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EXPERIMENTAL STUDY ON INTERMITTENT TURNING OF ALUMINUM METAL MATRIX COMPOSITES USING K10 GRADE CARBIDE INSERTS

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ABSTRACT

Metal matrix composites containing fly ash as reinforcement are primarily preferred because these materials possess lower density and higher strength to weight ratio. While turning Aluminum fly ash composites, presence of hard ceramic particles in the fly ash leads to the failure of the cutting tool. However the presence of the hard ceramic particulates in the composites induces hetrogeneous structure which causes chipping of the cutting tool during intermittent turning application. Selection of optimal cutting conditions for a given machining process is utmost important to enhance the tool life during intermittent turning operation. Thus the research work was aimed at the experimental investigation of the tool life during intermittent turning of Al6061 composites containing 0% to 15% of fly ash. The experiments were carried out following ISO3685 standards. Tungsten carbide inserts of grade K10 and CGGN120304 style inserts were the turning tools. The cutting speed selected was 150m/min, 300m/min, 450m/min, 600m/min and 750m/min, feed of 0.08 mm/revolution, 0.12mm/revolution, 0.16mm/revolution and radial depth of 1.2 mm. The experimental results revealed that the performance of K10 grade carbide insert found better when composites machined below 600 m/min cutting speed and feed of 0.08 mm/revolution irrespective of percentage fly ash.

Key Words: *Composite material, Aluminium, fly ash, intermittent turning, K10 carbide, tool life.*

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1. INTRODUCTION

Metal matrix composites consisting of Aluminum as matrix material and fly ash as reinforcement are preferred for aviation, automobile and structural application owing to their mechanical and thermal properties such as lower weight and higher wear resistance, tensile strength and thermal conductivity. Manufacturing aspects of Aluminum fly ash composites has been investigated by numerous researchers. The stir casting method found effective to manufacture metal matrix composites[1,2] C.Venkatesh et al. [3] introduced preheated SiC particles to the molten metal following stir casting route to fabricate composites. The wear resistance & thermal resistance of the composite material increases due to the presence of hard ceramic particles. Kenneth Kanayo Alaneme et al. [4] observed that the composites without graphite exhibited greater wear susceptibility in comparison to the composite grades containing graphite. However the wear resistance decreased with increase in the graphite content from 0.5 to 1.5 wt%. Ankesh Kumar et al. [5] carried characterization on Aluminum matrix hybrid composites reinforced with alumina, rice husk ash and graphite, and they found that hardness decreases with increase in the weight ratio of rice husk ash and graphite in the composites. N.Senthil kumar et al. [6] conducted experiments on turning process using taguchi method, they found that the insert shape contributes 36.94%, feed rate contributes 30.82% on its performance. However, while machining of Al6061-SiC-Gr, nano composites radial depth and tool advancement per revolution found significant on surface roughness [7]. During micro milling feed per tooth and spindle speed are important factors [8]. Further, C. R. Prakash Rao et al. [9] found that increased fly ash content in the composite reduces built up edge formation while machining composite materials.

While machining composites containing increased Si_3N_4 weight percentage accelerated tool wear were observed [10]. Since conventional tools give lower tool life, Preetkanwal Singh Bains et al. [11] suggested in their review paper that PCD & diamond coated tools are best suited for machining of metal matrix composites. R. Elangovan et al. [12,13] carried out research work on machining of Aluminum – fly ash-SiC hybrid composites, and they found that increased fly ash reduces PCD tool wear, however increased SiC percentage increases PCD tool wear. C. R. Prakash Rao et al. [14] Carried out research work on machining of composite materials using PCD & K10 grade carbide inserts of identical geometry, and they found that the surface roughness found lower when PCD inserts are used for turning. S. Kannan et al. [15] carried out experimental study on machining metal matrix composites and they found that increase in the cutting force as a result of increasing the particle size and volume fraction can be correlated to the increase in the average dislocation density. Ch. Shoba et al. [16] Carried out research work on machining of composite materials and they observed that cutting force components decrease with the increase in the weight percentage of the reinforcement. A.Pramanik et al. [17] observed that cutting forces increase with increased feed and Chip breakability was found to improve due to the presence of the reinforcement particles in the MMC. Further, K. Venkatesan et al. [18] carried out research work on machining of hybrid composites and found that the surface roughness deteriorates at higher feed rate.

