Influence of Varied Percent Filler on Surface Roughness, Built Up Edge and Built Up Layer Formation

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Abstract:- Using Al6061 grade aluminum alloy and its hybrid composites reinforced with Redmud and Silicon carbide (Hmmcs) using K10 grade uncoated and coated tungsten carbide inserts as cutting tools, this study aims to analyse, built up edge and built up layer formation, as well as the relationship between machining parameters and surface roughness. Early cutting tool failure occurs during machining of Al6061 and its Hmmcs, primarily because of built-up edge formation. The formation of built-up edges causes a change in the cutting tools shape, which affects the rake angle and leads to increased cutting forces. The tool overhang, machining parameters, tool signature, machine stiffness, and machining conditions decide the surface finish and lay formation on the machined component. With a fixed depth of cut, varied cutting speed and feeds were the parameters to machine Al6061 and its composite material, which contains 3% redmud and 6% silicon carbide reinforcement. Results of the experiments showed that the cutting speed and feed significantly affect the formation of built- up edge and built-up layers, which in turn caused poor surface texture when machining hybrid metal matrix composites containing red mud and silicon carbide as reinforcement with Al6061.

Keywords*:* Cutting speed, feed, Al6061, Hmmcs, surface roughness, BUE, and BUL, K10 grade carbide.

1. Literature Review

Although there is a limit for getting a suitable material having required mechanical properties such as hardness, wear resistance, strength, stiffness, toughness, and low density, Al6061 alloy is the most flexible engineering and construction material. When compared with traditional alloys, metal matrix composites excel in a number of key areas, including as specific modulus, damping capacity, and wear resistance. Fabrication of composites with various reinforcements has been the subject of research in recent years. Using a stir casting process and an aluminium alloy of grade LM6 reinforced with SiC particles, many have conducted research on the manufacture of mmcs. [1,2]. Prakash K et al. conducted research on varied permutations of stirrers: one with two blades, one with three blades, one with heat treatment, and one without heat treatment. [3]. After that, research on the significance of the stirrer blade angle demonstrated that a smaller blade angle results in a higher amount of particle reinforcement entering to the molten alloy [4]. The results of the experiments showed that the mechanical properties, such as hardness, strength, and wear resistance, were enhanced in the newly manufactured hybrid composites by adding reinforcements [5]. The authors emphasise the relevance of keeping the cutting tool's centre height during turning operations to achieve higher precision, longer tool life, and a higher level of finish [6]. Researchers discovered that Al2O3 coated inserts performed better than other coated inserts. Coatings on cutting tools unquestionably make the insert more wear resistant than an uncoated insert [7]. At low and medium velocities, the same cutting and ambient circumstances the PVD-coated insert had more mechanical wear than the CVD-coated insert [8]. When the speed was raised over 450 m/min, the authors noticed that the surface texture improved [9,10,11]. The researchers arrived to the conclusion that the incorporation of Gr. particles in the Hmmcs not only enhances the surface texture of the machined component but also boosts its machinability [12]. The surface roughness was measured higher when the turning process was performed with composite material that contained coarser particles [13]. During the machining experiments, BUE and BUL development were seen across all cutting tools. The wear mechanisms on the flank and nose mainly emerged at low feed rates [14]. Regardless of the machining setting, the generation of BUE decreased as the filler material's particle density increased [15, 16]. Cutting at lower rates did not result in the same rate of built-up edge formation (BUE) as cutting at higher speeds when machining composite material [17,18]. Using cutting fluids based on water during machining was reported to minimize BUE formation [19]. To machine Aluminum matrix composites, most effective

combinations were coated carbide insert, a high cutting velocity, a low feed, and sufficient cutting fluid [20].

While it is true that incorporating reinforcements into aluminium alloys might enhance the mechanical properties of an aluminium matrix composite, the machining challenges of such materials have received comparatively less attention. Nevertheless, the primary factor to be considered while machining Al6061 & Al6061-Red mud, SiC composite materials are the built-up edges formation on the cutting edge, since this alters the cutting tool's geometry and hence affects surface texture.

2. Experimental Details

2.1. Work Materials

Al6061 grade aluminium alloy was selected as matrix material for the experiments, with redmud and silicon carbide particles as reinforcements. Both the matrix material and the reinforcements' chemical compositions are detailed in Table 1, Table 2 and Table 3.

