Effect of machining parameters on Surface roughness and Power consumption for 6063 Al alloy TiC Composites (MMCs)

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ABSTRACT

Metal matrix Composites are new class of material which offers superior Properties over alloys. Problem associated with MMCs is that they are very difficult to machine due to the hardness and abrasive nature of Carbide particles. The main objective of this paper is to investigate the effects of different cutting parameters (Cutting Speed, feed rate, Depth of cut) on surface roughness and Power Consumption in turning of 6063 AL alloy TiC (MMCs). PCD tool was used as wear resistive tool in order to achieve desire surface finish. Full factorial Design in design of experiment was adopted in order to planning the experimental runs. Analysis of Variance was used to investigate percentage Contribution of Each process parameters on output Response. Results show that feed rate is significant parameter, which affect on surface roughness; and Cutting Speed is effective parameter which affect on power consumption. Conclusion based on results with Future direction is discussed at final section.

Keywords – **6063 Al alloy TiC Composites (MMCs), Surface Roughness (SR), Power Consumption (PC), ANOVA.**

I. INTRODUCTION

Matrix composites are new class of metal composites which offers superior properties over alloys. Therefore this material has recently been used in several applications in aerospace and automotive industries. [1,13]. The main attractive features of the MMCs are high strength to Weight ratio, Excellent Mechanical and thermal properties over conventional material and alloy, improved fatigue and creep characteristics, better wear resistance [2]. These properties have made these materials an excellent candidate to manufacture a wide range of products from aerospace parts to sports goods. Problem associated with MMCs is that they are very difficult to machine due to the hardness and abrasive nature of Carbide particles. MMCs are shown to cause excessive tool wear, which in turn induces such damage phenomena as fiber pullout, particle fracture, delaminating and deboning at the fiber or particle and matrix interface. The parameters that are the major contributors to the machinability of these composites are the reinforcement type, tool type, geometry and the machining parameters [3]. It had been found that global MMCs market will rise from 3.6 million kg in 2005 to 4.9 million kg by 2010 reflecting an average annual growth rate about 6.3 % [2].

Past research in machining of MMCs was concentrated on study of tool wear of different cutting tool, surface roughness of machined Component, chip formation analysis of Al-SiC MMCs. Rajesh Kumar Bhushan et al. (2010) found that tool wear of PCD tool is less compare to carbide tool in turning of Al alloy and 10 wt. % SiC particulate metal-matrix composites. Feed rate was found the most significant parameter on Surface in turning of alloy and MMCs [4]. Saeed chavosi (2010) investigated effect of process parameters on tool wear. It had been found that tool wear is increase with increase in cutting speed, feed rate and depth of cut [5]. Ge Yingfei et al. (2010) investigated tool wear pattern and it's mechanism of SPD tool and PCD tool in turning of AL-SiC. It had been found that Microwear, chipping, cleavage, abrasive wear and chemical wear are the dominating wear patterns of SCD tool and PCD tool, and are mainly suffered from abrasive wear on the rake face and adhesive wear on the flank face [6]. Metin Kok (2008) investigated the Performance of coating of cutting tool in turning of MMCs with relation of tool wear and surface roughness. It had been found that tool wear was less in coated cutting tool as compare to Uncoated cutting tool in all machining conditions [7]. M.El-Gallab et al. (1998) investigated the effects of tool geometry, cutting speed and feed rate on cutting forces and flank wear in turning of A356-20%SiC. Results were found that decrease in tool nose radius results in excessive chipping and crater wear on tool, as well as flank wear is increase with increase in negative rack angle [8]. Y.F.Ge et al. (2008) investigated surface integrity using different cutting tool under different cutting conditions. It had been found that cooling condition, particles reinforcement size, volume fraction have significant influence on surface integrity [9]. Pramanik et al., (2006) prepared mathematical model for prediction of cutting forces for machining of Al-SiC [10]. R.Venkatesh et al. (2009) investigated machinability of A356 –SiC(20_p) MMCs with relation to Power consumption and surface roughness. Power consumption was found to been increase with increase in cutting speed [11]. Ibrahim ciftci et al. (2004) investigated performance of coated tool. It had been found that cutting speed, reinforcement particles size and its weight fraction are the main responsible factor for occurrence of tool wear [12]. From the available literature on MMCs, it is clear that the machinability of AL-SiC had been investigated with different process parameter. But so far no work has been reported about the machining of 6063 Al alloy TiC Composites using PCD insert to assess surface roughness and power Consumption.

