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Study on Progressive Wear of Machine Reamer while Reaming Al6061/SiC Composite

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ABSTRACT

The present study deals with reaming of Al6061/SiC metal matrix composite. For the fabrication of the composite, stir casting technique was used. In the castings, 5 and 10 weight percentages of Silicon Carbide (SiC) 23µm size was used as the reinforcing material. The tensile and hardness tests carried out on the specimen indicated that it increased with the addition of SiC. The images from scanning electron microscope showed the fair distribution of reinforcement. After drilling 7.8 mm diameter holes, reaming was performed with 8mm diameter straight fluted HSS reamer under dry condition at cutting speeds of 18 and 24 m/min and feed rates of 0.2 and 0.4 mm/rev. Torque required for reaming was measured using 4 component Drill tool Kistler dynamometer 9272A. The estimation of progressive wear of the reamer was undertaken using a profile projector. With the introduction of SiC as reinforcement, the wear rate of the reamer increased as the reinforcement was highly abrasive in nature. The performance of HSS machine reamer was evaluated in terms of reaming torque, tool wear and surface roughness of the hole.

Keywords: Al6061/SiC, flank wear, machine reamer, metal matrix composite (MMC), stir casting

INTRODUCTION

The aluminium based matrix composites have emerged as materials for several applications in aerospace, automobile, defense and other sectors due to their high specific strength and stiffness, superior wear resistance as compared to the alloy (Kumar et al., 2011). Stir casting is one of the most widely used technique for processing of aluminium based metal matrix composite. Stir casting involves melting of the matrix

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material, followed by introducing reinforcement material into the melt, obtaining a suitable dispersion through stirring (Soltani et al., 2015). The composites are known as difficult to machine materials because of hardness and abrasive nature of reinforcement material (Srinivasan et al., 2012). The presence of harder and well bonded SiC particles in aluminium matrix that impedes the movement of dislocations increases the hardness. (Rahmana & Al Rashed, 2014). Abrasion is the major mechanism causing tool wear when machining metal matrix composite (MMC) reinforced with abrasive particles such as SiC (Chambers & Stephens, 1991). Higher weight percentage of SiC reinforcement needs higher cutting forces during machining and produced a higher surface roughness (Behera et al., 2011). The review of literature has revealed that majority of research work on machining of Al-SiC metal matrix composite has been carried out on turning and drilling. Reaming is one such important machining operation used to enhance the quality of drilled holes. The dimensional stability (diameter, roundness and cylindricity) and surface roughness of reamed holes in aluminum silicon SAE322 alloy using K10 cemented carbide welded blade reamers and found that accuracy of hole diameter can be increased by increasing the feed rate (Bezerra et al., 2001). Melo et al. (2019) concluded that feed rate was the most influential factor affecting the torque and cutting speed was the main factor influencing the quality of the reamed hole after conducting reaming study on AISI P20 hardened steel. While reaming C355 aluminium alloy by Rattanakit et al. (2015), smearing of Al material and BUE was prevalent on the flank faces of the uncoated WC reamers at low (32 m/min) and high (96 m/min) cutting speeds. However, this was not apparent with the brazed PCD or the CVD diamond 229 coated WC reamers, regardless of machining conditions (Rattanakit et al., 2015). While conducting reaming study on Al–Si–Mg alloy (6351) with different copper contents using HSS reamer, it was found that torque and thrust force were influenced more by feed when compared with thrust (Gonçalves et al., 2018). During reaming on ZL102 aluminium cast alloys by PCD reamer, the thrust was found to decrease significantly as a result of the growing cutting speed by fixing the cutting feed, whereas there was an increase in thrust with increasing feed in the same cutting speed (Wang et al., 2013). The experimental results on reaming AlSi12 alloys with PCD reamer are verified as a stable process in terms of the quality of the holes produced and the main surface anomalies are re-deposited work material (chip) onto already machined surface, surface grooves and notch, feed marks, surface shrinkage cavities and porosities, metal debris, and micro-pits (Yan et al., 2013). The study of influence of process errors and multi blade reamer geometry on the hole quality while reaming valve guides made of sintered steel alloys revealed that enlarged contact zone between the secondary cutting edge and the work piece material would lead to improved straightness tolerances (Schutzer et al., 2014). It is essential to create more knowledge about reaming on Al6061/SiC metal matrix composite. The aim of this study is to obtain the influence of varying percentage of SiC present in the matrix, cutting speed and feed on wear of reamer.

MATERIALS AND METHODS

Fabrication of MMC Specimens

The matrix material chosen for the present study was Al6061 alloy and was acquired from HINDALCO Industries Limited, India. The chemical composition of Al6061 compound, as given by the provider is given in Table 1. Silicon carbide particles of average size 23 microns was used as reinforcement material. Silicon carbide has properties such as high hardness and strength, chemical and thermal stability, high melting point, oxidation resistance and high erosion resistance. The schematic diagram of the setup used for fabrication of metal matrix composite is shown in Figure 1. Al6061 rods melted at a temperature of 800^{o}C in an electric furnace. Preheating of silicon carbide particles was done at 400^{o}C for an hour to remove the moisture and gases from the surface of the particulates. To increase the wettability of the silicon carbide particles in the matrix material, 1% by weight magnesium ribbon wA added to the molten metal at 750 ^{o}C (Hashim et al., 2001). Stirring of molten metal was done for 10 minutes during which SiC particles were added. The molten metal was degassed at a temperature of 750^{o}C using nitrogen gas. Degassing dispenses a variety of impurities which otherwise could act as deterrent in the creation of good castings. The solubility of hydrogen in liquid aluminum increases with temperature. Material must reject the hydrogen during solidification or else the quality of the composite is affected due to porosity.