Table 1: Chemical Analysis details of Al6061 grade Aluminium alloy:

Chemical composition	Mg	Si	Fe	Cu	Cr	Al
% wt	0.98	0.66	0.31	0.22	0.11	Rest

Table 2: Chemical Analysis details of Redmud:

Chemical composition	Fe2O3	Al2O3	TiO2	SiO2	CaO
% wt	56.0	22.6	16.5	3.4	1.5

Table 3: Chemical Analysis details of Silicon Carbide:

Chemical composition	Si	C	Al	Fe	Ca
% wt	62.0	26.5	2.5	0.56	0.60

2.2. Hardness measurement of work material

Using a 10 mm diameter steel ball indenter and a standard load of 500 kgf, the Brinell hardness testing machine was used to measure the hardness of the matrix material and its composites. The matrix and its composite material's hardness were determined by measuring it at various locations on the specimen. Figure 1, shows the effect of reinforcement on the hardness of Al6061 grade aluminum alloy and hybrid metal matrix composites.

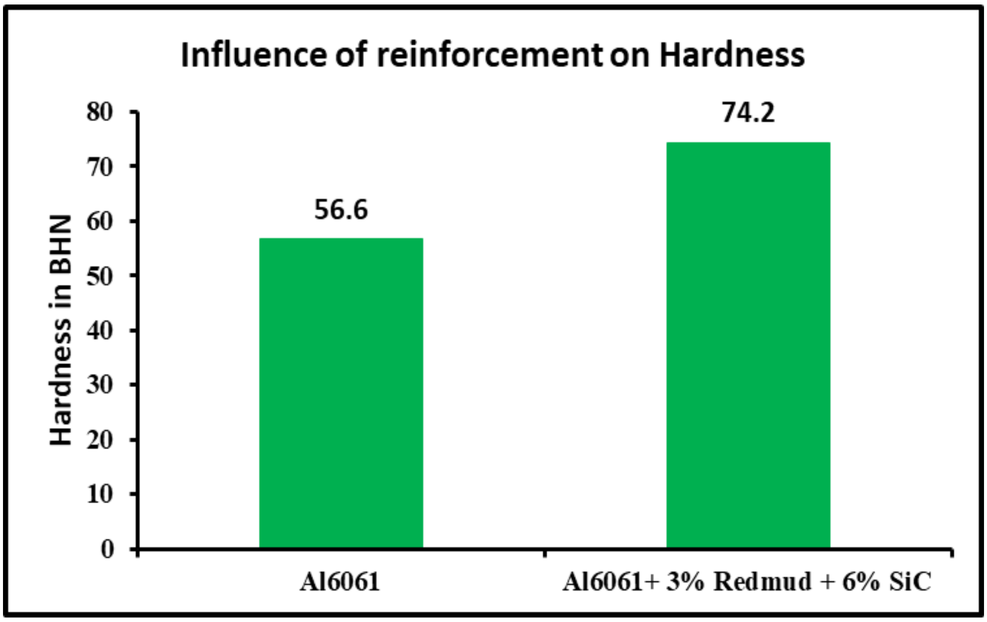


Figure 1: Effect of reinforcement on the hardness

2.3. Measurement of Density

The Archimedes immersion method was utilised to determine the matrix material's density as well as the density of its composites. Figure 2, displays the density of the composites that were measured through the use of experimental methods and also computed through the application of the Rule of mixtures as well.

