

## A COMPARATIVE STUDY ON VARIOUS INSERTS DURING MACHINING OF AL/10 VOL% AND 20 VOL% SiC-MMC

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### ABSTRACT

The paper presents the comparative study on various inserts through experimental investigation during machining of 10% volume and 20% volume silicon carbide particulate aluminium metal matrix composite. The different sets of experiments are performed to study the effect of the main machining parameter e.g. cutting speed on the machining performance criteria such as surface finish and tool wear. The effect of tool materials and geometry of different inserts on the surface finish and tool wear are also investigated during machining experimentations. The effect of use of cutting fluid during machining on the surface finish and tool wear are also investigated. Comparative performance study on various cutting tools during machining of Al/SiC-MMC have also been performed for searching out the most effective tools and coolant considering technological and economical factors of machining. Test results show that the coolants as well as the SiC particles are resisting the cutting action during machining of Al/SiC-MMC. The research work findings will also provide useful economic machining solution by utilizing suitable tool during processing of Al/SiC-MMC, which is otherwise usually machined by costly PCD tools.

**Keywords:** Cutting speed, Tool wear, Surface finish, Al/SiC-MMC.

### 1. INTRODUCTION

Al/SiC-MMC is one of the important composites among the metal matrix composite, which have SiC-particles with aluminium matrix is harder than tungsten carbide (WC), which pose many problems in machining. The presence of hard abrasive reinforced particles in the Al/SiC-MMC,s causes rapid tool wear during machining. However, the modern industries have developed an increasing demand for machining advanced composite materials like Al/SiC-MMC irrespective of their hardness, toughness, configurationally complexity, microstructure, electrical conductivity etc. for developing highly sophisticated products so as to achieve various requirements of those products e.g. high precision, high speed, high temperature resistance, wear resistance and low weight etc. The aluminium alloy reinforced with discontinuous ceramic reinforcements is rapidly replacing conventional materials in various automotive, aerospace and automobile industries [1]. But Al/SiC-MMC,s machining is one of the major problems, which resist its wide spread engineering application [2]. From some early conventional turning tests on Al/SiC-MMC,s [3-4], it is found that the tool wear is excessive

Al/SiC-MMC use of coolant increases tool wear and as well as produces very poor surface finish [5]. The hard SiCparticles of Al/SiC-MMC, which intermittently come into contact to the hard surface, are act as small and surface finish is very poor while carbide tip tools are used for machining. During machining ofcutting edges like those of a grinding wheel on the cutting tool edge which in due course is worn out by abrasion and resulting in formation of poor surface finish during turning [6]. Hence, cost effective machining with generation of good surface finish on the Al/SiC-MMC jobs during turning operation is a challenge to the manufacturing engineers in practice.

In view of these above mentioned machining problems, main objectives of the paper is to study the influence of cutting speed on the selected machinability characteristics such as surface finish and tool wear during turning of Al/SiC-MMC. The effect of use of cutting fluid during machining on the surface finish and tool wear are also investigated. The comparative performance study of various cutting tools during machining of Al/SiC-MMC has also been performed. The job surface condition and tool wear for different sets of experiments have

without use of coolant, which may overcome the machining barriers from Al/SiC-MMC.

## 2. PLANNING FOR EXPERIMENTATION

Two different aluminium base metal matrix composite e.g. Al/ 10 vol. % SiC-MMC and Al/ 20 vol. % SiC-MMC with Average Particle Size (APS): 45  $\mu\text{m}$  and 34  $\mu\text{m}$  respectively have been taken as work-piece materials for the present set of experimental investigation. The chemical, physical and mechanical properties of Al/ 10 vol. % SiC-MMC and Al/ 20 vol. % SiC-MMC as considered for the experimental investigation are listed in Table 3.1 and Table 3.2 respectively. A precession Lathe MK-4SR PREOPTIVE, Mfg. Alfred Herbert India is used for the experimental investigation. The experimental test has been conducted with cutting speed range 25 m/min to