From the above research articles we can infer that less work was done on intermittent turning of composites using throw away type tungsten carbide inserts. In automobile and machine tool industry most of the components are non symmetrical, such machining conditions optimum tool life can be obtained by selecting right machining parameters. Hence, the objective of present work is to determine the best machining parameter while intermittent turning of aluminum fly ash metal matrix composites using K10 grade throw away type carbide inserts.

2. WORK MATERIAL

2.1 MATERIALS

The Aluminum alloy of grade Al6061 was the matrix material and the filler material for the present research work was fly ash, the chemical composition of the Al6061 material is presented in Table 1 and filler fly ash in Table 2 respectively.

Table 1: Composition of base matrix Al6061 alloy

Parameter	Mg	Si	Fe	Cu	Cr	Al
Wt %	0.92	0.58	0.21	0.23	0.24	Rest

Table 2: Composition of fly ash

Parameter	SiO_2	Al_2O_3	CaO	MgO	Fe_2O_3	K_2O
Wt. %	58.32	24.23	4.39	1.20	4.13	0.92

2.2 Specimen Preparation

Cast composites containing varied percentage of filler fly ash was obtained following liquid metallurgy route. The moisture content was removed from the fly-ash by preheating before being introduced into the molten metal. Stirring process is carried out at 75 RPM for about 60 minutes maintaining temperature of molten metal as 690°C. The tri shaped cast composites of Al6061 alloy and its composites containing fly ash of 0%, 5%, 10% &15%. The diameters of composites are 120 mm and length 300mm. The cast matrix & composites used for the intermittent turning tests shown in Figure 1.

Figure 1: Tri shaped cast composite used for the experiment

3. CUTTING TOOL

Tungsten carbide inserts of style CGGN120304 were mounted on throw away type positive rake aluminum turning tool holder during conduction of the experiment which is shown in Figure 2 and the nomenclature of cutting tool is presented in Table 4.

Figure 2: Cutting tool used for the experiment

Table 4: Nomenclature of cutting tool used for the experiment

Description	K10 CARBIDE
Back rake angle	15°
Side rake angle	10°
End cutting edge angle	95°
Side cutting edge angle	95°
End clearance angle	15°
Side clearance angle	15°

Cutting tool type	Throw away insert

4. MACHINE TOOL

ACE Designers make JOBBER XL CNC lathe was the machine tool used for conducting the experiments, presented in Figure 3, and the specifications are tabulated in Table 5. The tri shaped castings were held between hydraulic chuck and revolving centre and used for Intermittent turning on CNC lathe.

Figure 3: JOBBER XL CNC Lathe

Table 5: Specification of JOBBER XL CNC lathe

Maximum turning diameter	270 mm
Maximum turning length	400 mm
R P M	50-4000
Clamping system	Hydraulic
Bar capacity	36 mm
Dimension (m)	2200X 1750X 1750

5. TURNING TESTS

The intermittent turning tests were carried out with different cutting speeds and feeds. The depth of cut, cutting tool overhang and cutting tool geometry were kept constant, following dry cutting conditions. The experimental studies carried out as per ISO 3685 standards. The cutting speed was 150 m/min to 750 m/min, feed of 0.08, 0.12 & 0.16 mm/rev and radial depth of 1.5 mm were the machining parameters. BUE and BUL formation on the cutting edges were cleaned frequently.

6. RESULTS & DISCUSSION

6.1 RESULTS OF HARDNESS TEST

The hardness test is carried out on model KB3000H Brinell hardness tester. The average of the three readings was taken to consider the hardness of composite material and is shown in the Table 3 and presented in Figure 5. Brinell hardness tester used for measuring hardness of the composites is shown in Figure 4.