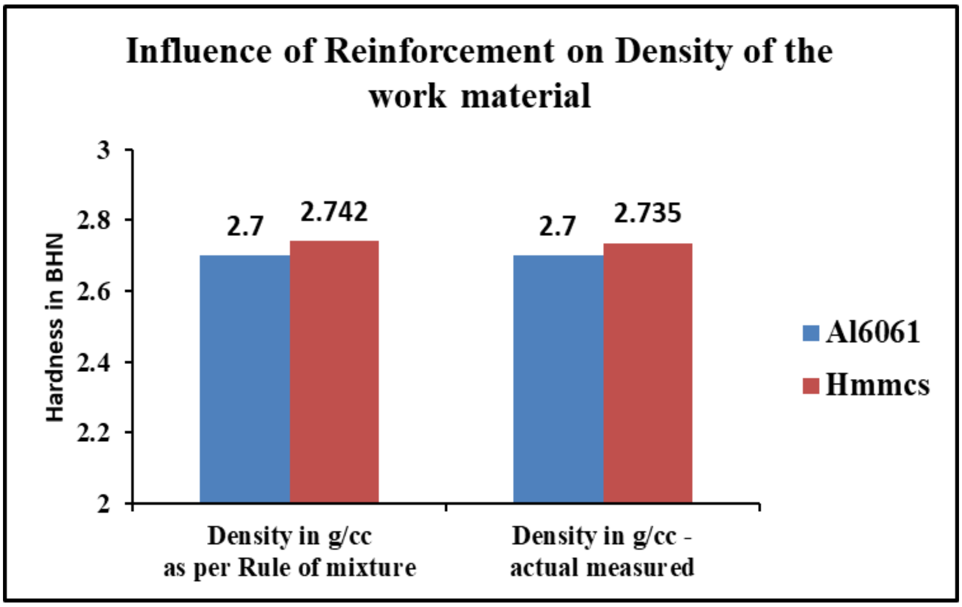


Figure 2: Influence of Reinforcement on Density of the work material

2.4. Microstructural details

Figures 3a and 3b illustrate a microphotograph of an aluminium alloy of grade Al6061 and its composite material, which contains 3% redmud and 6% silicon carbide reinforcement from a scanning electron microscope. The scanning electron microscopy (SEM) photographs of hybrid metal matrix composite material is shown to contain redmud and silicon carbide particles in it.

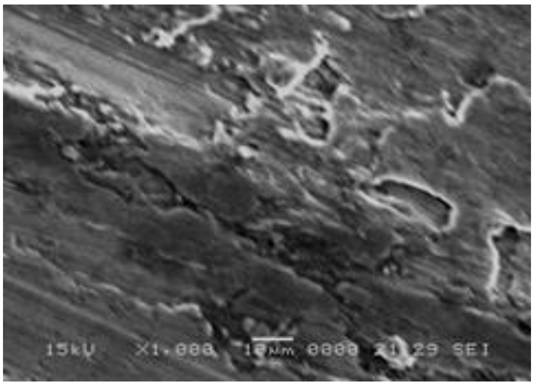


Figure 3a

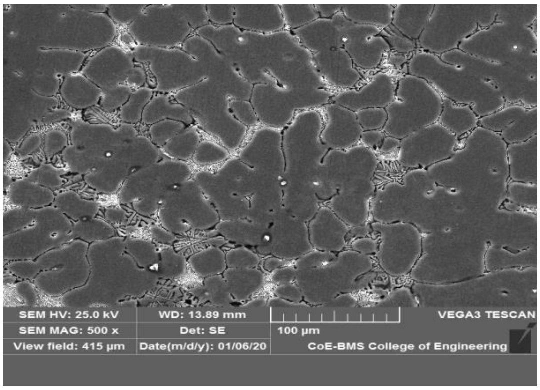


Figure 3b

Figure 3a: SEM images of Al6061 grade aluminium alloy,

Figure 3b: Hybrid composite containing 3% Redmud and 6% silicon carbide

The JEOL model JSM 6380 Scanning Electron Microscope was utilised in order to conduct a scanning electron microscopy (SEM) analysis on a composite material that contained 3% redmud and 6% silicon carbide particles. By analysing the machined components with a scanning electron microscope (SEM), it was determined that the distribution of silicon carbide and redmud particles throughout the composites was consistent. Through the use of the stir mixing method, the Redmud and silicon carbide particles have been distributed in a uniform manner, resulting in a significant reduction of porosity.

2.5. Machine tool & Cutting tool

2.5.1. Machine tool

The machine tool that was utilised for the turning trials was a JOBBER XL CNC lathe manufactured by ACE Designs. The JOBBER XL CNC lathe is shown in Figure 4, and the specification of the lathe is presented in Table 4.

Figure 4: JOBBER XL CNC Lathe used for the experiment

Table 4: Specifications of lathe used for the experiments

Maximum diameter can be machined	270 mm
Maximum length can be machined	400 mm
Spindle speed range	50 – 4000 RPM
Job clamping system	Hydraulic
Dimension of CNC lathe in mm	2200X1750X1750

2.5.2. Cutting tool

The Kennametal make standard positive rake angle throw away type turning tool holder was the cutting tool that was utilised for the experiment. During the course of the studies, both uncoated and coated tungsten carbide inserts of grade K10 were utilised. Details of tool holder used for experiment is Tabulated in Table 5.

Table 5: Details of tool holder used for experiment

Tool holder used	Al turning tool holder
Designation	SCLCL 2525 K12
Description	Throw away type tool holder
Insert style	CCGT120404-AL
Back rake angle	6º Positive
Side rake angle	6º Positive
End cutting edge angle	95º
Side cutting edge angle	95º
Lip angle	80°
Nose radius	0.4mm

2.5.3. Measurement of Surface roughness

Using an SJ201P style surface roughness tester, measurement of the surface roughness of machined components of Al6061 grade aluminium alloy and its composite containing 3% Red mud and 6% SiC particles as filler materials were carried out. Experiments were run using feed rates of 0.06mm/revolution, 0.12mm/revolution and 0.18mm/revolution, and a cutting speed of 300m/min to 500m/min in 50m/min increments. Throughout the experiments, the cutting depth and the tool holder overhang were held at constant values. ISO 3685 standards were followed to conduct the machining tests. The experiment was carried out using a dry machining technique. The cutting tools used were uncoated carbide inserts and PVD coated carbide inserts.

