the RSM based regression model. Sivasakthivel et al. (2010) presented an empirical model to determine the acceleration amplitude and were analyzed with respect to helix angle, spindle speed, feed rate and axial radial depth of cut. Palanikumar (2007) developed a Response surface method (RSM) model for GFRP composites to predict the surface roughness. The model uses CCD based four factors five level rotatable design to carry out the experimental sequence of investigation and the model was validated using analysis of variance (ANOVA) Muthukrishnan and PauloDavim (2009) explored the prediction of surface roughness by ANN and ANOVA modeling techniques. From the ANOVA it was found to the feed rate is most physical with a numerical influence on the surface roughness subsequent to the speed and depth of cut and the ANN methodology applies smaller time with superior accuracy. They showed that the most effective method is optimization of ANN while evaluated by RSM. Anilkumar et al. (2011) studied the properties of aluminium metal matrix composites reinforced with fly ash and found that the stir casting method used to prepare the composite could produce uniform distribution of the reinforced particles. Wahab et al. (2009) studied the characterization of aluminium metal matrix composites reinforced with aluminium nitride and found that a stir casting process which was set at 750^{o} c was successfully utilized for casting Al-Si matrix composite reinforced with AIN particle.

From the above literature it has been identified that most of the researches were made on the ferrous and nonferrous metals to determine the surface roughness and vibration characteristics of the milling process not on the composites. The experimental milling operations were performed and the prediction models (using DOE) were formed to determine the vibration and surface roughness characteristics of Aluminium alloys. Also researches were made on the composites to determine the vibration characteristics of the composites during the turning operations. End milling experiments were conducted on MMCs only to determine the vibration characteristics of the operation not to determine the surface roughness characteristics. Al reinforced MMC has very wide in the automobile and aerospace applications because of their corrosion and wear resistance properties and weight to density ratio characteristics. Meager numbers of studies were found in literature for vibration and machining characteristics of

Al reinforced MMCs and it requires further studies to develop the surface finish characteristics and to lessen the vibration during machining. To achieve better performance in machining of Al/SiC-MMC, the experimental responses are evaluated and analyzed improved.

2. DESIGN OF EXPERIMENTS

In the present work, acceleration amplitude(φ_a) and surface roughness(R_a) are taken as the response variables and the spindle speed(s), feed rate(f), depth of cut(d) and nose radius(r) are considered as the machining parameters. The machinability performance of acceleration amplitude and surface roughness are obtained, milling process, in order to analyze the machining parameters with help of response surface methodology(RSM). The relationship of preferred response and independent variables for input was represented in the quantitative form as follows.

$$Y = \Psi(s, f, d, r) \tag{1}$$

Where, Y - machining response, Ψ - response function and the milling variables are s, f, d, r. In the analysis procedure for approximation of response was projected by using the built-in second order polynomial regression as the quadratic model. The quadratic model for machining response as mentioned below.

$$Y = b_0 + \sum_{i=1}^{4} b_i x_i + \sum_{i=1}^{4} b_{ii} x_i^2 + \sum_{i<j}^{4} a_{ij}\, x_i x_j \tag{2}$$

Where, b_0 - constant, x_i- coded variables, b_i, b_{ii} and b_{ij} are the coefficient terms of linear, quadratic, intraction respectively. From the transformation equations provided the coded variables x_i=1, 2, 3, 4 as mentioned below:

$$x_1 = (s - s_0)/\Delta s \tag{3}$$

$$x_2 = (f - f_0)/\Delta f \tag{4}$$

$$x_3 = (d - d_0)/\Delta d \tag{5}$$

$$x_4 = (r - r_0)/\Delta r \tag{6}$$

Where x_i (i =1, 2, 3, 4) are the coded variables of parameters s, f, d and r respectively, s_o, f_o, d_o and r_o are the parameters s, f, d and r at the initial conditions ie. at zero level. Δs, Δf, Δd and Δr are the variation intervals of parameters s, f, d and r correspondingly. The acceleration amplitude (φ_a) and surface roughness (R_a) referred as $Y(\varphi_a)$ and $Y(R_a)$ respectively are the response functions. The values of variables required for making the models of response surface are composed from an empirical design with the adoption of collections of empirical values are with respect to central composite design (CCD).

