J. Adv. Manuf. Eng. 1(3) (2020) 71–82

JOURNAL OF ADVANCES IN
MANUFACTURING ENGINEERING

Surface Roughness of Aluminium Hybrid Metal Matrix Composites Affected by Tool Materials and Operating Conditions

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Received: 10.06.2020 *Accepted: 02.07.2020*

Abstract

The effect of the high speed steel (HSS) and tungsten carbide tool materials on the machining of the hybrid aluminium metal composite as-cast materials, age hardness and mild steel by measurement of surface roughness is reported in this article. The Al20204 + 10% SiC+2.5% Gr and Al20204 + 10% Al2O3 + 2.5% Gr composites are prepared. By casting and then by age hardening these hybrid composites are used. These four materials are used with HSS and Tungsten carbide tools to study the surface roughness. The four composites are compared with mild steel work piece and with as cast Al20204. The cutting speed is increased from 30 to 125 m/min and the feed rate from 0.006 to 0.125 mm/min. Depth of cut during the analysis is increased from 0.5 to 1.25 mm and vegetable oil as a coolant is used for entire investigation. The analysis in this study reveals that, regardless of materials the surface roughness reduced with cutting speed and increased with depth of cut and marginal increase with increase in feed rate. The Tungsten carbide tool, however, demonstrated greater strength than the HSS tool in producing more roughness.

Keywords: *Surface Roughness, High Speed Steel, Tungsten Carbide Tool, Feed, Depth of Cut, Composite.*

1. Introduction

Composites with aluminium matrix (ACM), due to low density, low cost and ease of composite manufacturing, are among the most promising materials for wear and structural applications. The use of silicon carbide, graphite or Al_2O_3 particles as reinforcements has attracted considerable importance in recent years. On the other hand, the superior mechanical characteristics achieved by aluminium reinforcements influence their workmanship significantly [1-5]. The mechanical characteristics, structure and compatibility of work materials depend on the work materials thermo-mechanical ability. One of the main factors affecting the utility, quality and cost of a product are the ease with which a metal can be machined [6-10].

Aksoy et al. [11] selected homogenized SiC-p aluminum content MMC for experimental research on tool wear and surface roughness [11]. Two K10 types (Uncoated and TiN-coated) have been used for the different cutting velocities (50 mm, 100 mm, 150 m / min, feed levels (0.1, 0.2 and 0.3 mm / ret) and cutting depths (0.5, 1 and 1.5 mm). When the tool was dry, the speed of cutting was mostly affected, and the cutting speed decreased. TiN, Al_2O_3 and Ti(C, N) CVD-based coatings were studied by Sahin et al. [12] for the machining of metal-matrix composites containing 10 wt% SiC particulate made of liquid metallurgy under various cut-off conditions. Different speeds and two cuts

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were employed in turning tests at constant feed rate and cutting depth with varying chip breaker geometries.

The Poly Crystalline Diamond insert (PCD) analysis was carried out by Venkatesh and Hariharan [13]. A material of 20% silicon carbide weight sections with a medium diameter between 55 µm and 80 µm is used in aluminium matrix. For machinability testing, mechanical test A356-SiC(20p) (MMC) is used. It is important that the main spindle is minimally operated, has good surface finish and has low tool wear. The effect of processing parameters such as current, time stim, time-off pulses, electrode polarity, voltage spacing and the electrode content was investigated by Wang and Yan [14]. Time pulse influences surface roughness and user rate directly. It was discovered experimentally. The rate of removal of material increases with a change in current.

The experimentally tested CNC-Wire cut EDM was Manna and Bhattacharyya [15] Al / SiC-MMC. The authors tested the WEDM parameter during processing and WEDM parameters for various output metrics were optimally combined. The low input pressure of the dielectrics was concluded to eliminate hardened particles during machining. The key machining parameters controlling deletion rate regulation are open gap and pulse on time. Krishnamurthy et al. [16] presented the findings of an experimental analysis on aluminium-silicon carbide and aluminium graphite-silicon comparative machinery Carbide Hybrids during turning with carbide system inserts. The experiments have been performed based on simple composite experimental architecture. For cutting speed, feed and depth, the effects of machining parameters can be seen in the resulting force. Hybrid composites have become more machinable in the same way as silicone silicon composites.