In the present work, effect of Cutting speed, feed and depth of cut have been found on surface roughness and power Consumption in turning of 6063 Al alloy TiC Composites using PCD insert.

II. EXPERIMENTAL PROCEDURE

2.1 Work Material

The work material selected for the study was 6063 Al alloy 5 % TiC MMC and 6063 Al alloy 10% TiC MMC of cylinder bars (36 mm Diameter and 200 mm length). It is widely used in automobile and aerospace industries because of their high strength to weight ratio and high wear resistance and low thermal expansion. Table 1 show the physical and mechanical properties of 6063 Al alloy TiC. The chemical composition of this material kept confidential.

Table 1 physical and Mechanical properties of 6063Al-TiC

Properties	Material	
	Al alloy 5 % TiC	Al alloy 10% TiC
Density (Kg/m^3)	2632	2734
Hardness (BHN)	95	113
Modulas Elasticity (Gpa)	77	82
Tensile Strength yield strength(Mpa)	103	127
Tensile Strength Ultm strength (Mpa)	140	152
% Elongation	3	1

2.2 Cutting tool insert

The cutting selected for machining of Al-TiC Metal matrix composites was polycrystalline diamond insert of fine grade (2000), because it had been found that PCD tool is best choice for machining of MMCs due to its high wear resistance [4,13]. The PCD insert used were of ISO coding DCMW 11T304 and tool holder PCLNR 25*25 M12. The Characteristics of insert are as follows: Average particles Size - 10µm, Volume fraction of Diamond – 89 to 93 %, Transverse Rapture strength - 2.20 GPa, Knoop hardness At 3 Kg load - 8378.5 kg/mm^2.

2.3 Experimental Plan

The Experiment was carried out on Engine lathe having spindle power of 2 Kw. The work material is machined at three different level of each parameter. In this Experiment, three process parameters (cutting Speed, Feed, and Depth of cut) were varied with three levels. In order to design the experimental plan, full factorial design in design of Experiment with three levels and three factors was used. According to this 3^3 Design, total 27 No of experimental run was Conducted as shown in table 3. Process parameters and their value are selected based on past research. The surface roughness was measured by Mitutoyo surf test SJ 210 with cut-off length and transverse length of 0.8 mm and 2.5 mm, respectively. Three reading were taken for each measurement and average of those three measurements was considered as final value.

Table 2: Process parameters and their levels

Factors	Unit	Level 1	Level 2	Level 3
Cutting Speed	m/min	170	103	63
Feed Rate	mm/rev	0.107	0.215	0.313
Depth of cut	mm	0.3	0.6	0.9

Table 3: Experimental Plan with Results of Surface Roughness for 6063 Al alloy 5 % and 10 % TiC