The factorial design is of CCD full factorial through all combination factors are at higher (+1) and lower (-1) levels and created the eight key positions, which the mid position is among the higher and lower levels. The key positions are at the cubic portion face of the design which is communicates to φ_a, α value of 1 and this type of design generally called as the face centered CCD. Table 1 illustrates the four machining parameter levels and communicating ranges. The parameter levels are preferred and derived from the prior work of associated with processing parameters of the equipment. The empirical systems for 31 runs were brought out using required conditions with esteem to face centered CCD absorbing the coded form as illustrated in Table 4. The generated designs with their results were examined by using the numerical package of MINITAB.

Table 1 Parameters and their levels.

Parameter	Unit	Symbol	Levels		
			-1	0	1
Cutting speed	m/min	s	30	60	90
Feed	mm/min	f	50	75	100
Depth of cut	mm	d	0.75	1	1.25
Nose radius	mm	r	0.4	0.8	1.2

Figure 1 HMT (FNIU) Milling machine.

Figure 2 Multi channel change amplifier.

3. EXPERIMENTAL WORK

3.1 Stir casting setup

A furnace heating temperature was increased to 750ºC, hold for 30 minutes until aluminium (6061) alloy melted completely. Aluminium dross then removed from the surface of the molten metal. Small amount particulate SiC preheated to 750 ºC were added continuously to the molten metal through the side of vertex created by mechanical stirring by the stir impeller. After mixing the melt was poured in to a prepared mould for the preparation of specimen. As the microstructure plays on important role in the overall performance of a composite and the physical properties of depends on the micro structure, reinforcement particle size, shape and distribution in the alloy, prepared models were analyzed with a scanning electron microscope (SEM). A uniform distribution of SiC particles without discontinuous can be observed from the micrograph. It was also found that there was good bonding between matrix material and SiC particle.

3.2 Vibration analysis

In the milling process, the tool and work piece travel together at frequency which is less than or equal to the machine tool natural frequency. Chatter, resonant vibration, the tool occurs due to the forces enforced on the tool and it causes the machine tool to vibrate at a natural frequency in which a smallest excitation makes the huge sense of vibration. After determining this position, the interaction among the tool and work piece will keep on amplitude and stable pulsation of the force decrease the life of tool and leads to poor surface finish finally, elevated vibration will cause machine tool to damage. Not only single parameters but also more parameters of the machine tool, roughly the machine components for tool and the system, are involving to create the amplitude. Chatter vibration, in general, in the machining process occurs at the machine and cutting tool condition by the lack of precession. There is a possibility prediction of exact cutting tool machining parameters to lessen the vibration and controlling the parameters affecting the vibration instead of altering entire milling process. In this study, spindle speed, feed rate, depth of cut and nose radius are considered as process parameters. A multi channel change amplifier (KISTLER, TYPE5070) used to measure vibration amplitude and the acceleration amplitude of the spindle is preferred axial direction. The wave length forms from the vibration measurement output and is available in forms of amplitude, velocity and displacement. The measurement signal from the analyzer is stored and if there several unstable or transient variation in signal are also noted down. From the wave form the identification of separate scratches due to developed boundary creation, resonance condition can be made also the amplitude wave form specifies that pulses occur infrequently. The frequency range is to be determined of the vibration response versus frequency and can be developed by using the wave form of digital FFT analysis. The peak level is the indication of highest vibration produced during milling, and the highest amplitude of the milling process is noted in this study.

3.3 Surface roughness measurement

The surface roughness is evaluated by using the TR100 surface roughness tester along the feed direction. The surface roughness response is the average value of at least three consecutive measurements obtained by various places at the machined surface and this will be recorded as R_a value.