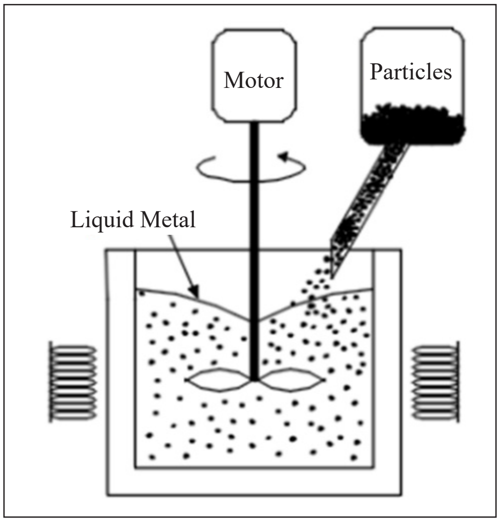


Figure 1. Schematic diagram of stir casting setup

Table 1
Chemical Composition of Al6061

Contents	Al	Si	Fe	Mn	Mg	Cu	Ti	Cr
Weight %	97.54	0.77	0.22	0.06	0.92	0.27	0.02	0.07

Characterization of Material

Vickers Hardness and Tensile Test. Standard specimen for hardness measurement were prepared after polishing with different grades of abrasive paper. Hardness test was carried out using Macro Vickers Hardness Tester (M/s Fuel Instruments, India). Three samples and five readings on each sample were taken for averaging the hardness value. The tensile test specimens were prepared by machining casting obtained in pin molds in CNC turning center, according to ASTM E8/E8M-11 standard, as shown in Figures 2 and 3. The tensile test samples were prepared. The tensile test was performed on an electronic tensometer (M/s Khudal Instruments, India). Three samples were taken for each weight percentage of SiC for averaging the tensile test value.

Figure 2. Casting used for Tensile test specimen

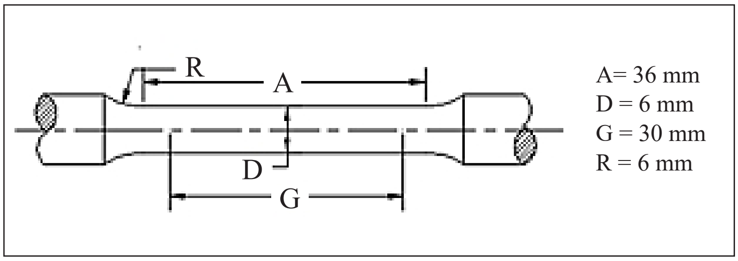


Figure 3. Tensile test specimen

Micro Structure. The microstructure affects the performance of the composite. The microstructure, reinforcement particle size, shape and distribution in the alloy influence the physical properties of the composite. Microstructure study of the composite was done using Zeiss EVO 18 Special Edition Scanning Electron Microscope.

Experimentation

The cast Al6061/SiC specimens were machined to billets of size 120 × 45 × 10 mm. The holes for reaming were prepared using carbide drills of diameter 7.8 mm. These holes were reamed in the specimen by high speed steel (HSS) straight four fluted machine reamer shown in Figure 4. The specification of the reamer used for experimentation is given in Table 2. For measuring torque produced during the reaming operation, 4 component drill tool dynamometer 9272A (Kistler make) was used. Reaming experiments were conducted on Computer Numerical control (CNC) vertical machining centre (M/s Ace Manufacturing Systems, Bangalore, India) at feed rates of 0.2 and 0.4 mm/rev. with speeds 18 and 24

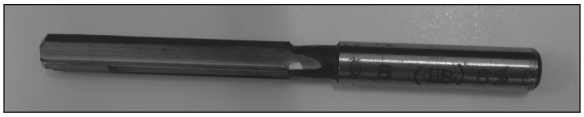


Figure 4. HSS straight, four fluted 8mm diameter machine reamer

m/min. The material behavior of Al6061/SiC composite was expected to be in between aluminium alloy and cast iron (CMTI, 1987). The cutting speed for the reaming operation was selected between the reaming speed for cast iron (14-18 m/min) and aluminium (24-28 m/min). The feed for the reaming operation was selected between the reaming feed rate for cast iron (0.1-0.2 mm/rev.) and aluminium (0.4-0.6 mm/rev.). The actual values of cutting parameters used for reaming is shown in Table 2. One hundred and four holes were reamed on specimens each with 5 and 10 weight percentage of SiC, 18 and 24 m/min cutting speed and 0.2 and 0.4 mm/rev. feed rate. Figure 5 shows the arrangement used for conducting reaming experiment. The torque during reaming was measured at regular intervals. The Dynoware software installed on a computer connected to the Kistler 9272A dynamometer through A/D converter and 5070A10100 charge amplifier provided the variation of torque with respect to time, during reaming. The schematic of data flow in the experimental setup is shown Figure 6. A sample specimen with reamed holes is shown in the Figure 7.