Ex p.r un	Process Parameters			5 % TiC	10 % TiC
	Cutting Speed	Feed Rate	Depth of cut	Surface Roughness, Ra	
	m/min	mm/rev	mm	µm	µm
1	170	0.107	0.9	1.556	1.628
2	170	0.215	0.9	3.102	3.421
3	170	0.313	0.9	5.014	5.213
4	170	0.107	0.6	1.356	1.582
5	170	0.215	0.6	2.918	3.196
6	170	0.313	0.6	4.818	5.134
7	170	0.107	0.3	1.098	1.168
8	170	0.215	0.3	2.645	3.201
9	170	0.313	0.3	4.627	5.162
10	103	0.107	0.9	2.456	1.943
11	103	0.215	0.9	3.842	5.628
12	103	0.313	0.9	5.703	7.316
13	103	0.107	0.6	2.110	1.617
14	103	0.215	0.6	3.713	5.219
15	103	0.313	0.6	5.543	7.137
16	103	0.107	0.3	1.846	1.537
17	103	0.215	0.3	3.281	4.618
18	103	0.313	0.3	5.172	6.943
19	63	0.107	0.9	2.843	2.617
20	63	0.215	0.9	4.431	5.813
21	63	0.313	0.9	6.826	7.631
22	63	0.107	0.6	2.546	2.273
23	63	0.215	0.6	4.343	5.774
24	63	0.313	0.6	6.512	7.218
25	63	0.107	0.3	1.914	1.905
26	63	0.215	0.3	3.214	5.267
27	63	0.313	0.3	6.327	6.751

The power consumption by the main spindle is measured by two watt meter method using clamp meter in which current coil is connected into series and pressure coil is connected into parallel. The product of voltage and current directly gives the value of power on digital screen.

Table 4: Experimental Plan with Results of Power Consumption for 6063 Al alloy 5 %, 10 % TiC

Ex p.run	Process Parameters			5 % TiC	10 % TiC
	Cutting Speed	Feed Rate	Depth of cut	Power consumption	
	m/min	mm/rev	mm	Kw	Kw
1	170	0.107	0.9	1.01	0.98
2	170	0.215	0.9	1.11	1.23
3	170	0.313	0.9	1.24	1.35
4	170	0.107	0.6	0.97	1.06
5	170	0.215	0.6	1.09	1.18
6	170	0.313	0.6	1.21	1.34
7	170	0.107	0.3	0.92	0.99
8	170	0.215	0.3	1.14	1.13
9	170	0.313	0.3	1.23	1.27
10	103	0.107	0.9	0.75	0.88
11	103	0.215	0.9	0.84	1.01
12	103	0.313	0.9	0.96	1.14
13	103	0.107	0.6	0.71	0.81
14	103	0.215	0.6	0.82	0.94
15	103	0.313	0.6	0.91	1.08
16	103	0.107	0.3	0.64	0.76
17	103	0.215	0.3	0.76	0.88
18	103	0.313	0.3	0.87	1.03
19	63	0.107	0.9	0.61	0.72
20	63	0.215	0.9	0.69	0.84
21	63	0.313	0.9	0.73	0.98
22	63	0.107	0.6	0.66	0.69
23	63	0.215	0.6	0.74	0.80
24	63	0.313	0.6	0.86	0.95
25	63	0.107	0.3	0.63	0.63
26	63	0.215	0.3	0.72	0.78
27	63	0.313	0.3	0.88	0.92

III. ANALYSIS OF VARIANCE

Analysis of Variance (ANOVA) is a powerful analyzing tool which is used to identify significant of each parameter on output response. Study of ANOVA table for a given analysis helps to determine which of the factors need control and which do not. The Minitab 15 Software is used to identify various terms in ANOVA. The table 5, 6, 7 and 8 shows the ANOVA for surface roughness and Power consumption. The ANOVA table shows effect individual effect of each parameter and interaction effect of each parameter on output response. Here in ANOVA table, "A" is Consider as Cutting Speed, "B" is Consider as Feed rate and "C" is Consider as Depth of cut.