3.4 Experimental setup

In the present work, the experiments were conducted on the HMT FNIU milling machine used with tungsten carbide end mill cutter through dry condition. The specimen was aluminium (Al6061) alloy reinforced with silicon carbide particle (SiC_p) of 15 % weight fraction. The material was manufactured by stir casting method. The milling test was taken on HMT FNIU milling machine with following specifications. Table 1070 mm, length 230 mm, width, speed range 180-1400 rpm, feed range 16-100 mm/min and the power of motor is 2.2 KW. The milling operation was performed by TE 90AX 220 with ISO specifications of the tool cutters. The tungsten carbide tool insert AXMT 0903 PER EML TT 8020 was used with following specification. The work specimen size was 100mm X 100 mm X 30 mm. AS per condition of the given design matrix, the machining operation carried out at random to avoid systematic error. The acceleration amplitude evaluated through multi channel change amplifier (KISTLER, TYPE5070) shown in Figure 2. The amplitude was evaluated in the feed direction on the work piece holder. The measured data are attained and tabulated for the mathematical model.

4. GENERATION OF MATHEMATICAL MODEL

Table 2 Regression analysis coefficients for acceleration amplitude (φ_a).

Symbol	Coefficient	P value
Constant	-13.61100	0.294
x_1 (s)	0.06231	0.210
x_2 (f)	0.21735	0.184
x_3 (d)	34.26700	0.000
x_4 (r)	5.61152	0.000
x_1^2	-0.00028	0.193
x_2^2	-0.00128	0.001
x_3^2	-12.54030	0.001
x_4^2	-1.47202	0.221
$x_1 x_2$	0.00002	0.833
x_1x_3	-0.06162	0.000
$x_1 x_4$	0.02880	0.000
$x_2 x_3$	-0.06610	0.000
$x_2 x_4$	-0.02216	0.009
$x_3 x_4$	-3.44097	0.000

Table 3 Regression analysis coefficients for surface roughness (R_a).

Symbol	Coefficient	P value
Constant	2.41390	0.000
x_1(s)	-0.04324	0.000
x_2 (f)	0.01410	0.000
x_3(d)	0.09974	0.000
x_4(r)	0.08858	0.003
x_1^2	0.00031	0.000
x_2^2	-0.00021	0.000
x_3^2	1.00739	0.029
x_4^2	-0.02120	0.899
$x_1 x_2$	0.00014	0.000
x_1x_3	-0.01455	0.000
$x_1 x_4$	-0.00330	0.002
x_2x_3	-0.00578	0.004
x_2x_4	0.00187	0.095
x_3x_4	0.30952	0.010

Table 4 Experimental design–central composite design.