Table 6: Specifications of Surface roughness tester used for the experiments

Make	Mitutoyo
Model	SJ201P
Operating temperature	5ºC to 40ºC
Evaluation length	1.25mm to 12.5 mm
Measurement Range	350 microns
Measuring force	4mN
Traversing speed	0.25mm/s – 0.8 mm/s

Figure 5: Surface roughness tester used for the experiment

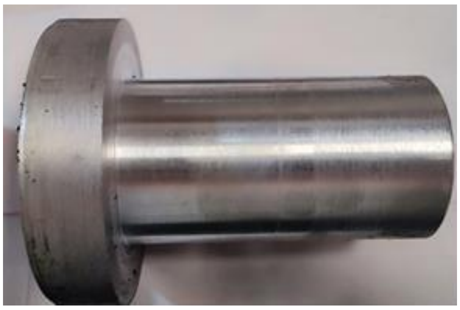


Figure 6a: Al6061 casting

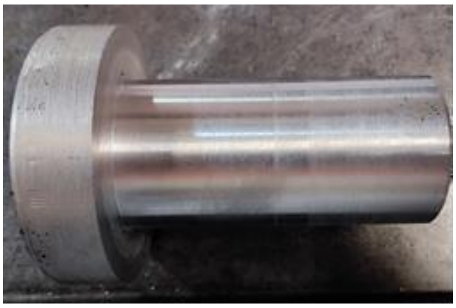


Figure 6b: Hmmcs casting

Figure 6: Surface roughness tested specimens

The experiment was carried out with different cutting speeds and feeds. The geometry of the cutting tools was kept constant during the experiment.

The cutting speeds used were in the range of 300m/min to 500m/min in steps of 50m/min. The feed rates used were 0.06mm/revolution, 0.12mm/revolution, 0.18mm/revolution, and the depth of cut kept constant as 1.5 mm. The specifications of surface roughness tester are tabulated in Table 6. Figure 5, shows measurement of surface roughness, using SJ201P, the portable surface roughness tester. The surface roughness tested specimens at machining parameters of cutting speed of 500 m/min and a feed of 0.12mm/rev for Al6061 grade aluminium alloy and its composite containing 3% Red mud and 6% SiC particles as filler materials is presented in Figure 6, Figure 6a, shows Al6061 machined component and Figure 6b, presents Hmmcs machined component.

3. Result and Discussion

3.1. Analysis of Surface roughness

3.1.1. Analysis of Surface roughness - Al6061 castings

The surface roughness measured on the work surface after performing continuous turning operation of grade Al6061 aluminum alloy castings are tabulated in the Table 7 and Table 8, using uncoated and coated inserts respectively.

Table 7: Surface roughness values on Al6061 castings using uncoated insert

Vc, m/min	Feed, mm / revolution		
	0.06	0.12	0.18
300	0.896	1.348	1.981
350	0.742	1.119	1.736
400	0.572	0.942	1.488
450	0.516	0.801	1.364
500	0.464	0.822	1.433

Table 8: Surface roughness values on Al6061 castings using coated insert

Vc, m/min	Feed, mm / revolution		
	0.06	0.12	0.18
300	0.624	0.984	1.558
350	0.562	0.952	1.354
400	0.492	0.861	1.236
450	0.428	0.797	1.154
500	0.348	0.755	0.966