ANOVA Terms & Notations:

D.F =Degree of Freedom
Seq S.S = Sum of Squares
M.S = Mean Square
F =Variance Ratio
P = Probability
% C = Percentage Contribution

Table 5: ANOVA of Surface Roughness for 6063 Al alloy 5 % TiC

Source	D.F	Seq S.S	M.S	F	P	C%
A	2	7.7930	3.8965	212.98	0.000	10.963
B	2	60.3489	30.174	1649.2	0.000	84.899
C	2	1.8343	0.9171	50.13	0.000	2.5804
A*B	4	0.6485	0.1621	8.860	0.000	0.9123
A*C	4	0.1950	0.0487	2.660	0.111	0.2743
B*C	4	0.1174	0.0293	1.600	0.264	0.1651
Error	8	0.1464	0.0183			0.2059
Total	26	71.0833				100

Table 6: ANOVA of Surface Roughness for 6063 Al alloy 10% TiC

Source	D.F	Seq S.S	M.S	F	P	C%
A	2	14.9105	7.4552	244.65	0.00	12.353
B	2	100.770	50.385	1653.4	0.00	83.486
C	2	1.2107	0.6054	19.87	0.001	1.0030
A*B	4	3.3522	0.838	27.5	0.00	2.7772
A*C	4	0.1903	0.0476	1.56	0.274	0.1576
B*C	4	0.0249	0.0062	0.2	0.929	0.0206
Error	8	0.2438	0.0305			0.2019
Total	26	120.703				100

Table 7: ANOVA of Power consumption for 6063 Al alloy 5% TiC

Source	D.F	Seq S.S	M.S	F	P	C%
A	2	0.7104	0.3552	535.1	0.000	73.211
B	2	0.22002	0.1100	165.71	0.000	22.671
C	2	0.0020	0.0010	1.56	0.269	0.213
A*B	4	0.0046	0.0011	1.74	0.234	0.4764
A*C	4	0.0231	0.0057	8.7	0.005	2.3814
B*C	4	0.0048	0.0012	1.82	0.218	0.5000
Error	8	0.00531	0.0006			0.5472
Total	26	0.97046				100

"A*B", "A*C" and "B*C" Show the interaction effect of each parameter with another parameter. The percentage Contribution by each of the machining parameter in the total sum of squared deviation S.S can be used to evaluate the importance of machining parameter changes on the performance characteristic. In addition Fisher's F-test can also used to determine which machining parameter has significant effect on the performance characteristic. Percentage contributions of each parameter are shown in table 5,6,7,8.

Table 8: ANOVA of Power consumption for 6063 Al alloy 10% TiC

Source	D.F	Seq S.S	M.S	F	P	C%
A	2	0.5872	0.2936	550.58	0.000	59.298
B	2	0.3584	0.1792	336.02	0.000	36.190
C	2	0.0310	0.0155	29.08	0.000	3.1322
A*B	4	0.0024	0.0006	1.14	0.405	0.2445
A*C	4	0.0052	0.0013	2.48	0.128	0.534
B*C	4	0.0016	0.0004	0.79	0.562	0.1705
Error	8	0.0042	0.0005			0.4308
Total	26	0.9904				100

IV. RESULTS AND DISCUSSIONS

Surface roughness play important role in many areas and is a factor of great importance in the evaluation of machining accuracy. Process parameter must have to control to obtain the desirable surface finish, because process parameters have significant influence on surface roughness. Value of surface roughness for 6063 Al alloy 5 % TiC and 6063 Al alloy 10 % TiC with different Cutting speed, feed rate and depth of cut are shown in table 3.

Figure 1 and 2 Show the value of surface roughness at different feed rate and depth of cut at 170 m/min cutting speed for 6063 Al alloy 5 % TiC and Al alloy 10 % TiC, respectively. It can be seen from the figures 1, 2 that at 0.3 mm depth of cut and 170 m/min cutting speed, as the feed rate is increase from 0.107 mm/rev to 0.313 mm/rev. The value of Surface roughness is increased from 1.098 µm to 4.627 µm for 6063 Al alloy 5 %TiC and 1.168 µm to for workpiece having 10 % TiC. This is because why higher feed rate values increases temperature in cutting zone and causes to decrease the bonding effect between TiC particles and Al alloy matrix and produced rough surface. Surface roughness of the workpiece having 10 % TiC is maximal in most cutting condition as compare to workpiece having 5 %TiC. This is why because of the effect of interactions between TiC particles increase at higher volume fraction which causes poor surface finish.