Run	Coded factors				Acceleration amplitude (φ_a) m/sec^2			Surface roughness (R_a)µm		
	x_1	x_2	x_3	x_4	observed value	predicted value	%error	observed value	predicted value	%error
1	1	-1	1	1	10.822	10.905	-0.8	1.803	1.809	-0.4
2	-1	-1	-1	-1	11.205	11.366	-1.4	2.024	1.991	1.6
3	1	0	0	0	11.795	11.738	0.5	1.343	1.350	-0.5
4	1	1	1	-1	7.175	7.340	-2.3	1.034	1.014	1.9
5	1	1	1	1	6.922	6.805	1.7	1.271	1.280	-0.8
6	-1	0	0	0	12.004	12.230	-1.9	2.166	2.133	1.5
7	0	0	0	0	12.457	12.236	1.8	1.449	1.464	-1.0
8	-1	-1	1	-1	12.533	12.694	-1.3	2.756	2.748	0.3
9	1	-1	1	-1	10.600	10.554	0.4	1.615	1.618	-0.2
10	0	0	0	1	11.689	11.953	-2.3	1.574	1.583	-0.6
11	0	0	-1	0	11.810	12.007	-1.7	1.270	1.263	0.5
12	0	-1	0	0	13.051	12.867	1.4	1.643	1.681	-2.3
13	-1	-1	1	1	11.712	11.662	0.4	3.114	3.097	0.6
14	0	1	0	0	9.651	10.004	-3.7	1.043	0.979	6.2
15	-1	1	1	1	7.490	7.499	-0.1	2.153	2.152	0.0
16	0	0	0	0	12.068	12.236	-1.4	1.469	1.464	0.4
17	0	0	0	0	12.604	12.236	2.9	1.431	1.464	-2.3
18	-1	1	-1	-1	9.909	9.741	1.7	1.093	1.116	-2.2
19	1	1	-1	-1	9.421	9.513	-1.0	0.845	0.839	0.7
20	1	-1	-1	-1	11.168	11.074	0.8	1.268	1.298	-2.4
21	0	0	0	-1	12.142	12.048	0.8	1.374	1.338	2.6
22	0	0	0	0	11.981	12.236	-2.1	1.409	1.464	-3.9
23	0	0	0	0	11.953	12.236	-2.4	1.468	1.464	0.3
24	1	-1	-1	1	12.582	12.802	-1.7	1.435	1.365	4.8
25	-1	1	1	-1	9.593	9.416	1.8	1.682	1.728	-2.7
26	0	0	0	0	12.846	12.236	4.8	1.485	1.464	1.4
27	-1	-1	-1	1	11.962	11.711	2.1	2.167	2.216	-2.3
28	-1	1	-1	1	9.110	9.199	-1.0	1.443	1.416	1.8
29	0	0	1	0	10.924	10.897	0.3	1.810	1.791	1.1
30	1	1	-1	1	10.601	10.354	2.3	0.942	0.981	-4.1
31	0	0	0	0	12.247	12.236	0.1	1.456	1.464	-0.5

Table 5 Summary of regression analysis.

Responses	S value	R^2%	Adjusted R^2%
Amplitude(φ_a)	0.298220	98.27	96.76
Surface roughness(R_a)	0.042255	99.61	99.27

The general form of a quadratic polynomial which gives the relationship between responses Y (φ_a) and Y (R_a) and the machining parameters x(s, f, d and r) under investigation is given Eq.(2). The parameter p values, interactions for higher order coefficients of regression analysis for acceleration amplitude (φ_a) and surface roughness (R_a) is given in Table 2 and Table 3.

From the Table 2 shows that the p values of regression analysis for φ_a in the linear, square and interaction of depth of cut with nose radius are mainly considerable, while the cutting speed with feed and the nose radius are not accordingly essential. The p values of regression analysis for R_a in Table 3 specifies the linear, square and interaction of machining parameters s, f, d with r are most significant.

A statistical software MINITAB was employed to evaluate the value of these coefficient and the mathematical models were expanded. The Eq. (7) and. Eq. (8) represents the regression model equations for acceleration amplitude (φ_a) and surface roughness (R_a). Not only had the main cause on the response of the single changeable term but also the interaction of square results reflected on the reformation of the replica efficiency. The expanded Mathematical model is employed to examine the effect of the parameters on acceleration amplitude and surface roughness during milling of composite materials.

The regression equation for amplitude (φ_a)

$$\begin{aligned}Y(\varphi a) = {} & 13.61100 + 0.06231x_1 + 0.21735x_2 + \\ & 34.26700x_3 + 5.61152x_4 - 0.00028X_1^2 - \\ & 0.00128x_2^2 - 2.54030x_3^2 - 1.47202x_4^2 + \\ & 0.00002x_1x_2 - 0.06162x_1x_3 + \\ & 0.02880x_1x_4 - 0.06610x_2x_3 - \\ & 0.02216x_2x_4 - 3.44097x_3x_4\end{aligned} \tag{7}$$