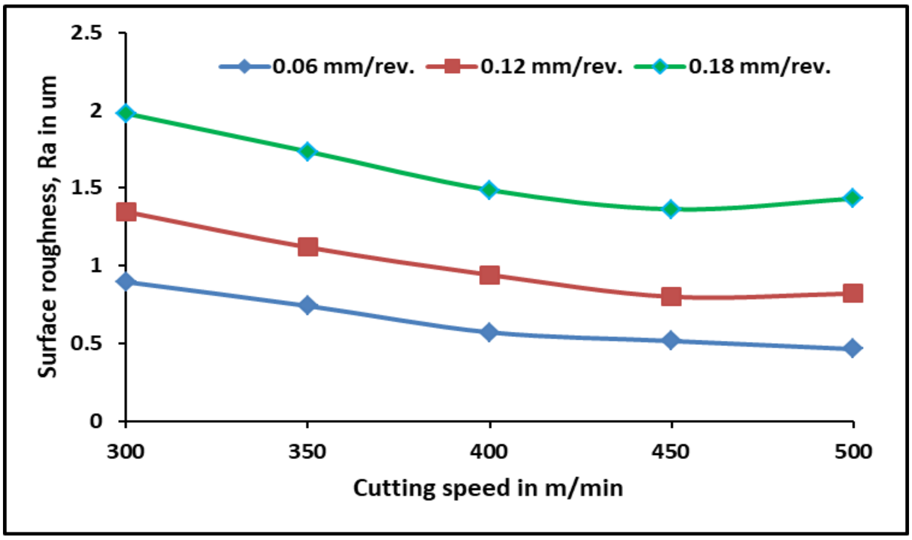


Figure 7: Effect of cutting speed on surface roughness on Al6061 castings - uncoated.

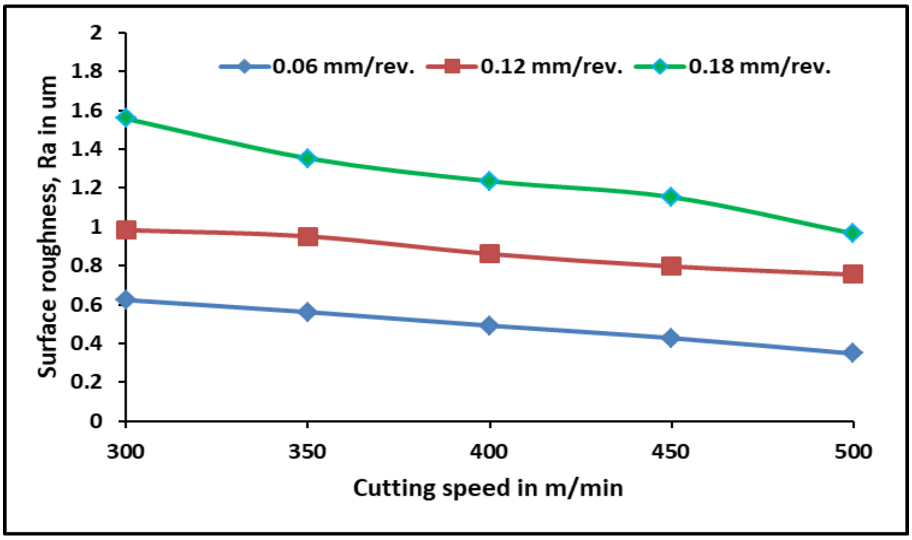


Figure 8: Effect of cutting speed on surface roughness on Al6061 castings - coated

Figure 7 and Figure 8 shows the influence of cutting speed and feed on surface roughness when uncoated and coated inserts were used for machining of Al6061 castings material. As the cutting speed increases, a decrease in the surface roughness measured at 0.06, 0.12 and 0.18 mm/revolution feed.

3.1.2. Analysis of Surface roughness - Hmmcs castings

Table 9: Surface roughness on Hmmcs turned work piece using uncoated insert

Vc, m/min	Feed, mm / revolution		
	0.06	0.12	0.18
300	0.914	1.432	1.963
350	0.764	1.133	1.711
400	0.568	0.963	1.452
450	0.537	0.812	1.344
500	0.471	0.834	1.337

Table 10: Surface roughness on Hmmcs turned work piece using coated insert

Vc, m/min	Feed, mm / revolution		
	0.06	0.12	0.18
300	0.761	1.126	1.663
350	0.656	0.987	1.442
400	0.551	0.854	1.279
450	0.477	0.759	1.157
500	0.416	0.736	1.133

The surface roughness measured on the Hmmcs material containing 3% Redmud and 6% SiC particles after continuous turning was measured using SJ201P portable surface

roughness testor, the average of three readings are tabulated in the Table 9 to Table 10, using uncoated and coated inserts respectively.