TABLE 3: Hardness and density of Al6061 and its composites containing filler fly-ash

Material	BHN	Density (g/cc.)	
		Predicted	Experimental
Al6061	36.24	2.7	2.7
Al6061+5% fly ash	44.68	2.605	2.56
Al6061+10% fly ash	53.55	2.51	2.47
Al6061+15% fly ash	65.60	2.415	2.38

The tri shaped cast composite containing 0% - 15% of fly ash

Figure 4: Hardness testing of the composite specimen using KB3000H Brinell hardness tester

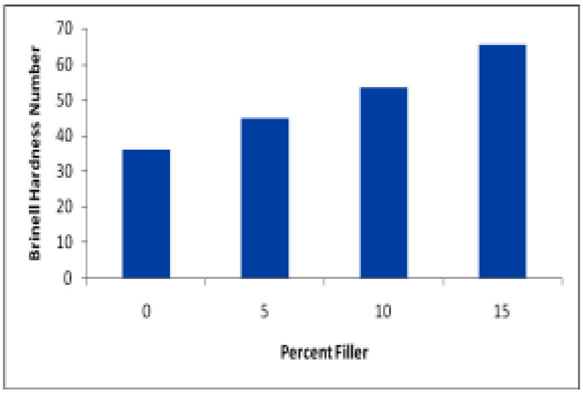

Figure 5: Variation of hardness with varied percent filler fly ash

The hardness test of the work materials were evaluated following standard procedures. Addition of fly ash content to Al6061 matrix material resulted in increase of hardness of composite material.

6.2 RESULTS OF DENSITY MEASUREMENT

The density measurement values are compared with calculated density values as per rule of mixture for Al6061 metal matrix composites containing 0% to 15% percent fly-ash, and are presented in Table 3. From Figure 6, it is clear that measured density values are closer to the predicted density values and hence proves liquid metallurgy techniques followed for composite preparation. The increase in fly ash percentage in the matrix resulted in decrease of the density of its composites.