Figure 3 and 4 shows the value of surface roughness at different cutting speed and depth of cut at 0.107 mm/rev feed rate for 6063 Al alloy 5 % TiC and Al alloy 10 % TiC, respectively. It is found that increase in cutting speed results in decrease in surface roughness. Because of at lower cutting speed, the built up edge (BUE) is formed and the chip fracture readily produce the rough surface. As the cutting speed increase, the BUE vanishes, chip fracture decreases and hence the surface roughness is decrease. Furthermore at higher cutting speed, removal of TiC particles from the aluminum matrix becomes easier. It is found from ANOVA that cutting speed has 10.96 % effect on surface roughness; feed rate has 84.89 % effect and depth of cut has 2.58 % effect on surface roughness for workpiece having 5 % TiC. While that for workpiece having 10 % TiC, the effect on surface roughness is 12.35 % for cutting speed, 83.48 % for feed rate and 1.00% for depth of cut. It is clear from value of percentage Contribution of ANOVA that feed rate has significant effect on Surface roughness as compare to cutting speed and depth of cut.

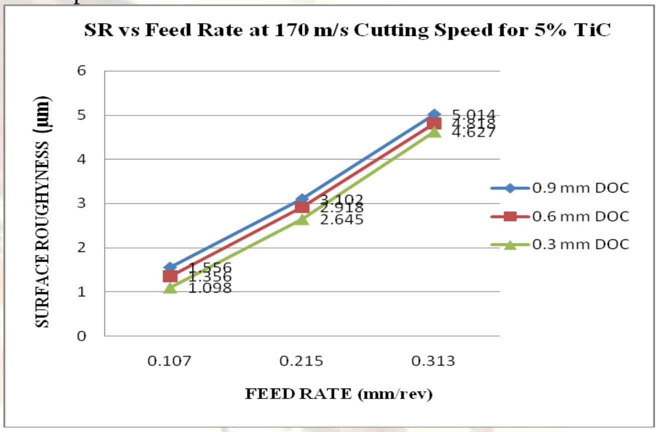

Fig 1: Variation of Surface roughness of 6063 Al 5 % TiC at 170 m/s Cutting Speed

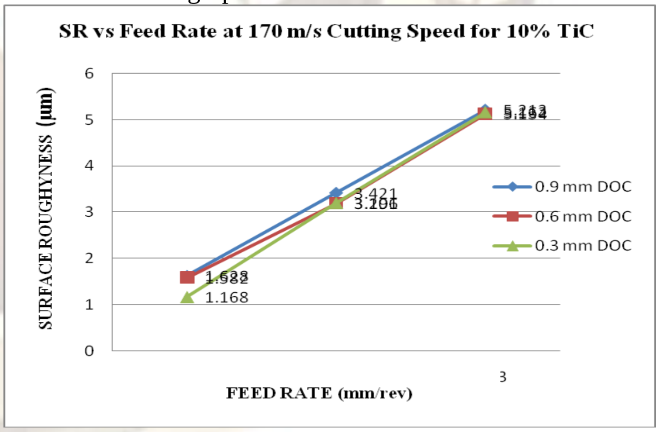

Fig 2: Variation of Surface roughness of 6063 Al 10 % TiC at 170 m/s Cutting Speed

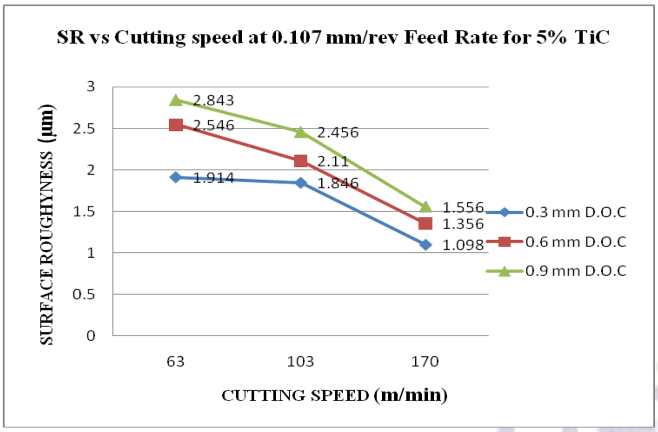

Fig 3: Variation of Surface roughness of 6063 Al 5 % TiC at 0.107 mm/rev feed rate

Value of Power Consumption for 6063 Al alloy 5 % TiC and 6063 Al alloy 10 % TiC are shown in table 4.