The regression equation for surface roughness (R_a)

$$Y(Ra) = 2.41390 - 0.04324x_1 + 0.01410\,x_2 + 0.09974\,x_3 + 0.08858\,x_4 + 0.00031x_1^2 - 0.00021x_2^2 + 1.00739\,x_3^2 - 0.02120x_4^2 + 0.00014x_1x_2 - 0.01455x_1x_3 - 0.00330x_1x_4 - 0.00578\,x_2x_3 + 0.00187\,x_2x_4 + 0.30952x_3x_4 \tag{8}$$

Where $Y(\varphi_a)$ and $Y(R_a)$ are response of acceleration amplitude and surface roughness and x_1, x_2, x_3, x_4 represents decoded values of s, f, d and r respectively. The higher value of R^2 is superior to determine the regression equation coefficient for Ra is effectively than of φ_a.. The fitness of model determines the closeness of the adjusted R^2 value with R^2 value. The Table 5 specifies the closer value of adjusted R^2 and R^2 for both cases.

5. ANALYSIS OF DEVELOPED MATHEMATICAL MODEL

The analysis of variance (ANOVA) is used to analysis the model adequacy. The ANOVA showed in Table 6 and Table 7 for acceleration amplitude and surface roughness. The percentage of F distribution standard for 5% confidence limit is 4.06. The F value is 0.63 and 3.72 from the Table 6 and 7, the for lack of fit of the model is lesser than 95% of confidence limit for the standard value. The models are sufficient together and in 95% of confidence limit. It has been identified that the P values of both φ_a and R_a models are linear also cutting parameters square interaction results are found to be significant.

6. RESULT AND DISCUSSION

In multi phase materials of MMC during milling process, the cutting boundary abrasion in addition to forces caused by grinding of harder coarse particles and materials heterogeneity particularly. The prediction model specified in Eq. (7) and Eq. (8) expanded by the empirical observation and RSM. The studies are prepared to examine the result of the various machining parameters on the acceleration amplitude and surface roughness.

6.1 Effect of acceleration amplitude (φ_a)

The effect of spindle speed, feed rate, depth of cut and nose radius were experimentally investigated during the milling process. The spindle speed has considerable effect on vibration it understood from Figure 3. The cutting force acting on the work piece fixture is keep on increasing by the spindle speed at parallel to the axis of spindle. It is observable from the empirical that the vibration increased up with the speed. The fixture is the important of vibration by increasing spindle speed and the trend of vibration decreases in axial direction. There is a significant effect on vibration when increasing / decreasing the feed rate. The vibration tendency got reduced when feed rate is high ie.100mm/min. The feed rate increase enhances to transfer the large extent of the cutting to material at the hardened layer. The cutter takes a few rotations to complete a required surface which decreases the rubbing abrasion between the work piece and tool. It is understood from Figure 4, when the vibration reduced with increase in feed rate. The depth of cut in the axial direction is the considerable effect on vibration. The depth of cut in the axial side makes the effect on acceleration amplitude. The depth cut creates a tool work piece steady which leads in lessening of vibration.

Table 6 Analysis of variance for amplitude (φ_a).

Source	DOF	Sum of square	Adjusted mean square	F value	P value
Regression	14	80.8412	5.77437	64.93	0.000
Linear	4	43.5542	1.11681	12.56	0.000
Square	4	26.5430	6.63575	74.61	0.000
Interaction	6	10.7440	1.79067	20.13	0.000
Residual Error	16	1.4230	0.08893		
Lack-of-Fit	10	0.7294	0.07294	0.63	0.752
Pure Error	6	0.6936	0.1156		
Total	30	82.2642			

Table 7 Analysis of variance for surface roughness (R_a).