Table 2
Cutting parameters used while reaming

Cutting Parameter	Value
Cutting Speed (m/min)	18, 24
Feed (mm/rev)	0.2, 0.4

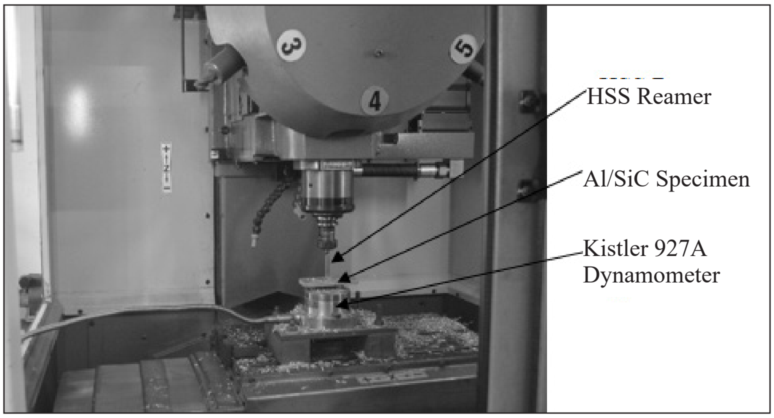


Figure 5. Arrangement used for conducting reaming experiments on composites

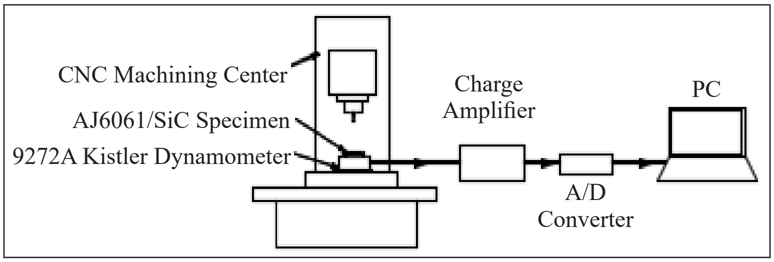


Figure 6. Schematic of data flow in the experimental setup

The specification of reamer used in the experiment is given in the Table 3.

Table 3
Reamer Specification

Material	M42 HSS
No. of flutes	4
Shank	Cylindrical
Helix angle	0˚
Chamfer	2×45˚
Rake Angle	8˚
Primary Clearance Angle	6˚
Secondary Clearance Angle	15˚
Overall length	92 mm
Flute length	47 mm
Cutting diameter	8 mm

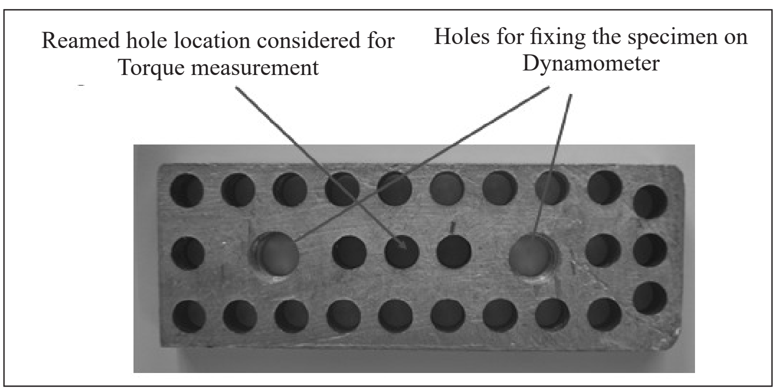


Figure 7. Al6061/SiC specimens with reamed holes

Measurement of Flank Wear

The wear pattern of the machine reamer was measured using a Profile Projector (METZER, India make) with micrometer accuracy of 0.01 mm and magnification of 20× on the display. The display of the reamer was located on the screen by adjusting the micrometer of the projector such that the axis of the tool coincided with the cross hair in the projector screen. The reading in the micrometer in this position indicated the location of the axis of the reamer. The outer contour along the axial direction of the reamer was traced on the projector screen to set the reference for subsequent measurements as shown in Figure 8. The outer contour of the tool in the display after reaming 26 holes was made to coincide with the reference previously set in the projector. The difference between previous and present micrometer readings was calculated as the reduction in height of the tooth (h) as shown in Figure 9. The procedure was repeated to get the progressive reduction in height of the tooth after reaming 52, 78 and 104 holes. The progressive reduction in height of the tooth was marked as a point on rake face in each case. The horizontal lines were drawn from these points to intersect the flank surface. The progressive flank wear (h_f) was estimated by measuring the length of each line. The procedure adapted is shown in Figure 10.

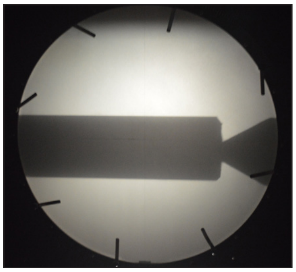


Figure 8. Display of reamer profile in the Profile Projector

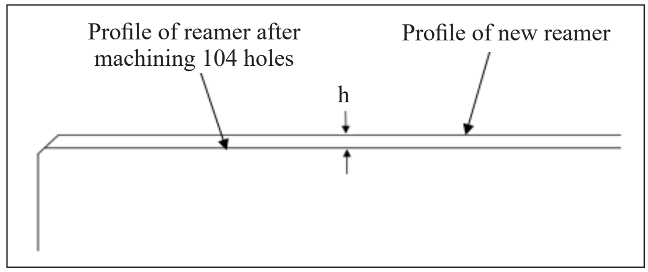


Figure 9. Profile of the reamer tooth

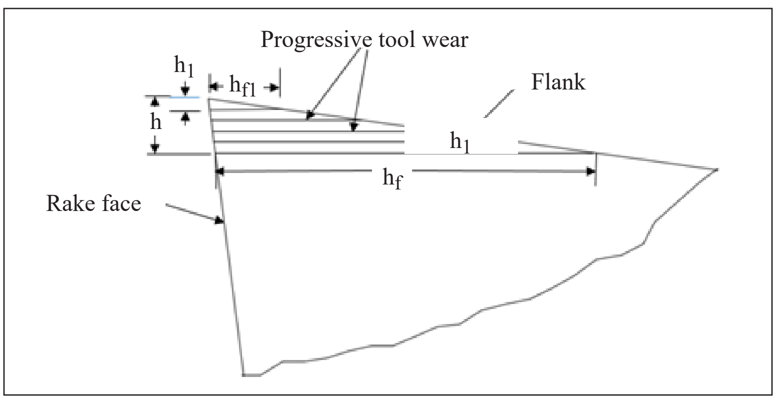


Figure 10. Flank Wear (h_f) derived from reduction in height of the tooth (h)

Measurement of Surface Roughness

Surface roughness of the reamed holes (hole no. 1,26,52,78 and 104) for all composites (5 weight. %, and 10 weight. % of SiC) was measured using Surtronic 3+ surface roughness measuring instrument. The sampling length for each measurement of surface roughness was 0.25mm. The surface roughness of each hole was estimated as the average of three readings.