Figure 5 and 6 show the value of Power consumption at different cutting speed and feed rate at 0.3 mm depth of cut for 6063 Al alloy 5 % TiC and Al alloy 10 % TiC, respectively. It can be seen from figure 5 that power Consumption is increase with increase in cutting Speed. At 0.107 mm/rev feed, as the cutting speed is from 63 m/min to 170 m/min, power Consumption is increase from 0.63 Kw to 0.92 Kw. As the feed rate is increase from 0.107 mm/rev to 0.313 mm/rev. power consumption is increase from 0.63 kw to 0.88 Kw for 6063 Al alloy 5 %TiC.

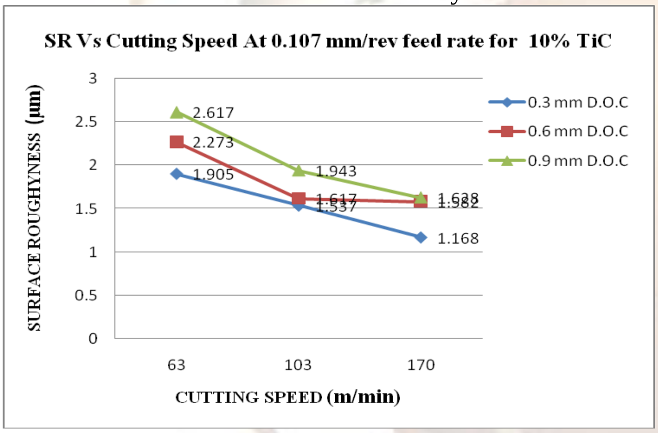

Fig 4: Variation of Surface roughness of 6063 Al 10 % TiC at 0.107mm/rev feed rate

Similarly For workpiece having 10 % TiC, power consumption is increase with increase in cutting speed in all machining conditions. At 0.107 mm/rev feed rate with 0.3 mm depth of cut, as the cutting speed is increase from 63 m/min to 170 m/min, power consumption is increase from 0.63 kw to 0.99 Kw. At 63 m/min cutting speed, as the feed rate is increase from 0.107 mm/rev to 0.313 mm/rev, Power consumption is increase from 0.63 Kw to 0.92 Kw.