Source	DOF	Sum of square	Adjusted mean square	F value	P value
Regression	14	7.3546	0.525327	294.22	0.000
Linear	4	6.4982	0.120591	67.54	0.000
Square	4	0.4266	0.10665	59.73	0.000
Interaction	6	0.4298	0.071636	40.12	0.000
Residual Error	16	0.0286	0.001785		
Lack-of-Fit	10	0.0246	0.00246	3.72	0.061
Pure Error	6	0.0040	0.000662		
Total	30	7.3832			

Asymptotic border line of stability arises at vital depth of cut when the machine tool below in which no vibration occurs. From Figure 5 clarify that the depth of cut rises from 1mm to 1.25mm the amplitude reduces in axial direction. The nose radius is the important cause on amplitude. The vibration has selected in axial cutting direction with increasing the nose radius the trend of amplitude can be reduced. The tool deflection reduced which is increase in nose radius, which will reduces tendency of vibration. The vibration lessened with raise in nose radius is accomplished from Figure 6.

6.2 Effect of surface roughness (R_a)

The various parameters of machining effect on surface roughness (R_a) studied are derived from the results of mathematical model Eq. (8). The rough surface producing chips fracture readily at a low cutting speed. When the chip fracture decreases as the cutting speed raises and the surface roughness reduced. The effect of surface roughness from the Figure 3 that the spindle speed increasing from 30 m/min to 60 m/min the surface roughness suddenly decreases and the speed increasing from 60 m/min to 90 m/min surface roughness gradually decreases. It is concluded from Figure 3 that the spindle speed is increased to decrease the surface roughness. The spindle speed mainly makes considerable effect on surface roughness. The lesser feed rates with the BUE produces readily and is accompanied by feed marks effecting in raised surface roughness. The effect of surface roughness raises which the minimal feed in 50 mm/min. The feed rate increases from 50 mm/min to 100 mm/min which decreases the surface roughness. The evident from Figure 4 the effect of feed rate is the most significant parameter on surface roughness. The effect of lower depth of cut on the surface roughness is decreases.

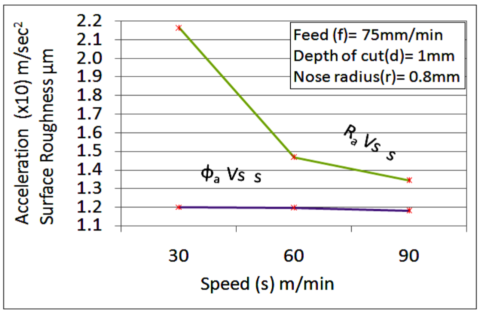

Figure 3 Direct effect of spindle speed vs acceleration amplitude & surface roughness.

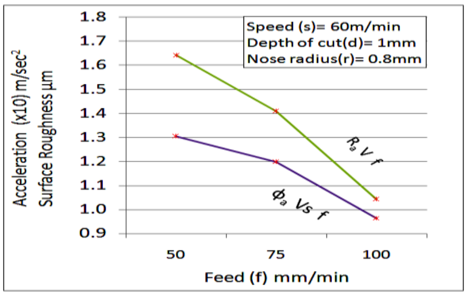

Figure 4 Direct effect of feed rate vs acceleration amplitude & surface roughness.

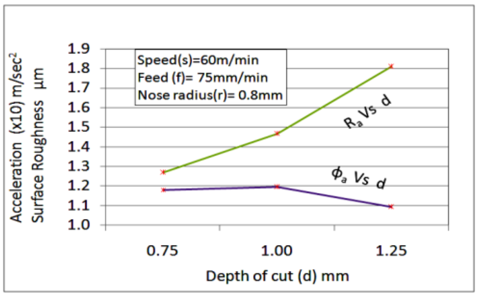

Figure 5 Direct effect of depth of cut vs acceleration amplitude and surface roughness.

The depth of cut increases from 0.75 mm to 1.25 mm which the surface roughness increases. It is evident from the Figure 5 support the earlier statement. At the higher nose radius, the unstable larger BUE is formed, so the surface roughness increased. It is evident from the Figure 6 lower the nose radius decreases the surface roughness and increasing the nose radius from 0.4 mm to 1.2 mm increases the surface roughness. The nose radius and depth of cut are the important effect on surface roughness.