RESULTS AND DISCUSSIONS

Characterization of Al/SiC Composite

Table 4 shows the hardness values of metal matrix composites at different percentages of SiC. The hardness value increased with increase in weight percentage of SiC. This trend is conforming with the same reported earlier (Su et al., 2010). The increase in hardness could be attributed to the influence of hard SiC particle acting as barriers to the movement of dislocations within the Al6061 matrix (Kannan & Kishawy, 2008).

Table 4
Vickers micro hardness test results

Material	Vickers Hardness Number (VHN)
Al + 5 weight. % SiC	81.4
Al + 10 weight. % SiC	98.5

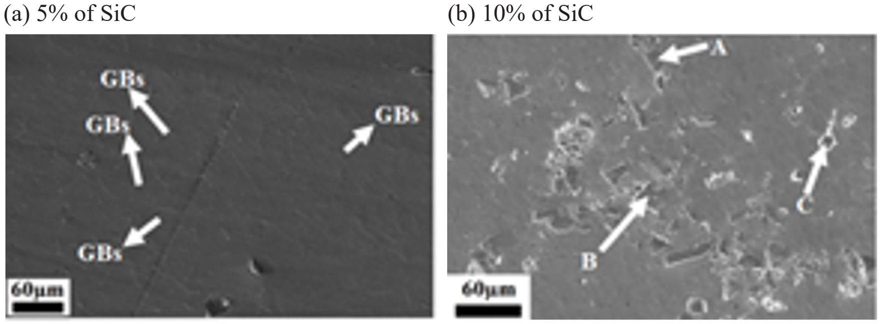
From Table 5, it is observed that the ultimate tensile strength (UTS) measured using a tensometer increased with the addition of SiC. This increase in UTS may be due to the increased presence of SiC particles acting as barriers to dislocation in microstructure (Kannan & Kishawy, 2008)

Table 5
Tensile test results

Material	Average Ultimate Tensile Strength (MPa)
Al + 5 weight. % SiC	118.27
Al + 10 weight. % SiC	146.4

The literature (Wenner & Holmestad, 2016) available reports recipe for sample preparation for studying distribution of precipitates, inclusions under electron microscopy. An attempt was made to bring out the precipitate details in the samples under investigation. Using energy dispersive spectroscopy (EDS), the composition for the precipitate-like-structures were brought out, showing significant presence of silicon and carbon which could be possible signatures of silicon carbides or other complexes. As in Figure 11, the micro features are possibly SiC.

(a) 5% of SiC (b) 10% of SiC



A			B			C		
Element	Wt%	At%	Element	Wt%	At%	Element	Wt%	At%
C	51.40	71.21		40.69	61.61		42.75	63.59
Si	48.60	28.79		59.31	28.29		57.25	36.41

Figure 11. Composition of Al/SiC composite

The addition of silicon carbide introduced subtle differences in microstructures which are brought out in the Figure 12. These differences are largely seen in terms of grain size refinement, nature of grain boundary, formation of dendritic structures etc. With addition of 5% SiC, the grain size is relatively larger with serrated boundaries as apparent in the microstructures. With 10% addition of SiC, fine dendritic structures are seen to be nucleating at multiple sites within the microstructure. Presence of dendritic structures introduced strengthening due to fine grain distribution leading to ‘grain refinement strengthening’.

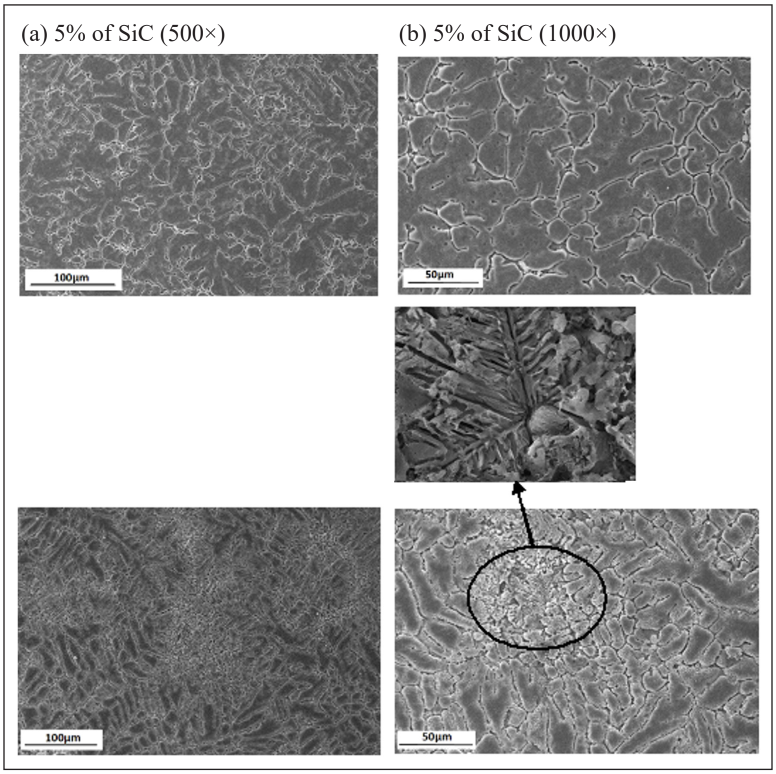


Figure 12. Microstructure of Al/SiC composite

Flank Wear

The torque required for reaming Al/SiC MMC was measured at regular intervals. This was done for indirect assessment of the progressive wear of reaming tool. The typical plot of torque captured in during reaming is shown in Figure 13. It was expected that the torque had to increase gradually from zero to its peak value as the chamfer section of the reaming tool progressively engaged with the hole for finishing. It got stabilized when the chamfer section fully engaged with the hole. The torque decreased gradually from the peak value to become zero when the chamfer section of the tool progressively emerged out and gets disengaged from the hole. The qualitative trend shown in the Figure 13 fully confirms with the expected pattern of variation of torque during reaming.