150 m/min. The experimental investigations are carried out considering 0.25 mm/rev constant feed and 0.5 mm constant depth of cut. The nose radius of cutting tool inserts has been selected as 0.4 mm for machining of 10vol% and 20vol% reinforced silicon carbide aluminium metal matrix composites. The discontinuous reinforced aluminium metal matrix composite of 50 mm diameter bar is used for the experimentation. Kyon, IC-20, GC-3015, GC-415, CBN and PCD tools are used for the turning experiments with and without use of coolant. Fatty mineral oil is emulsified in water is used as a coolant during turning operation. The machined surface integrity has been measured using Surfcom 120A-TSK surface texture measuring instrument. The flank wear of the cutting tools are measured using toolmakers microscope of accuracy level 0.01 mm.

Table 3.1 Chemical composition of Al/SiC-MMC used for experimentation

Types of MMC	Types of reinforced particles	%SiC	%Si	%Mg	%Fe	%Cu	%Mn	%Zn	%Ti	Al
2080/Al/SiC	SiC	10.00	7.01	0.60	0.12	0.18	0.10	0.10	0.10	Rem.
6061/Al/SiC	SiC	20.00	9.25	0.55	0.15	0.20	0.10	0.10	0.10	Rem.

Table 3.2 Physical and mechanical properties of Al/SiC-MMC used for experimentation

Material	Density, gm-cm <sup>-3</sup>	Ultimate tensile strength	Yield strength, N-mm <sup>-2</sup>	Specific modulus, (10 <sup>7</sup> )	Specific fatigue strength, (10 <sup>7</sup> )
2080/Al-SiC/10%	2.69	429.05	325.26	3.5	7.6
6061/Al-SiC/20%	2.72	551.7	448.2	3.8	7.9

## 3. EXPERIMENTAL RESULTS AND DISCUSSION

### 3.1 Influence of the Cutting Speed on Tool Wear

Fig.3.1 shows the influence of cutting speed on flank wear of different cutting tools of 0.4 mm nose radius during turning of Al/10 vol.% SiC-MMC without use of coolant. The machining experiments were performed at constant feed 0.25 mm/rev. and 0.5 mm depth of cut. From the experimental results it can be concluded that the flank wear of the Kyon (Kennametal) insert is comparatively more as compared to the other inserts used for the experimentation. For Kyon insert flank wear decreases with increase of cutting speed. For 50 mm continuous length of turning at 25 m/min cutting speed, without use of coolant the flank wear of Kyon tool is 1.1 mm where as at 150 m/min cutting speed flank wear is only 0.8 mm. From the experimental results it also observed that for GC-415 insert, tool wear proportionately increase with the increase of cutting speed. For IC-20 (K10) and GC-3015 inserts, the tool flank wears increase rapidly with increase of cutting speed. For CBN insert, the flank wear is very less at high cutting speed. From the test results it is concluded that influence of cutting speed on the PCD tool is very less. The flank wear of PCD tool slightly decreases with decrease of cutting speed. The

flank wear is marginal in the case of PCD tool as compared to the other inserts.

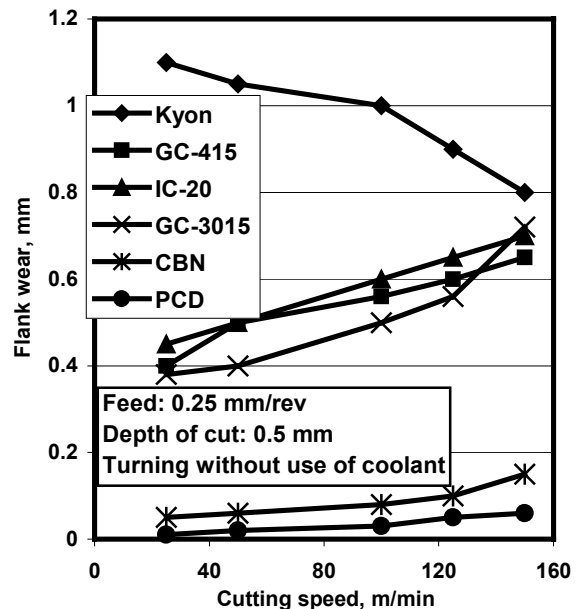


Fig. 3.1 Cutting speed vs Flank wear graph during machining of Al/10 Vol.%SiC-MMC