Multi-reinforced aluminum composites, commonly used due to the improvement of the mechanical and tribological characteristics (hybrid AMCs) and also suitable for individually strengthened composites replacements, have been used by the Suresha and Sridhara [17]. Dry sliding studies have been conducted for the effects of gr particles, freight sliding speed and sliding measurements with a cumulative wear strengthening of 2.5 percent, 5 percent, 7.5 percent, and 10 percent, with equivalent weight for SiC and Gr. Hybrid composites, similar to SiC alone, have very good wear features. Sahin and Aclair [18] have tested for cast composites and associated microstructure properties on the aluminum composite hybrid matter, which is reinforced by zircon and graphite particles (manufactured by means of stir casting technique), hardness, wear properties, and properties.

Rajashekar and Naveed [19] focused on the production and hybridisation of Al6061 alloy. Constant 5% wt silicon carbide was illuminated with graphite particulate particle variable percent wt using a stir casting technique. SEM, hardness and ultimate tensile strength of the composites that have been produced are evaluated. Shivaprakesh [20] studied the stiffness, tensile and impact properties of the GCI-based AA6061 composite both under cast and under peak aging conditions in the current study microstructure.

2. Methodology

The process of the composite preparation is stir casting. The basic material Al2024 is used and the matrix Al2024 is heated and melted (713°C) in a resistance furnace with spiral heat elements and the concrete is used as a base layer. The average temperature is 1000 ° C; hexaclhoethane tablets are used to degass before agitation. The optimum temperature is 1000 ° C.

To get the distribution of Al_2O_3 equally, SiC and Gr were pre-heated and blended into Al2024 melting, then separated and dissolved into preheated metal mold for 5 minutes (300 rpm). The composites were heat treated with aluminum and then tempered to a condition of T6, i.e. the samples then heated to 530 ° C for 3 hours and instantly quenched in water at room temperatures, eventually the composites were chemically aged in the furnace at 100 ° C for 6 hours and then immersed in water at room temperature directly afterwards.

Aluminum Composite composites as cast, age hardened with specific content blends and mild steel are machined (turned) at varying rates, feeds and depths with cut in a typical lath with HSS and Tungsten carbide devices. A work is being performed in order to examine the impact of metallurgical microscope on tool wear and tool existence by calculating flank wear thickness. Throughout manufacturing of various aluminum hybrid composites using HSS and carbide devices under varying working environments the cutting powers and the surface finishing.

2.1 Fabrication of Composite Rods

Composites are prepared by the liquid metallurgy route vortex process. For the composite specimens it allows a more consistent distribution of application particles the swirl casting method has been utilized. This approach may be rendered with discontinuous fibers or particles in the most economical manner. Content alloy (Al2024) was then superheated above the melting point first and then the point slowly fell below the temperature of the liquid in a semi-solid state to preserve the matrix alloy. At this temperature, the SiC, Al2O3, Gr particles were injected into the slurry using a graphite stirrer, which was preheated, with various amounts of average size 25 µm.

Average stirring speed of 300-350 rpm was raised to complete liquid and automated stirring was held over five minutes. Particles tend to distribute the matrix material evenly. The fine was then overheated at the temperature of the liquids and eventually packed into the mold of cast iron for measuring specimen. The composite rods developed are specificated for 60 mm diameters and 300 mm long, 22 mm diameters and 270 mm wide. The composite rods obtained are shown in Figure 1. The heat treated rods are also shown in this Figure 1.