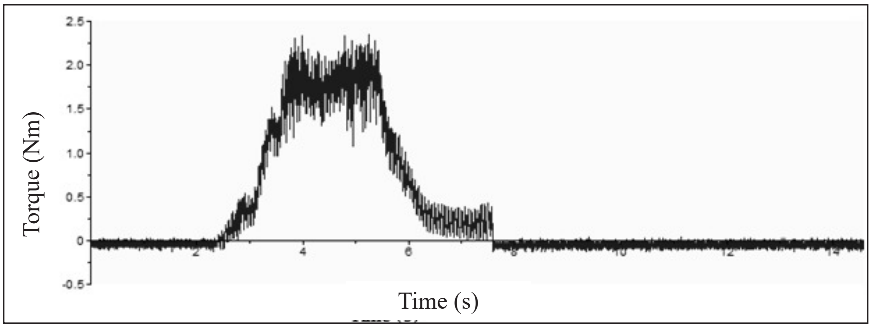


Figure 13. Sample plot for torque variation during reaming

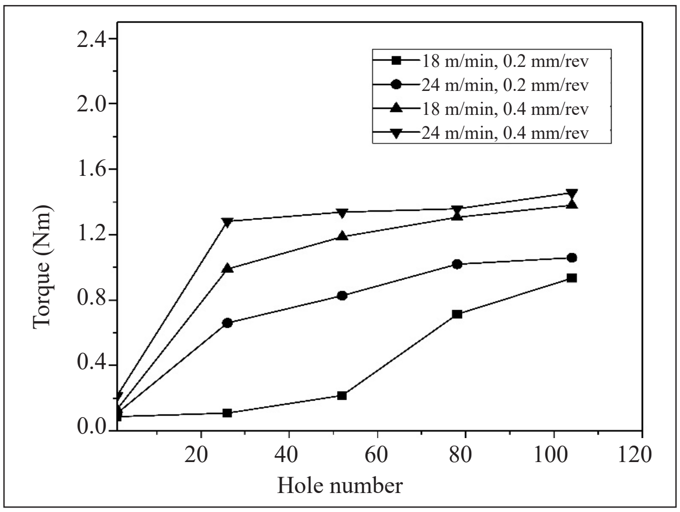


Figure 14. Torque while machining 1, 26, 52 and 78 and 104 holes for 5 weight % SiC at various speeds and feeds

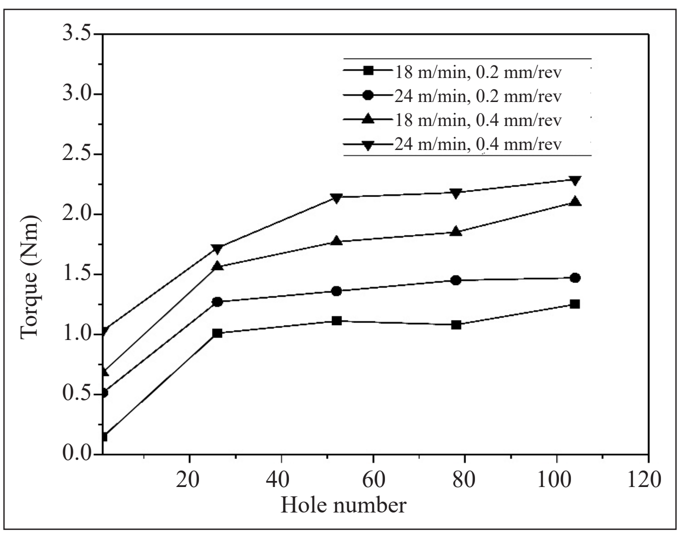


Figure 15. Torque while machining 1, 26, 52 and 78 and 104 holes for 10 weight % SiC at various speeds and feeds

It is observed from Figures 14 and 15 that increase in weight % of SiC, speed and feed rate increased the torque required for reaming. While reaming the first hole in the specimen with 5 weight % SiC at 18 m/min speed and 0.2 mm/rev. feed, the torque required is 0.087 Nm while it increased to 0.108 Nm at the speed of 24m/min and at same feed rate. While reaming the first hole in the same specimen at 24 m/min speed and 0.2 mm/rev. feed, the torque required was 0.108 Nm while it increased to 0.214 Nm at the feed of 0.4mm/rev. and at same speed.

While reaming 104th hole in the specimen with 5 weight % SiC at 18 m/min speed and 0.2 mm/rev. feed, the torque required was 0.934 Nm while it increased to 0.1059 Nm at the speed of 24 m/min at same feed rate. While reaming the 104^{th} hole in the same specimen at 24 m/min speed and 0.2 mm/rev. feed, the torque required was 1.059 Nm while it increased to 1.456 Nm at the feed of 0.4 mm/rev. and at same speed.

During machining, increase in feed rate enhances the chip load while increase in speed reduces the chip load. Influence of feed rate on the torque required for machining is higher as both material removal rate (MRR) and chip load increase with feed rate. However, influence of speed on the torque required for machining is lower as with the speed, MRR increases but the chip load decreases. From the results, it is evident that for a given speed, increase in feed has greater influence on torque required for reaming when compared with the influence of increase of speed for a given feed. It is because while reaming, the increase of feed proportionately increases the chip load on the cutting edges as the chip load on cutting edge is a direct function of feed. Whereas, the increase of cutting speed does not increase the chip load on cutting edges in the same proportion. A similar trend was observed while reaming the holes in the composite with 10 weight % of SiC. The only difference was that the torque levels in 10 weight % of SiC composite were higher when compared with the same in 5 weight % of SiC at all combinations of speed and feed. Further, it was also noticed that for all combinations of speed and feed, there was progressive increase in torque with increase in number of holes reamed. This is possibly because of the damage due to progressive wear undergone by the reaming tool.