Fig. 3.2 shows the influence of cutting speed on the flank wear of different cutting tools of 0.4mm nose radius at constant 0.25 mm/rev feed and 0.50mm depth of cut during turning of Al/10 vol.% SiC-MMC with use of coolant. From the experimental results and from Fig.3.2, it is concluded that the flank wear of Kyon

(Kennametal) tool is comparatively more as compare to the other inserts used for the experiments. For 50 mm continuous length of turning at 25 m/min cutting speed, with use of coolant the flank wear of Kyon tool is 1.25 mm where as at 150 m/min cutting speed flank wear is only 0.95 mm. IC-20 (K-10) insert shows very high rate of flank wear with increase of cutting speed. GC-3015 and GC-415 inserts show less flank wear as compared to the Kyon. CBN tools show less tool wear as compared to the other tools except PCD tool. PCD shows very less tool wear and marginally influenced on the cutting speed.

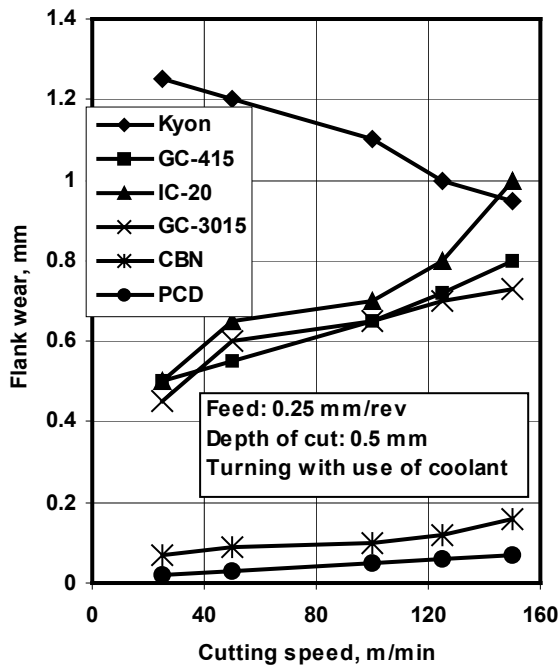


Fig. 3.2 Cutting speed vs Flank wear graph during machining of Al/10 Vol.%SiC-MMC

Fig. 3.3 shows the influence of cutting speed on the flank wear of different cutting tools of 0.4 mm nose radius at constant 0.25 mm/rev feed rate and 0.5 mm depth of cut during turning of Al/20vol.%SiC-MMC without use of coolant. From the experimental results it is concluded that the tool flank wear is maximum for the Kyon (Kennametal) insert as compare to the other inserts used for the experiments. For 50 mm continuous length of turning at 25 m/min cutting speed, without use of coolant the flank wear of Kyon tool is 1.3 mm where as at 150 m/min cutting speed flank wear is only 1.1 mm. For GC-415, IC-20 and GC-3015 inserts, the flank wears proportionately increase with the increase of cutting speed. For CBN and PCD tools, the flank wears are very less.