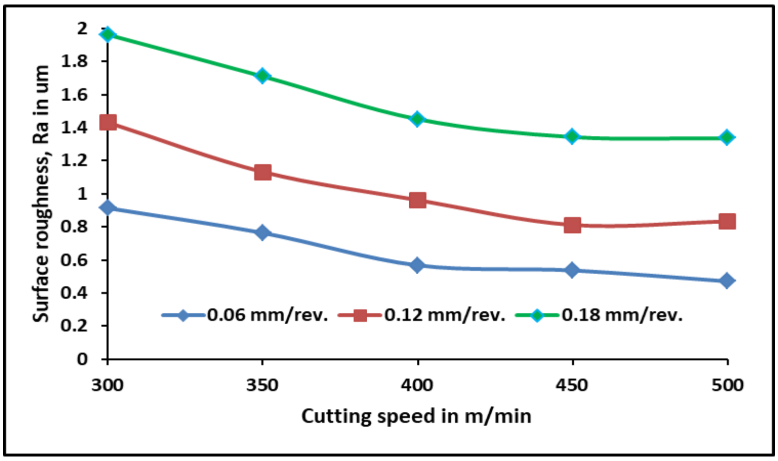


Figure 9: Effect of cutting speed on surface roughness on Hmmcs castings-uncoated inserts

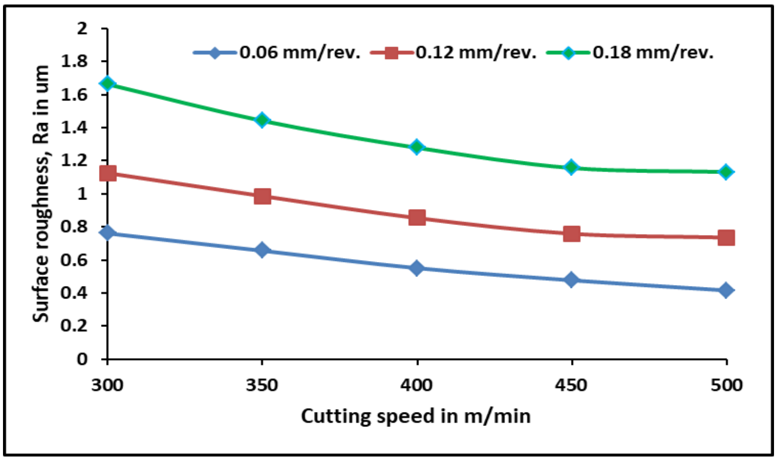


Figure 10: Effect of cutting speed on surface roughness on Hmmcs castings- coated inserts.

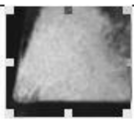
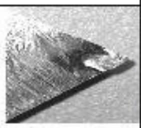
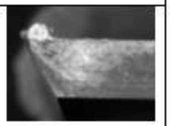
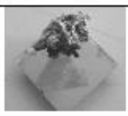
Using uncoated and coated carbide inserts to machine Hmmcs material reinforced with 3% Redmud and 6% SiC particles, Figure 9 and Figure 10 compares the impact of cutting speed and feed on surface roughness. Surface roughness was found to reduce between 0.06 and 0.12 mm/rev as cutting speed was increased. Surface roughness was shown to be decreased when cutting speeds were increased, however at 0.18 mm/revolution feed the surface roughness found high irrespective of cutting speed and type of inserts.

3.1.3. Analysis of Built up edge formation

Extensive study on machining aluminum alloy and Hmmcs were carried out at varied machining parameters. During machining aluminum alloy and its composites in depth study on sticking of material to the cutting tool and its impact on the geometry of the cutting tool

was carried out. Adhering of the work material to the cutting edge is termed as built up edge. From the study different types of built up edge and built up layer formed on the cutting tool was tabulated. Built up edge and built up layer formation on the cutting edges were recorded and rated as shown in Table 11.

Table 11: Rating for BUE and BUL formation on the cutting edges

Rating for BUE	1	2	3	4	5
BUE image					
	Built up layer (BUL)	BUE formation on C E	BUE – 2-3mm on Rake face	BUE 5-6 mm on Rake face	BUE 5-6 mm on Rake bumpy BUE
Rating for BUE	10	9	8	7	6
BUE image					
	High BUE at rake and nose	High BUE at nose	BUE partly on rake and nose	Bumpy BUE on rake face and CE	BUE 5-6 mm on Rake & chip weld

Grading of built up edge and built up layer formed on the edge of the cutting tool while machining aluminum alloy and Hmmcs at varied cutting speed and feed according to the Table 11, is tabulated in Table 12 to Table 14. The rate of BUE formation during continuous turning is tabulated in Table 12, Table 13 and Table 14 at 0.06mm/ revolution, 0.12mm/ revolution and 0.18mm/revolution feed respectively

Table 12: Grading of BUE and BUL observed at feed of 0.06 mm/rev.

Cutting speed in m/min	Al6061	Hmmcs
300	10	10
350	8	7
400	7	5
450	6	4
500	4	4

Table 13: Grading of BUE and BUL observed at feed of 0.12 mm/rev.