It is observed from Figure 16 that increase in weight % of SiC, speed and feed rate increased the progressive wear of the reamer. After reaming the 26^{th} hole in the specimen with 5 weight % SiC at 18 m/min speed and 0.2 mm/rev. feed, the progressive wear was 0.0046 mm while it increased to 0.0067 mm at the speed of 24m/min and at same feed rate. After reaming the 26th hole in the same specimen at 24 m/min speed and 0.2 mm/rev. feed, the progressive wear was 0.0067 mm while it increased to 0.014 mm at the feed of 0.4mm/rev. at same speed. After reaming 104^{th} hole in the specimen with 5 weight % SiC at 18 m/min speed and 0.2mm/rev. feed, the progressive wear was 0.046 mm while it increased to 0.051 mm at the speed of 24 m/min at same feed rate. After reaming the 104th hole in the same specimen at 24 m/min speed and 0.2 mm/rev. feed, the progressive wear

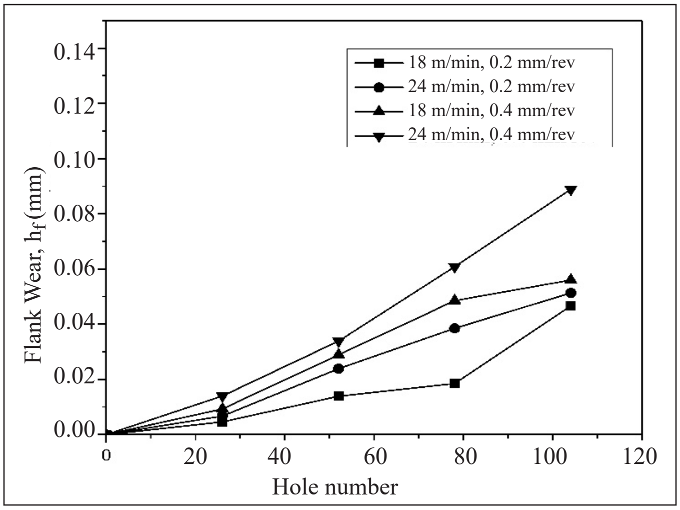


Figure 16. Flank wear after machining 26, 52 and 78 and 104 holes for 5 weight % SiC at various speeds and feeds

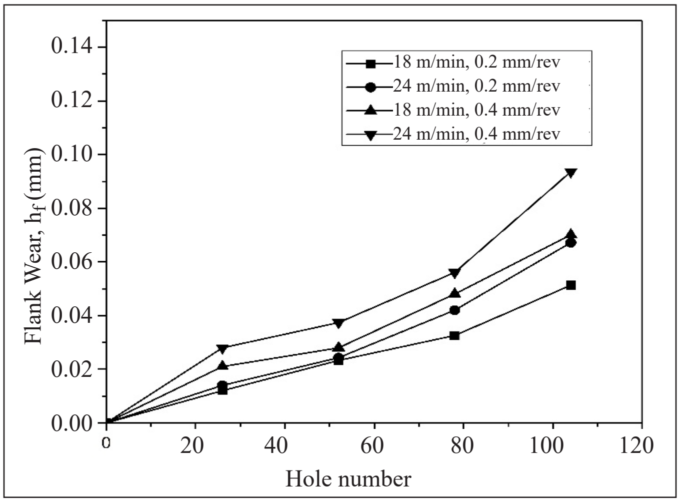


Figure 17. Flank wear after machining 26, 52 and 78 and 104 holes for 10 weight % SiC at various speeds and feeds

was 0.051 mm while it increased to 0.088 mm at the feed of 0.4 mm/rev. at same speed. Increase in chip load on the tool due to increase in feed rate enhanced the torque required for reaming resulting in higher force on the cutting edge and greater rubbing action of the flank of tool with the wall of drilled hole. The increased requirement of torque at higher feed rate enhances the rate of run in wear of the tool.

From the Figure 17, it was found that while reaming the holes in 10 weight % of SiC specimen, the patterns of variation of progressive wear for different combinations of speed and feed were similar to those observed in case of 5 weight % of SiC. For a given speed, the rate of initial run in wear was greater at the feed rate of 0.4 mm/rev. when compared with the same at 0.2 mm/rev. Increase in speed at a given feed rate also increased the rate of run in wear but to a much lesser extent. This trend is because of dominating influence of feed rate on reaming process when compared with that of cutting speed as discussed already. In addition to this, magnitude of progressive wear on the flank of tool for 10 weight % of SiC was much higher when compared with the same for 5 weight % of SiC. Increase in percentage of SiC in the composite increased the rate of abrasion at the interface of tool flank and hole due to the presence of more particles of SiC.

Further, it is also noticed that for all combinations of speed and feed, there was increase of progressive wear magnitude with increase in number of holes reamed. With the progression of reaming process, the reaming tool lose its sharpness of cutting edge and became dull. Increased flank wear results in progressive reduction of clearance angle on the clearance face of the tool. Reaming of holes further with the same tool continuously increased magnitude of energy required. The increase in torque during reaming with increase in number of holes, as shown in Figures 14 and 15 further strengthened this phenomenon. Reduced clearance at flank increases the frictional resistance. It produces wear land on the flanks of the tool, on account of the rubbing action of the machined surface. In the beginning of reaming process, the tool is sharp with no wear land. However very soon the wear land develops and grows in size on account of abrasion, adhesion and shear (Teti, 2002). The maximum value of flank wear (0.0936 mm) was after reaming 104 holes at the speed of 24 m/min and the feed of 0.4 mm/rev with the composite having 10 weight % of SiC.