Fig. 3.4 shows the influence of cutting speed on the flank wear of the different cutting tools of 0.4 mm nose radius at constant 0.25 mm/rev feed rate and 0.5 mm depth of cut during turning of Al/20vol.%SiC-MMC with use of coolant. From the experimental results it is concluded that the flank wear rate is rapidly increase for IC-20 (K-10), GC-3015, GC-415 inserts with the increase of cutting speed. The Kyon (Kennametal) shows the maximum flanks wear as compare to the

other tools used for the experimentation. For 50 mm continuous length of turning at 25 m/min cutting speed, with use of coolant the flank wear of Kyon tool is 1.35 mm where as at 150 m/min cutting speed flank wear is 1.15 mm. PCD and CBN tools shows the less flank wear at all cutting speed as compare to the other cutting tools used for the experiments.

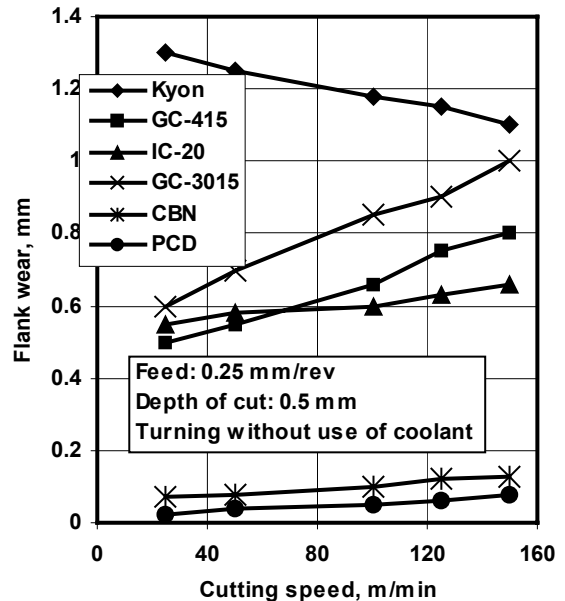


Fig. 3.3 Cutting speed vs Flank wear graph during machining of Al/20 Vol.%SiC-MMC

### 3.2 Influence of Cutting speed on Surface Finish

The influence of cutting speed on the surface finish during machining of Al/10 vol.% SiC-MMC using different cutting tools at constant feed and depth of cut with use of coolant is shown in Fig. 3.5. It is observed that the CBN tool produces better surface finish with increase of cutting speed. GC-415 tool shows less effect on the surface finish even at increase of cutting speed. The Kyon (Kennametal) tool shows overall better surface finish as compared to the IC-20, GC-415 and GC-3015 tools. The value of surface roughness,  $R_a$  is 3.8  $\mu\text{m}$  at 25 m/min cutting speed while using Kyon tool where as at 150 m/min cutting speed the value of surface roughness is only 2.6  $\mu\text{m}$ . The PCD tool shows overall better surface finish at all cutting speed as compare to the other cutting tools used for the experimentation.

Fig. 3.6 exhibits the effect of cutting speed on the surface finish during machining of Al/10 vol.% SiC-MMC using Kyon (Kennametal), IC-20, GC-3015, GC-415, CBN and PCD tools at constant 0.25 mm/rev feed rate and 0.5 mm depth of cut without use of cutting fluid. From the experimental results it is concluded that the GC-3015 and IC-20 (K-10) produce very poor surface finish as compared to the other cutting tools used for the experiments. The Kyon (Kennametal) tool shows overall better surface finish as compared to the