Cutting speed, m/min	Al6061	Hmmcs
300	10	10
350	8	7
400	6	4
450	4	3
500	4	3

Table 14: Grading of BUE and BUL observed at feed of 0.18mm/rev.

Cutting speed, m/min	Al6061	Hmmcs
300	8	8
350	8	7
400	5	4
450	4	3
500	4	2

The Built up layer of type 1 is observed at 500 m/min cutting velocity. The type 1 Built up layer was observed while machining Aluminium alloy reinforced with 3% Red mud and 6% Silicon Carbide composites material when tested at 500 m/min and 0.18 mm/revolution feed.

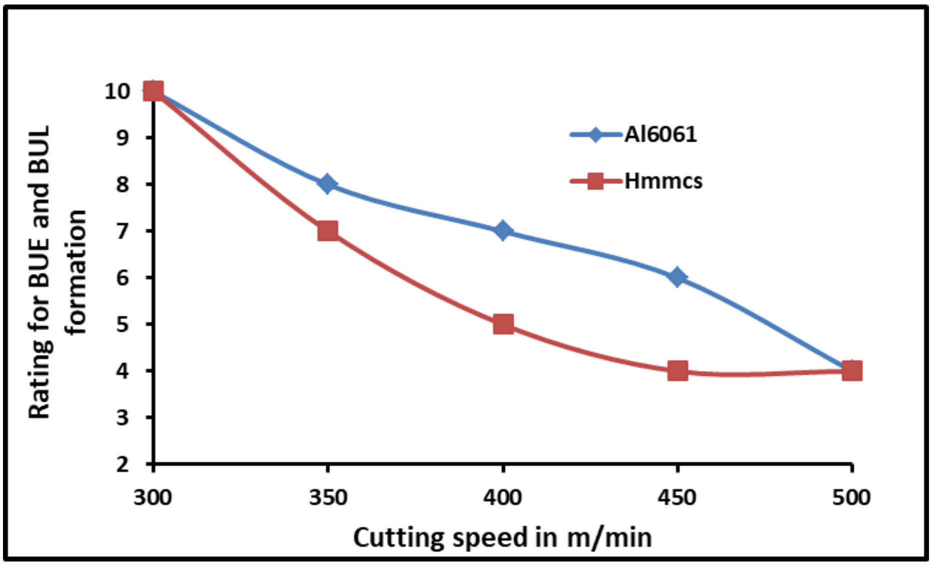


Figure 11: Influence of cutting speed on BUE formation at 0.06 mm/revolution

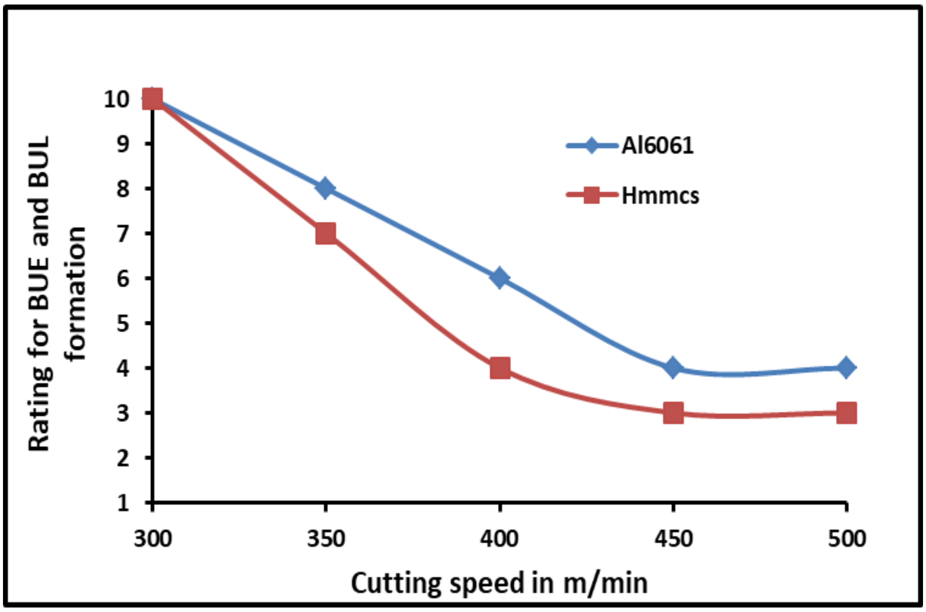


Figure 12: Influence of cutting speed on BUE formation at 0.12 mm/revolution

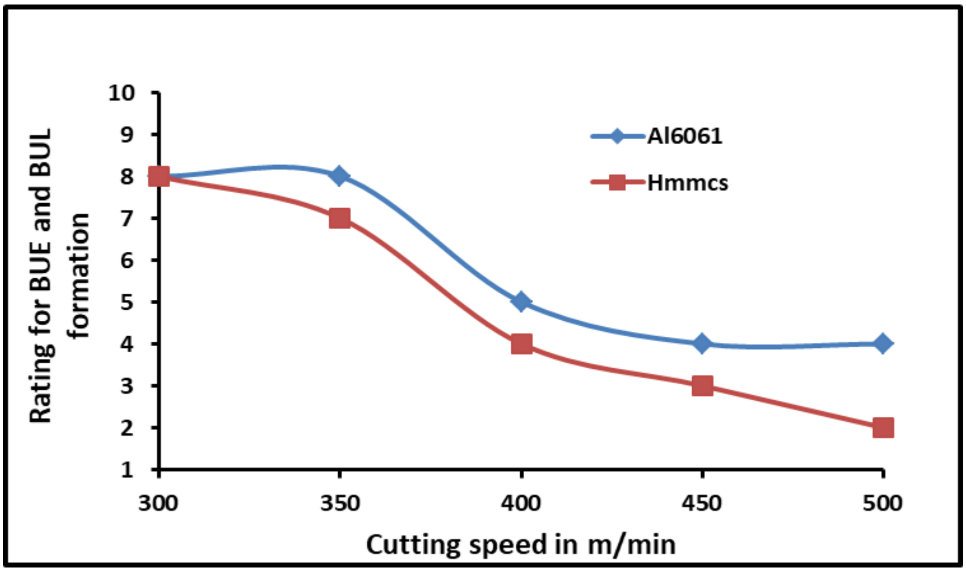


Figure 13: Influence of cutting speed on BUE formation at 018 mm/revolution

Figure 11, Figure 12 and Figure 13 shows the influence of cutting speed and feed on built up edge formation while machining Aluminium alloy reinforced with 3% Red mud and 6% Silicon Carbide composites materials using Carbide K10 grade insert. At lower cutting speeds and lower feed the built up edge formation found higher with all materials. Formation of Built up edge found high while machining at 300m/min at all feeds irrespective of the work materials. As the cutting speed was increased the rate of built up edge formation reduced due to higher chip velocity. However, built up edge formation found high with Aluminium alloy when compared to Hmmcs reinforced with 3% Red mud and 6% Silicon Carbide, at all cutting speeds for identical machining conditions. At higher cutting speeds Aluminium alloy reinforced with 3% Red mud and 6% Silicon Carbide composite material using Carbide K10 grade insert, the built up edge formation was negligible.

4. Conclusion

The study exhibits the successful fabrication of Aluminium Hmmcs that follow the liquid metallurgical technology and incorporate 3% Redmud and 6% SiC particles as reinforcements. The examination performed with a SEM provides insight into the morphological characteristics of the Red mud and Silicon carbide particles found in Hmmcs. Good retention of Red mud and Silicon carbide particles and even distribution of the reinforcements were observed in the SEM microphotograph of Hmmcs.