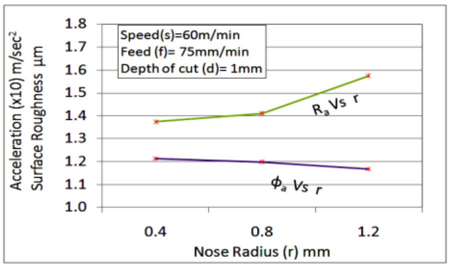

Figure 6 Direct effect of nose radius vs acceleration amplitude and surface roughness.

6.3 Interaction effect on acceleration amplitude

An interaction effect was studied among the various parameters for acceleration from Figure 7, 8 and 9.

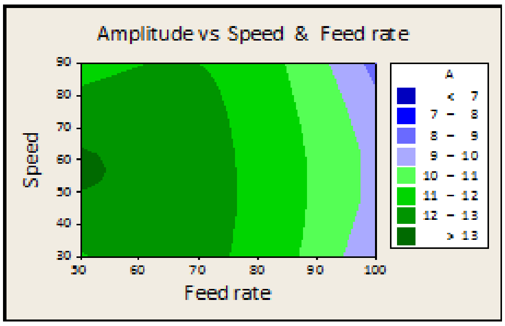

Figure 7 Interaction effect of spindle speed and feed rate on acceleration amplitude.

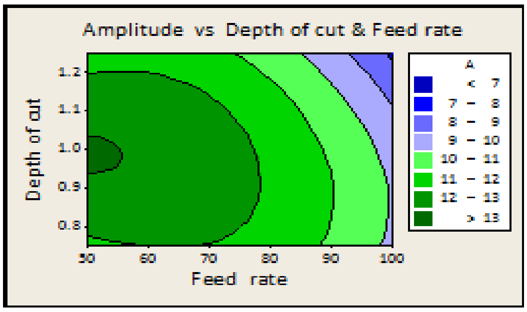

Figure 8 Interaction effect of feed rate and depth of cut on acceleration amplitude.

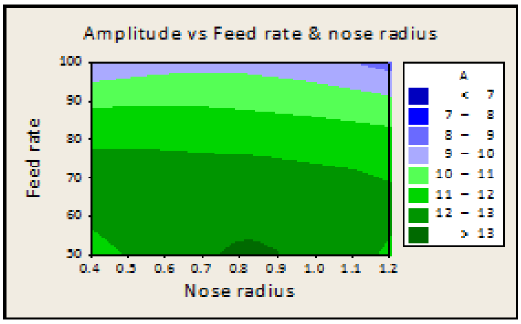

Figure 9 Interaction effect of feed rate and nose radius on acceleration amplitude.

The effect of depth of cut and feed rate on acceleration in the contour graph reveals that when the feed rate and depth of cut enhances, it effects in reduce the vibration. The raise in feed rate with modify the stage of depth of cut in raising order has not supported the staying effect of the aluminium MMC. The trends inverted at modify of level from 87 mm/min in the feed. The interaction result of spindle speed and feed rate increases with decrease in vibration. In the midpoint levels are increases in speed that increases in acceleration.

The tendency obtains inverted in feed at the level of 87mm/min, increases in feed rate decrease in vibration. The interaction effect of nose radius and feed rate are minimal range of nose radius decreases vibration. The similar tendency is continuous for modification in the stage of feed rate.

6.4 Interaction effect on surface roughness

The interaction effect was found in surface roughness from Figure10, 11 and 12.

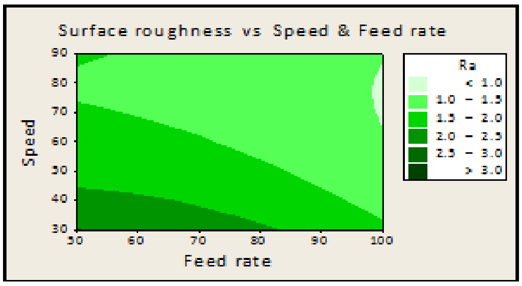

Figure 10 Interaction effect of feed rate and speed on surface roughness.