GC-415, IC-20 and GC-3015 tools. The value of surface

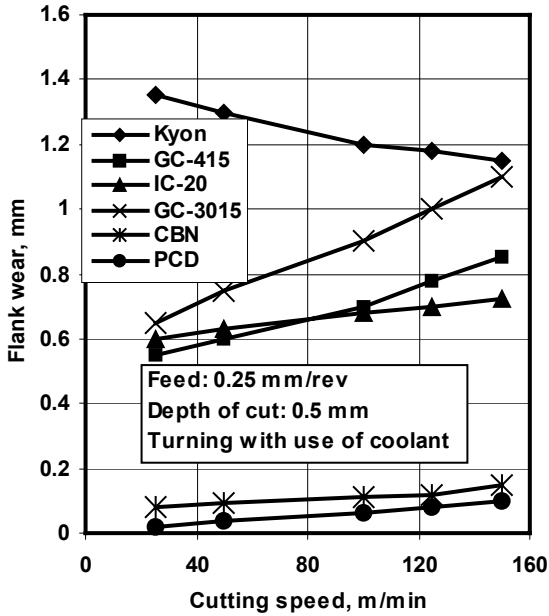


Fig. 3.4 Cutting speed vs Flank wear graph during machining of Al/20Vol.SiC-MMC

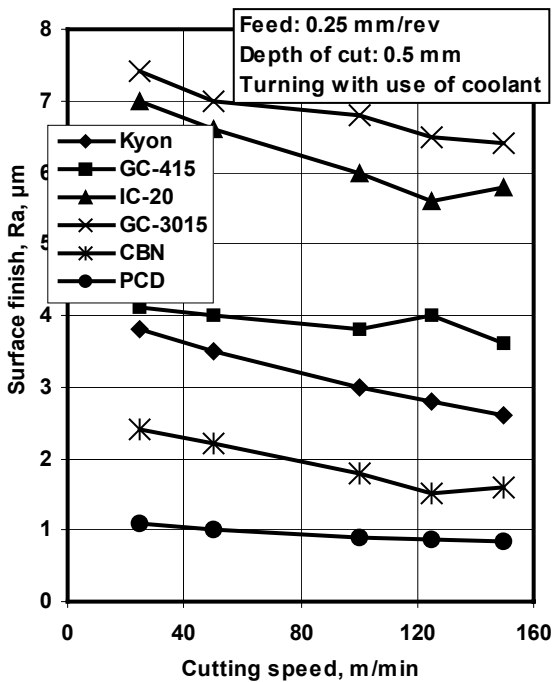


Fig. 3.5 Cutting speed vs Surface finish graph during machining of Al/10 Vol.%SiC-MMC

roughness,  $R_a$  is  $3.2 \mu\text{m}$  at  $25 \text{ m/min}$  cutting speed while using Kyon tool where as at  $150 \text{ m/min}$  cutting speed the value of surface roughness is only  $2.0 \mu\text{m}$ . CBN tool produces better surface finish with increase of cutting speed. The PCD tool has no significant effect on the surface finish with increase of cutting speed.

The influence of cutting speed on the surface finish during machining of Al/20 vol.% SiC-MMC using different cutting tools at constant feed and depth of cut with use of coolant is shown in Fig. 3.7. It is observed that the CBN tool produces better surface

finish with increase of cutting speed. CBN tool also produces better surface finish as compared to the other cutting tools used for the experimentation except PCD tool. The Kyon (Kennametal) tool shows overall better surface finish as compared to the GC-415, IC-20 and GC-3015 tools. The value of surface roughness,  $R_a$  is  $4.5 \mu\text{m}$  at  $25 \text{ m/min}$  cutting speed while using Kyon tool where as at  $150 \text{ m/min}$  cutting speed the value of surface roughness is  $3.7 \mu\text{m}$ . The PCD tool shows overall better surface finish at all cutting speed as compare to the other cutting tools used for the experimentation.