Figure 1. Composite rods and heat treatment of material for hardening

2.2 Age Hardening of Composites

Age hardening, which is also called precipitation hardening, is a method of thermal treatment employed to improve the materials 'yield power, for certain aluminum, magnesium, nickel and titanium framework alloys, as well as some stainless steels. It depends on temperature-based shifts in solid solubility in order to create finer particles of an impurity type that prevent dislocation movement or defects in a crystal grid. The aluminum composites have been heat-treated and polished to T-6 quality, i.e. the samples were heated in the atmosphere at 530 ° C for 3 hour and then transferred directly into the water at room temperature and then instantaneously water quenched at room temperature. Lathe machine (Precision turn master 350) is used for machining purpose. Lathe Tool dynamometer (model 830/8 Contech micro system) is used for machining the model for turning. Figure 2 shows lathe machine and Mitutoyo made surface measuring instrument.

The cutting parameters selected for the surface roughness analysis are 1) cutting speed in m/min ranging from 20 to 80 2) feed in mm/rev from 0.06 to 1.25 and 3) depth of cut (mm) from 0. 5 to 1.25. The composite material whose property is analyzed is surface roughness for variation in aforementioned parameters. These parameters are selected based on the previous studies of Aksoy et al. [11] and Krishnamurthy et al. [16]. Moreover the experimental facility available for the material property was restricted. Based on these mentioned research works and facility the cutting parameters were decided.

Figure 2. Surface roughness measurement on the work piece

3. Results and Discussions

The surface finish has numerous parameters, including geometry of cutting tools, geometry of work parts, rigidity of machine tools, work piece material, cutting conditions, tool material and cooling properties and the lubrication of fluid cutting products.

The surface finish is known for the chemicals composition, hardness, microstructure and metallurgical quality. Carbon content, for example, is of great significance in the case of steel. Steels that have 0.1 per cent or less carbon create an embedded edge and spoil the surface during chip forming. This phenomenon is being reduced by the addition of the so called free machining elements such as sulphur, selenium or plum.

Speed cutting, surface finishing patterns. That is why. This is why. The cutting forces are high at low cutting speeds and the inclination to a built-up edge is also higher. When the cuts are larger, the forces of cutting and the tendency to shape a built-up edge weakens due to increased temperature and consequent reduction in frictional stress on the face of the rake. Both effects are useful for finishing the floor. Feed and cutting depth have a major influence on surface finishing. The effect of both feeds is substantially larger. High peaks and valley depths of markers are equivalent to the feed square per revolution.

Average roughness value (mean roughness value) **Ra** is normally employed as a roughness factor to measure superiority of finished part. **Ra** is the arithmetic mean of the absolute values of the profile deviations) from the mean line. **Ra** is analysed in this article for different operating conditions using HSS and Tungsten carbide tool.