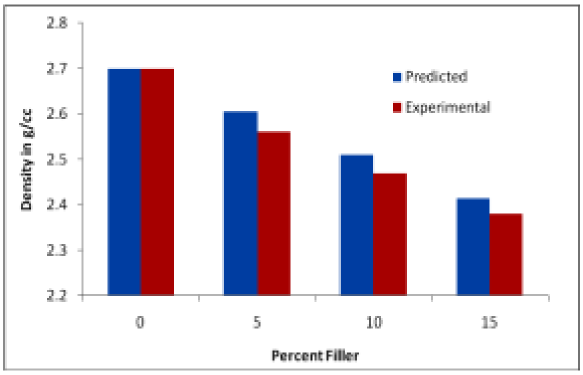

Figure 6: Variation of Density with varied percent filler fly ash

6.3 RESULTS OF SEM MICROPHOTOGRAPHS

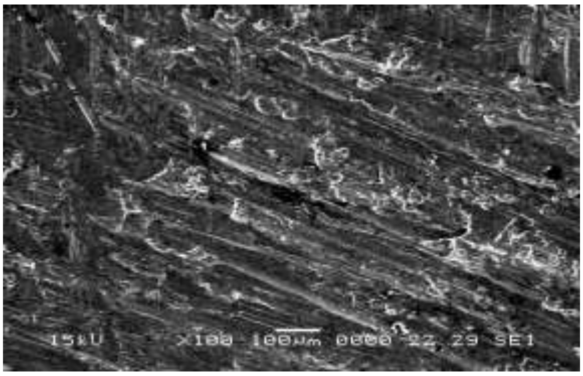

Figure 7: SEM microphotographs of as cast matrix

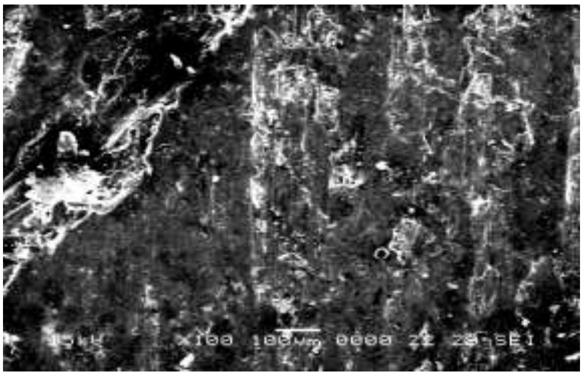

Figure 8: SEM microphotographs of composite - 5% fly ash

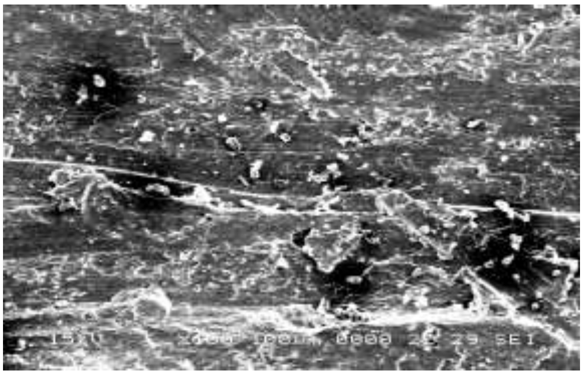

Figure 9: SEM microphotographs of composite - 10% fly ash

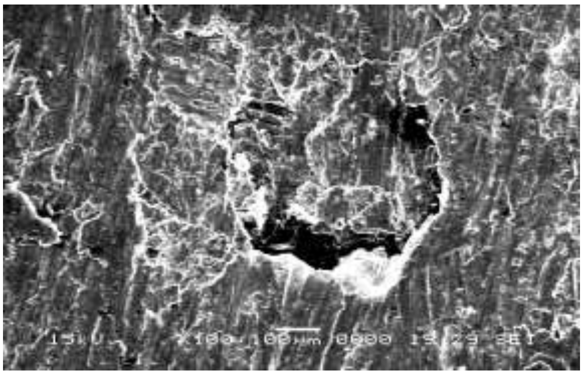

Figure 10: SEM microphotographs of composite -15% fly ash

Figure 7 to 10 presents the Scanning Electron Microscope images of Al6061 base matrix and its composites containing 0%, 5%, 10% and 15% fly ash and from images we can observe the distribution of fly ash particles in the composite materials. The SEM images confirm the suitability of the process adopted to manufacture aluminum fly ash composites.

6.4 RESULTS OF INTERMITTENT TURNING TEST

The outside diameter turning test was carried out after skin turning of cast surface. K10 Grade carbide inserts were used for intermittent turning experiment. The tool life during Intermittent turning of composite materials as a function of percentage filler were presented in Table 6, Table 7 and Table 8.

Table 6: Tool life of K10 grade Carbide inserts at 0.08mm/rev

Cutting speed in m/min.	Number of impacts before failure while machining composites containing % filler fly ash			
	0	5	10	15
150	84638	81367	78064	71142
300	69156	66368	63767	58466
450	56982	53350	51230	44354
600	47839	45654	43230	35404
750	41635	38804	35528	29424

Table 7: Tool life of K10 grade Carbide inserts at 0.12mm/rev

Cutting speed in m/min.	Number of impacts before failure while machining composites containing % filler fly ash			
	0	5	10	15
150	69876	66706	63624	58350
300	56182	53887	51326	45466
450	46526	43912	41579	36516
600	38324	36890	34196	29412
750	33100	30459	27364	17661

Table 8: Tool life of K10 grade Carbide inserts at 0.16mm/rev

Cutting speed in m/min.	Number of impacts before failure while machining composites containing % filler fly ash			
	0	5	10	15
150	53317	50046	48197	44559
300	42407	39406	37950	34661
450	34932	32516	30929	27879
600	27790	26126	24161	22306
750	21395	19915	18216	10597

The criteria of changing cutting edge was failure of K10 grade inserts by BUE formation on the cutting edge followed by micro chipping or chipping of the cutting edge. From Figures 11 to 18, it can be observed that when composite material subjected to intermittent turning application cutting edge chipping found high at higher percent filler and when machined at higher cutting speeds.