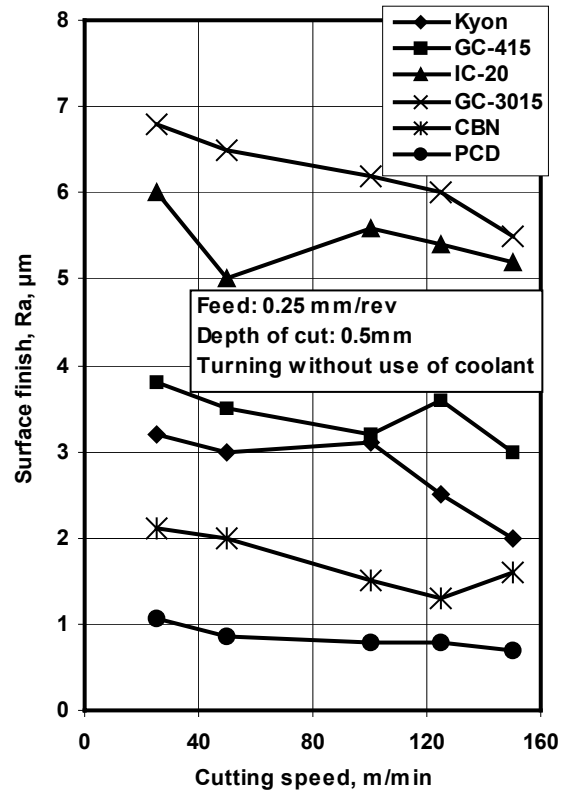


Fig. 3.6 Cutting speed vs Surface finish graph during machining of Al/10Vol.%SiC-MMC

Fig. 3.8 exhibits the effect of cutting speed on the surface finish during machining of Al/20 vol.% SiC-MMC using Kyon (Kennametal), IC-20, GC-3015, GC-415, CBN and PCD tools at constant  $0.25 \text{ mm/rev}$  feed rate and  $0.5 \text{ mm}$  depth of cut without use of cutting fluid. From the experimental results it is concluded that the GC-3015 and IC-20 (K-10) produce very poor surface finish as compared to the other cutting tools used for the experiments. The Kyon (Kennametal) tool shows overall better surface finish as compared to the GC-415, IC-20 and GC-3015 tools. The value of surface roughness,  $R_a$  is  $4.0 \mu\text{m}$  at  $25 \text{ m/min}$  cutting speed while using Kyon tool where as at  $150 \text{ m/min}$  cutting speed the value of surface roughness is only  $3.6 \mu\text{m}$ . CBN tool produces better surface finish with increase of cutting speed. The PCD tool has no significant effect on the surface finish with increase of cutting speed.

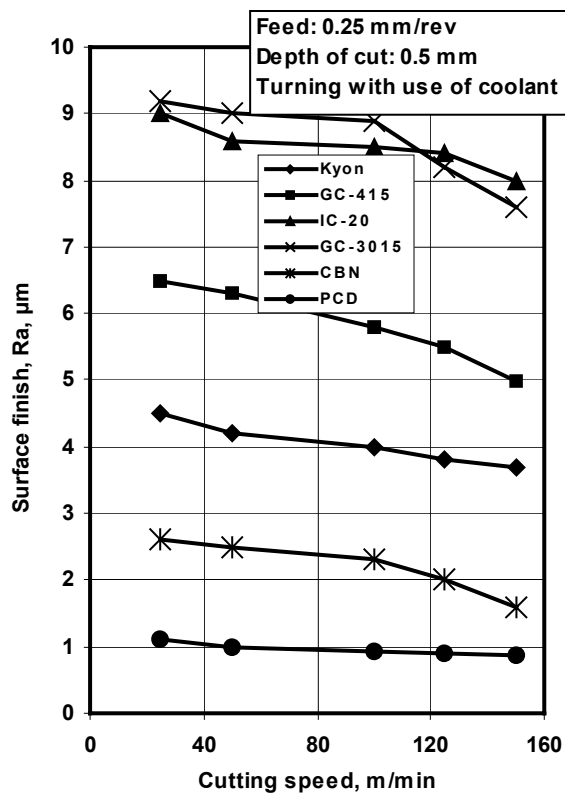


Fig. 3.7 Cutting speed vs Surface finish graph during machining of Al/20 Vol.% SiC-MMC