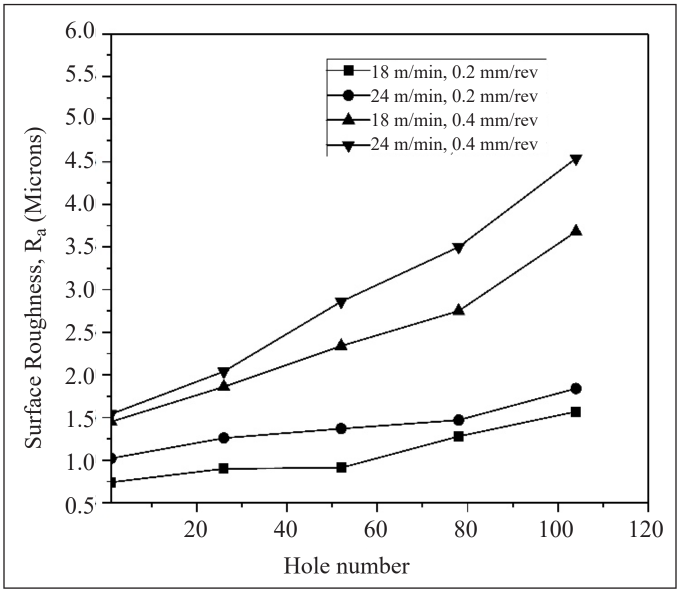


Figure 18. Surface Roughness of reamed holes 1, 26, 52 and 78 and 104 for 5 weight % SiC at various speeds and feeds

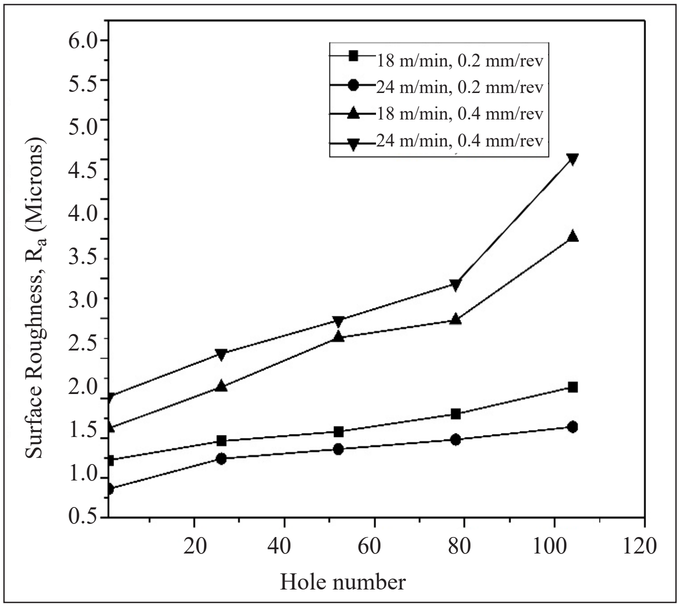
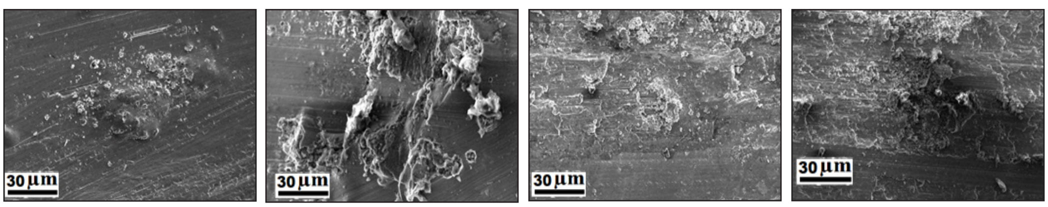


Figure 19. Surface Roughness of reamed holes 1, 26, 52 and 78 and 104 for 10 weight % SiC at various speeds and feeds

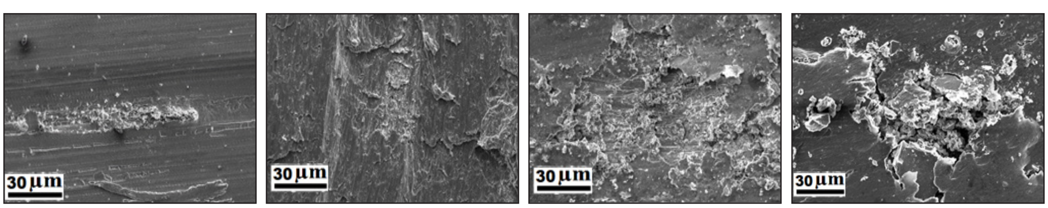
It is observed from Figure 18 and 19 that increase in weight % of SiC, speed and feed rate enhanced the surface roughness of the reamed hole surface. After reaming the first hole in the specimen with 5 weight % SiC at 18 m/min speed and 0.2 mm/rev. feed, the surface roughness (Ra) is 0.74 microns while it increased to 1.02 microns at the speed of 24 m/min at same feed rate. After reaming the first hole in the same specimen at 24 m/min speed and 0.2 mm/rev. feed, the surface roughness was 1.02 microns while it increased to 1.54 microns at the feed of 0.4mm/rev. at same speed. After reaming 104^{th} hole in the specimen with 5 weight % SiC at 18 m/min speed and 0.2mm/rev. feed, the surface roughness was 1.57 microns while it increased to 1.84 microns at the speed of 24m/min at same feed rate. After reaming the 104th hole in the same specimen at 24 m/min speed and 0.2 mm/rev. feed, the surface roughness required was 1.84 microns while it increased to 4.54 microns at the feed of 0.4mm/rev. at same speed. For a given speed, the surface roughness value was greater at the feed rate of 0.4mm/rev. when compared with the same at 0.2 mm/rev. A similar trend was observed while reaming the holes in the composite with 10 weight % of SiC. Increase in speed at a given feed rate also increases the surface roughness, but to a much lesser extent. This trend is because of dominating influence of feed rate on reaming process due to increase in chip load when compared with of cutting speed, as discussed already in this paper. Further, it is observed that the surface roughness of the reamed hole increased progressively with the increase in number of holes. This is true with all speeds, feeds and weight percentages of SiC particles. Flank wear affects the geometry of the tool and its cutting action. This would lead to the poor surface finish of the reamed hole. It is a fact that the hard reinforcing particles in the matrix of composites may not get sheared off when they come across the cutting edge of the tool. Instead, they would either remain embedded to the surface or get dislodged from the surface creating dents on the reamed surface. The progressively damaged (worn out) portions of the cutting edges of machine reamer which interact with surface of the hole affect the surface finish of reamed holes.