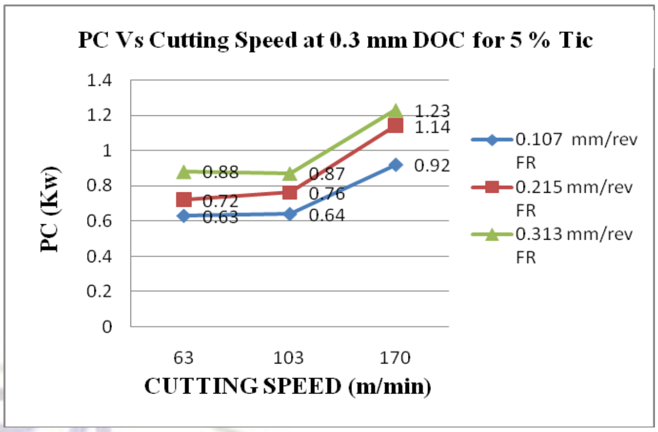

Fig 5: Variation of Power Consumption of 6063 Al 5 % TiC at 0.3 mm DOC

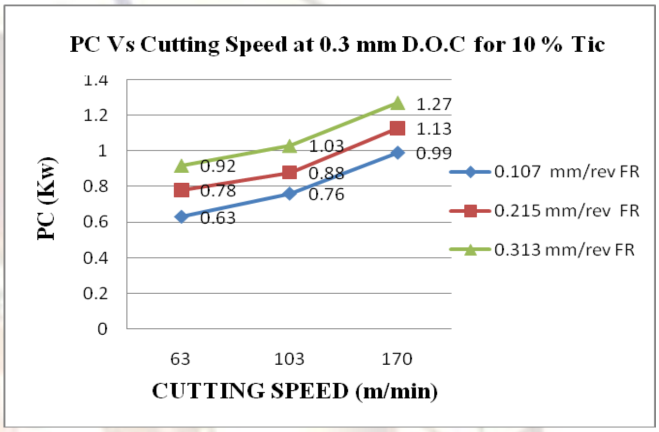

Fig 6: Variation of Power Consumption of 6063 Al 10 % TiC at 0.3 mm DOC

Fig 7 and 8 Show the value of Power consumption at different depth of cut and Cutting speed at 0.107 mm/rev feed rate for 6063 Al alloy 5 % TiC and Al alloy 10 % TiC, respectively. it can be seen from the figure 7,8 that power consumption is increase with increase in depth of cut in all machining condition. it is can be seen that power consumption is increased with increase in cutting speed, feed rate and depth of cut. This is quite obvious because as all this three parameters increases, the material removal rate also increase which forcing the system to spend more power.

In the most cases, with same combination of parameter, Power consumption is more for workpiece having 10 % TiC as compare to 5 %TiC. This is because why increase in volume fraction of reinforcement material, more power required to pull the reinforcing particles rather than cutting it.

From the ANOVA table, it can be seen that feed rate and depth of cut have 22.67 % and 2.13% effect on power consumption, and that for cutting speed has 73.21 % effect on power consumption which is maximal for workpiece having 5 % TiC. In the case of workpiece having 10 % TiC, feed rate has 36.18 % effect, depth of cut has 3.13 % effect and Cutting speed has 59.29 % effect which is maximal. So it can be said that cutting speed is most effective parameter for consumption of power.

V. CONCLUSIONS

In this work, effects of various cutting parameter in turning of 6063 Al alloy TiC have been investigated on surface roughness and power consumption. The following conclusions are drawn based on the above experimental work:

1. Feed rate is found the most significant effect on surface roughness. The increase of feed rate increases the surface roughness.
2. In majority of results, surface finish of workpiece having 5 % TiC is better than workpiece having 10 % TiC.
3. ANOVA shows the feed rate is only significant parameter which Contributes to the surface roughness. The second factor which contributes to the surface roughness is cutting speed.
4. Cutting speed is found to have effect on surface roughness. Value of surface roughness is decrease with increase in cutting speed.
5. Power Consumption is increase with increase in cutting speed, feed rate and depth of cut. Cutting speed is most effective parameter on power consumption; the second factor which affect on power consumption is feed rate, while depth of cut has lesser effect.
6. ANOVA shows the cutting speed is significant parameter which contributes to power consumption. The second factor which contributes to power consumption is feed rate.

VI. FUTURE DIRECTION OF RESEARCH

Future advancement in the area of machining of metal matrix composite will continue towards understanding the fundamental of machining of MMCs as broadening the application of the process for the industries. Following is a list summarizing the future research opportunities, Challenges and guidelines in the area of Machining of metal matrix composites.

1. Efforts should be made to investigate effect of different cutting tool geometry on cutting forces in turning of AL-TiC as workpiece material.
2. Effect of different cooling Environment on surface roughness and material removal rate in turning of Al-TiC.
3. Influence of Process Parameters on tool wear in turning of AL-TIC.
4. Influence of matrix type, reinforcement volume fraction and particles Size in turning of AL-TIC.
5. Machining performance of various cutting tool (Coated and Uncoated) in turning of Al-TiC.
6. Chip formation analysis in machining of Al-TiC.

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