### 3.3 Comparative Study on Suitability of Kyon, IC-20, GC-3015, GC-415, CBN and PCD Inserts

From the above test results, it can be observed that the use of coolant during machining of Al/SiC-MMC increases tool wear. With the use of coolant during machining, the reinforced particles adhere to the lower side of the chip. The coolant and the particles are resisting together against the cutting action, which causes higher tool wear and increases surface roughness. Kyon (Kennametal), IC-20 (K-10), GC-3015 (Sandvik), GC-415 (Sandvik) tools with use of coolant are unsuitable for machining of Al/SiC-MMC. CBN tool is better than the above-mentioned tools for machining of Al/SiC-MMC. PCD tool is suitable for machining of Al/SiC-MMC. The comparative test results on the basis of tool wear for same geometry of tools i.e. 0,0,9,0,60,30,0.4 mm are (i) flank wear of Kyon tool is much more than other tools and hence it is unsuitable for turning of Al/SiC-MMC. (ii) tool wear rate of IC-20 (K-10) is very high but better than Kyon and GC-3015 tools. (iii) flank wear rate of GC-3015 tool is slightly better than IC-20 and GC-415 tools. (iv) GC-415 is slightly better than IC-20 and Kyon tools. (v) CBN tool is better than all above tools and tool wear rate is very poor. (vi) PCD tool produces least flank wear compare to the other tools.

The comparative test results on the basis of surface finish for same geometry of tools i.e. 0,0,9,0,60,30,0.4 mm are (i) Kyon tool is not suitable for finish operation

but better than GC-415, IC-20 and GC-3015 tools. (ii) IC-20 tool is better than GC-3015 tool. (iii) GC-415 produces poor surface finish but better than IC-20 and GC-3015 tools. (iv) CBN produces better surface finish as compared to the other tools except PCD tool. (v) PCD tool produces very good surface finish as compared to the other tools.

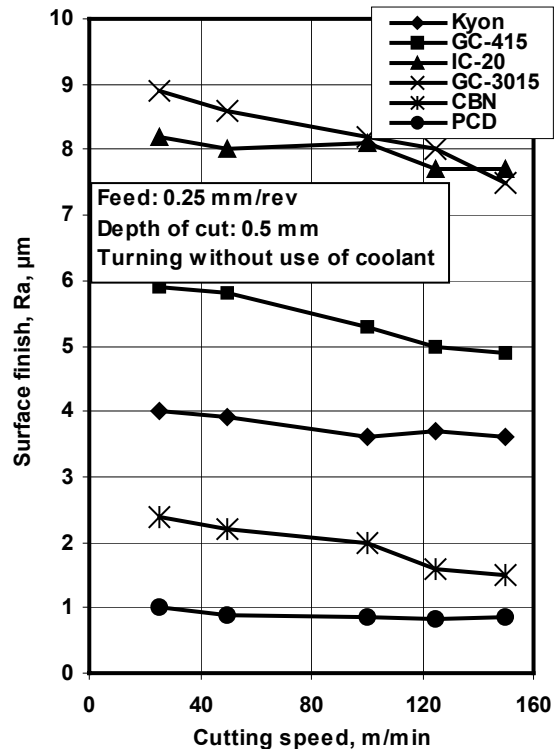


Fig. 3.8 Cutting speed vs Surface finish graph during machining of Al/20 Vol.% SiC-MMC

## 4. CONCLUSIONS

Based on the performance and test results of the various set of experiments, the following points can be concluded as listed below

- (i) The PCD tool exhibits superior wear resistance and hence it can be recommended for proper machining of Al/SiC-MMC without use of coolant.
- (ii) The CBN and PCD tools are recommended for better surface finish during machining of Al/SiC-MMC.
- (iii) Use of cutting fluid during machining increases tool wear and surface roughness. The circulation of cutting fluid during machining decreases the temperature at the chip formation zone, which increases the matrix strength and helps to adhere the reinforced particles on the lower side of the chip and cutting edge of the tool, which will resist together cutting the metal during machining.

#### 4. REFERENCES

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