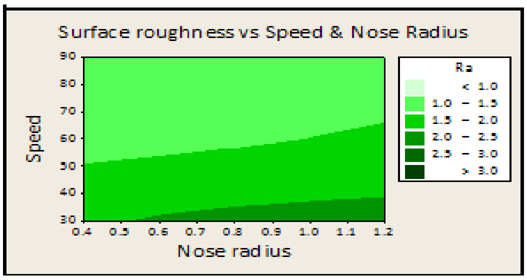

Figure 11 Interaction effect of spindle speed and nose radius on surface roughness.

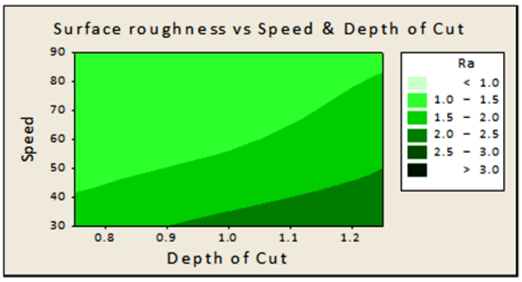

Figure 12 Interaction effect of spindle speed and depth of cut on surface roughness.

The interaction result of spindle speed and feed rate are increases the speed resulted in decreasing in surface roughness at minimal level of feed rate. The trend was found to get changed at 74 m/min in spindle speed; the surface roughness reduces with raising speed. The better surface finish attained at the lesser feed at highest spindle speed combination. The interaction result of spindle speed and nose radius indicates which increase the speed resulted in decreasing surface roughness at minimal attained on the smallest nose radius in uppermost speed level of nose radius. The interaction effect of spindle speed and depth of cut indicates that increases the speed resulted in decreasing in surface roughness at minimal level of depth of cut. The tendency was create to obtain the modified 0.9 mm in depth of cut, roughness raises with raising the depth of cut. The best surface finish was achieved at the lowest depth of cut in highest speed.

7. VALIDATION OF THE MODEL

The parameter level checked in model validity, which has not been comprised in the empirical design. The empirical data justifications are shown in Table 8. The evident from the Table 8 that the error aroused between the empirical value and calculated value is less than 5% and hence the model validity confirms.

8. CONCLUSION

With respect to the above experimentation and the RSM results of the Al/MMC the conclusions remarks were arrived as following. In the manufacturing of MMC, the stir casting method could produce uniform distribution of the reinforced SiC particles. The investigation of CCD based RSM to develop a empirical model as a function of spindle speed , feed rate, depth of cut and nose radius to predict acceleration amplitude and surface roughness is presented . The increase of vibration with reduces in feed rate and depth of cut is identified. At less amplitude levels the spindle speed and nose radius is increase and further the feed rate is the mainly considerable parameter that reduces the vibration of the SiC reinforced composite material. The surface roughness is found to be low at higher speeds and high at lower feed rates. The increase in depth of cut and nose radius directs to raise in surface roughness.

The regression models for the cutting speed and feed rate are created to be more significant when compared to other the suggested models for the prediction of surface roughness. The validity of the model is checked with help of the conformity test and the error identified is within 5%. However, for Aluminium composite with 15% of weight fraction of SiC particles the acceleration amplitude and surface roughness were seen to be decreasing.

Table 8 Results of conformity test.

Specimen No	control factor				Acceleration amplitude m /sec^2			Surface roughness µm		
	s	f	d	r	Observed value	predicted value	%error	Observed value	predicted value	%error
1	-1	-1	-1	-1	11.687	11.366	2.8	1.952	1.991	-2.0
2	1	1	1	1	6.529	6.805	-4.1	1.312	1.280	2.5

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