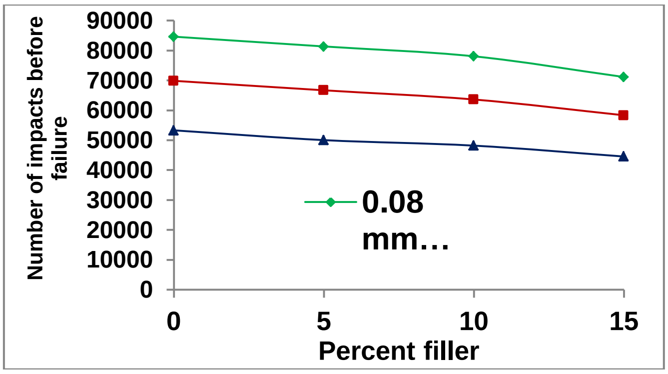

Figure 11: Influence of percent Filler & Feed/revolution on tool life when intermittent turning at 150m/min cutting speed.

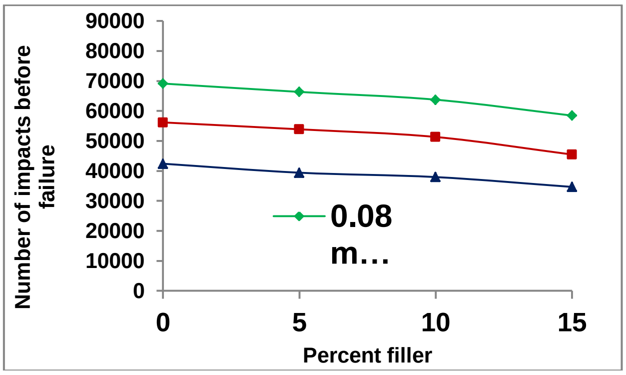

Figure 12: Influence of percent Filler & Feed/revolution on tool life when intermittent turning at 300m/min cutting speed.

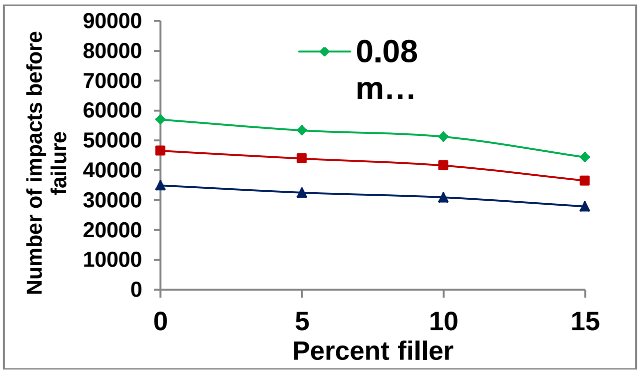

Figure 13: Influence of percent Filler & Feed/revolution on tool life when intermittent turning at 450m/min cutting speed.

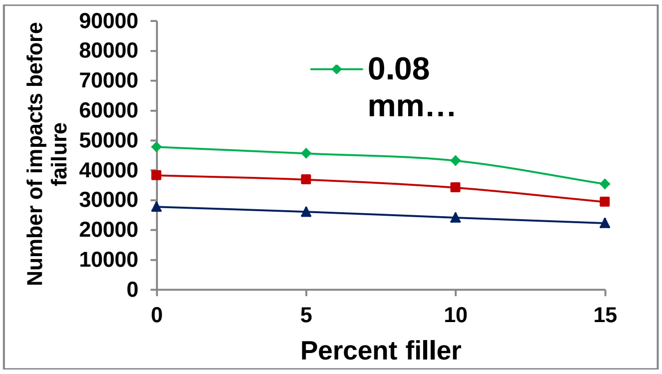

Figure 14: Influence of percent Filler & Feed/revolution on tool life when intermittent turning at 600m/min cutting speed.

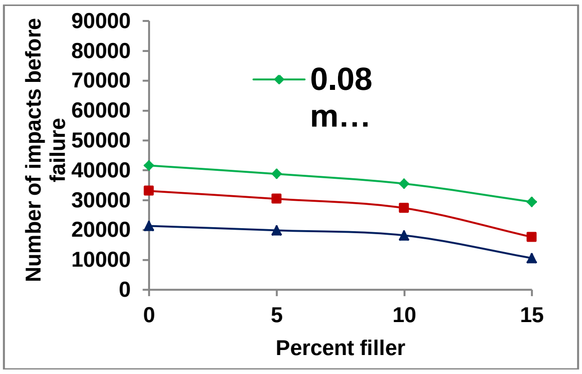

Figure 15: Influence of percent Filler & Feed/revolution on tool life when intermittent turning at 750m/min cutting speed