The surface morphology images of the reamed hole surfaces were captured using Zeiss EVO 18 Special Edition Scanning Electron Microscope. The morphology study was undertaken to investigate on the possible mode of failure of work material causing the formation of chips, during reaming. It is evident from SEM images shown in Figure 20 to 21 that the mode of failure of work material is due to ductile fracture of matrix material of chips. It also reveals the possible debonding or dislodging, during the process.



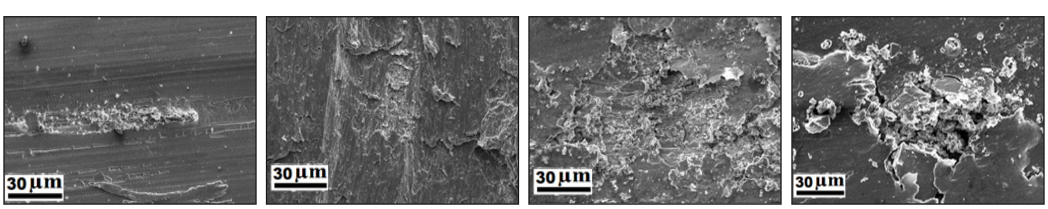
(a) (b) (c) (d)

Figure 20. SEM image (2000×) of reamed surface of specimen with 5 weight. % SiC at 18 m/min speed (a) First Hole (b) 104th Hole at 0.2 mm/rev (c) First Hole (d) 104th Hole at 0.4 mm/rev.



(a) (b) (c) (d)

Figure 21. SEM image (2000×) of reamed surface of specimen with 10 weight. % SiC at 18 m/min speed (a) First Hole (b) 104th Hole at 0.2 mm/rev (c) First Hole (d) 104th Hole at 0.4 mm/rev.



(a) (b) (c) (d)

Figure 22. SEM image (2000×) of reamed surface of specimen with 10 weight. % SiC at 24 m/min speed (a) First Hole (b) 104th Hole at 0.2 mm/rev (c) First Hole (d) 104th Hole at 0.4 mm/rev.

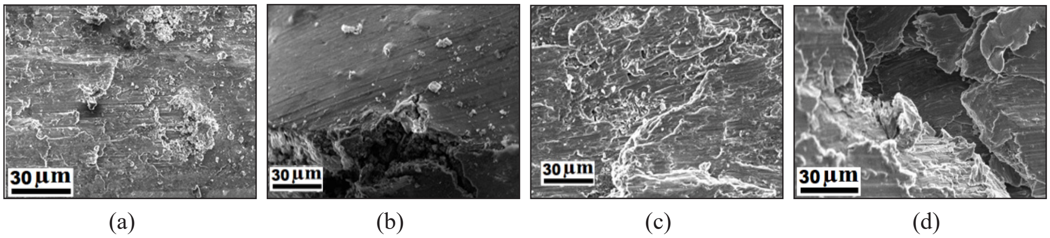


Figure 23. SEM image (2000×) of reamed surface of specimen with 10 weight % SiC at 24 m/min speed (a) First Hole (b) 104th Hole at 0.2 mm/rev (c) First Hole (d) 104th Hole at 0.4 mm/rev.

Work hardening of the soft matrix and cracking or debonding of the particles are typical sub surface defects in machining of MMCs. From SEM images shown in Figure 20 to 23, it was evident that increase in speed and weight % of SiC particles from 5 to 10 had resulted in flaky reamed hole surface and poor surface finish. Further, from Figure 23(b) and 23(d), it was evident that tendency for possible dislodging of SiC particles from the hole surface increased with increase in feed. With the increase in number of holes reamed, the flank of the cutting edge of the reamer might get worn out due to rubbing action of dislodged SiC particle from the reamed hole surface, as shown in Figure 22(d) and 23(d). Such debonded particles might get entrapped between the flank of cutting edge of reamer and hole surface during reaming act as abrasive particles and caused damage to the hole surface, resulting in poor surface finish.

CONCLUSIONS

In this experimental investigation, the performance of uncoated four flued HSS machine reamer is evaluated in the form of tapping torque, progressive flank wear and surface roughness of reamed surfaces. The conclusions derived from the outcome of this study are as follows:

- Increase in the weight percentage of SiC particles results in the increase of hardness and tensile strength of composite influences the rate of flank wear of tool.
- The torque required and flank wear during reaming increase with increase in weight percentage of SiC in Al/SiC composite, cutting speed and feed rate.
- The feed rate has dominating influence on torque required for reaming and progressive flank wear of reaming tool when compared with that of cutting speed.
- The progressive wear out of reaming tool increases the torque required for reaming. Further, at higher feed rates, dislodging of SiC particles from the hole surface deteriorates the surface quality of the reamed holes.

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