Because of the inclusion of Al2O3, Fe2O4, Si, and C particles in the Reinforcement, the hardness of the Hmmcs material with a composition of Al6061+ 3% Redmud and 6% SiC particles measured the higher. The measured densities and the theoretical values are getting very close to being in agreement with one another, and hence the method for the production of the composite material was reliable.

When the cutting speed was increased, the surface roughness of both the Al6061 grade of aluminium alloy and its hybrid composite, which contained 3% Redmud and 6% SiC particles, was observed to reduce. Regardless of the work material, an increase in the feed rate produced a higher level of surface roughness in the finished work piece.

The failure of the cutting tools that occurred during the machining of aluminium Hmmcs was mostly caused by micro chipping and BUE development. The built-up edge creation fundamentally alters the geometry of the cutting tool, which in turn alters the rake angle of the cutting tool and results in increased cutting forces. Additionally, the cutting tool loses its keen cutting edge, which leads to a dull cutting edge and a degradation of surface finish. The flow of high-velocity chips across the surface of the cutting tip, which occurs at a

higher cutting speed, is what causes the built-up layer to form. Because of the increased cutting speed, the rate of BUE production decreased, which can be attributed to the greater chip velocity. During the turning of Al6061 and Aluminium Hmmcs castings at slower cutting rates, BUE development was seen on the cutting tool. When turning Hmmcs material, the BUE and BUL formation was almost nonexistent or least when the cutting speed was set to 500m/min and a coated carbide insert was used.

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