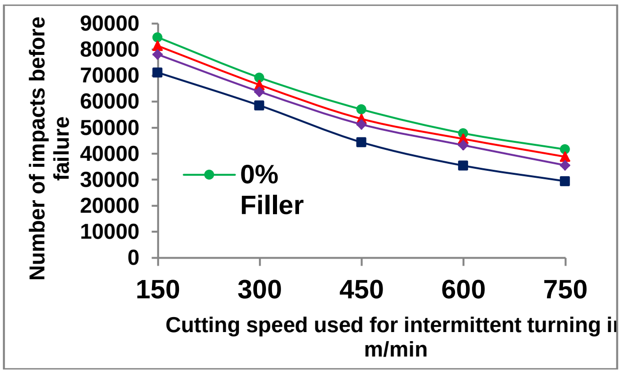

Figure 16: Influence of percent Filler & Feed/revolution on tool life when intermittent turning at 0.08mm/revolution feed.

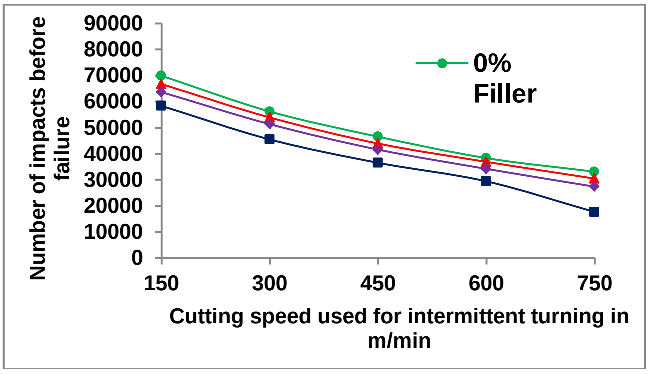

Figure 17: Influence of percent Filler & Feed/revolution on tool life when intermittent turning at 0.12mm/revolution feed.

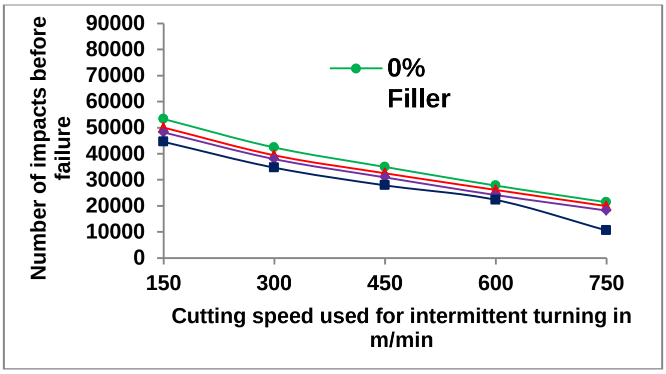

Figure 18: Influence of percent Filler & Feed/revolution on tool life when intermittent turning at 0.16mm/revolution feed.

From Figures 11 to 18 we can also conclude that the toughness of the CGGN120304 style inserts of grade K10 found higher when intermittent machining is carried out at lowest cutting speed and feed. However at all cutting speeds performance of the cutting tools found higher at lower feeds. The feed per revolution found significant, it is also observed that as increase in percent filler leads to the reduction in tool life. Hence while intermittent turning of the composite material containing varied percent fly ash, the failure of the cutting tool is mainly due to the increased filler content and higher feed per revolution.

7. CONCLUSION

1. Hardness of the composite material found higher with higher percent fly-ash.
2. Density of the composite material found lower with higher percent filler.
3. K10 grade carbide insert failed by micro chipping while machining composite containing 15% filler material.
4. Intermittent turning application of composite material containing 15% fly ash using K10 grade inserts beyond 600m/min cutting speed and 0.16 mm/revolution feed, resulted in rapid reduction in tool life.
5. Intermittent turning application of composite material, the performance of the tungsten carbide inserts of grade K10 and style CGGN120304 found better at lower cutting speeds and lower feed irrespective of percentage fly ash.

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