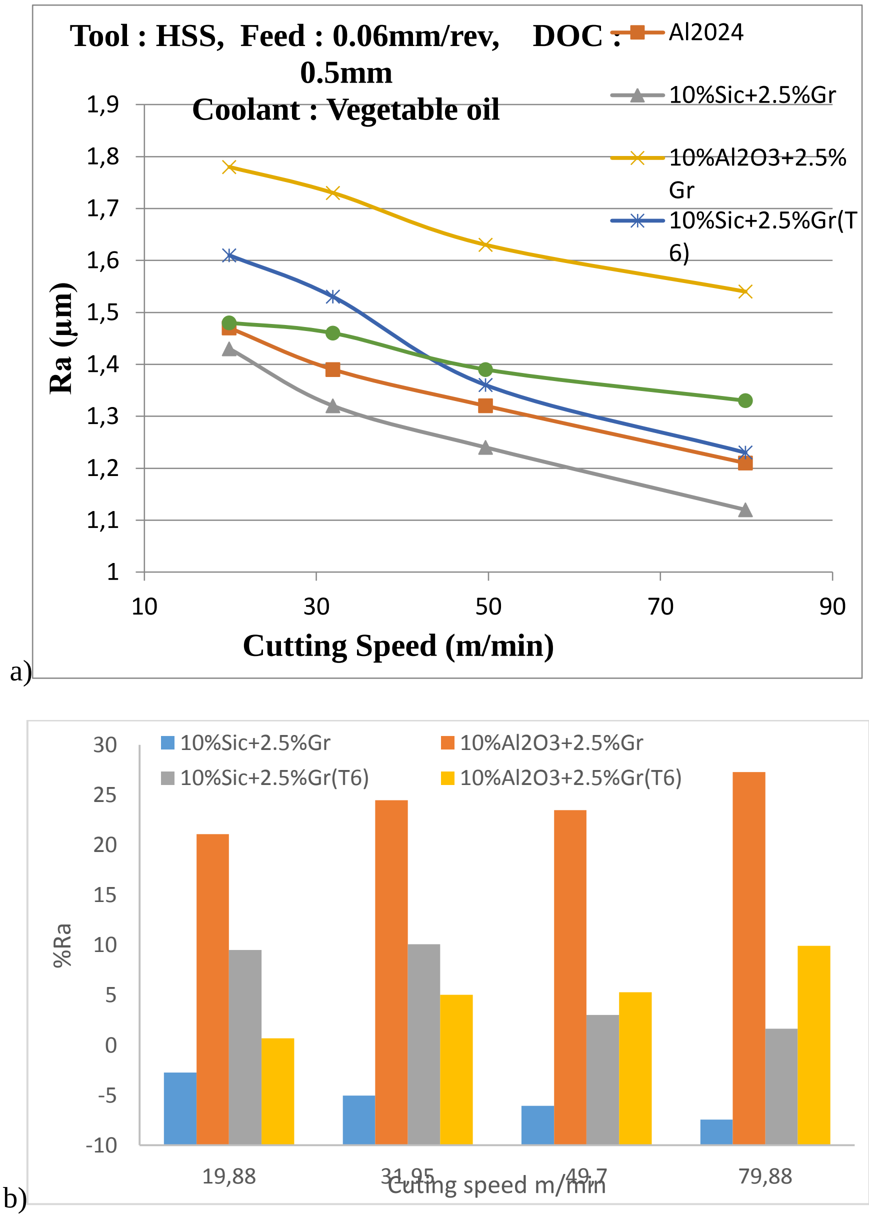
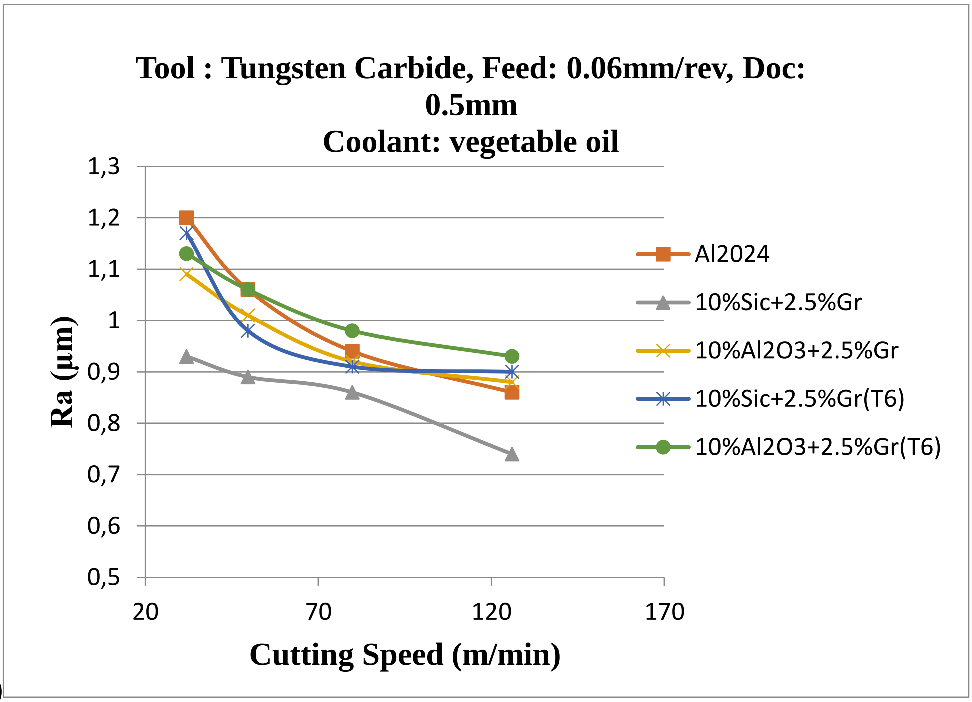
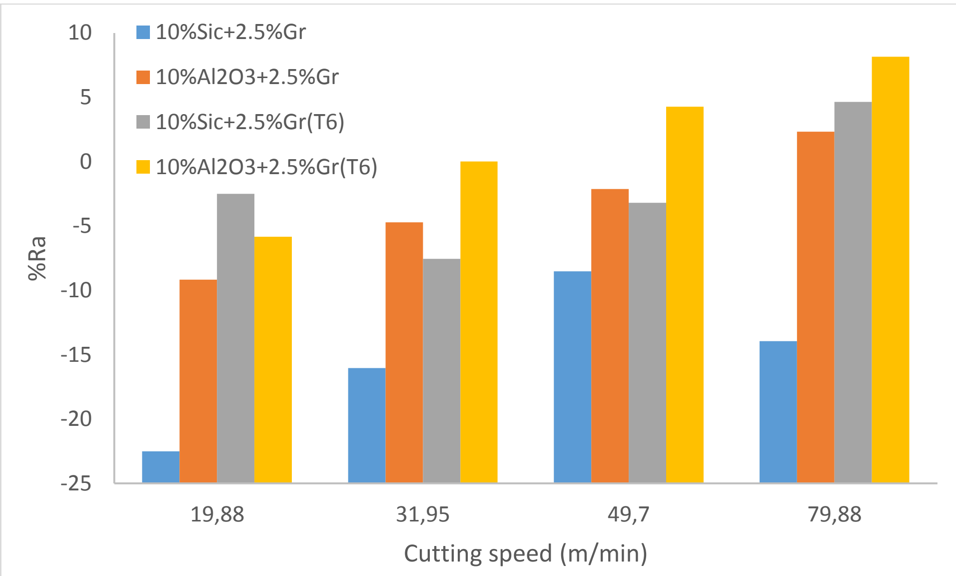


Figure 3. Surface roughness using HSS tool with cutting speed a) Surface roughness with respect to Al2024, b) % change in surface roughness

The surface roughness with increasing cutting speed from 20 to 80 m/min for hybrid composite materials having 10% SiC + 2.5% Gr and 10% Al_2O_3+2.5%Gr as-cast and the same age hardened are compared with mild steel and Al20204 composite in Figure 3 (a). The % increase/decrease in surface roughness with speed with respect to Al2024 is provided in Figure 3 (b). The surface roughness reduces with increase in cutting speed smoothly and it is highest for mild steel. The lowest is seen for 10% SiC + 2.5% Gr as cast. Age hardening causes the surface roughness to increases slightly. % SiC + 2.5% Gr after hardening is among the most vulnerable to providing surface roughness at all speeds. The depth of cut is fixed here at 0.5 mm and the feed rate is 0.06 mm/rev. In Figure 4 (a) the surface roughness trend is very similar to Figure 3 by Tungsten carbide at all cutting speeds. The material nature has provided the same impact by the tool on surface roughness at different speeds. The surface roughness is however more by the HSS tool than the Tungsten carbide tool at all speeds. The composite materials however form a cluster close to each other irrespective of any speed and tool used for turning operation. The surface roughness is purely dependent on the cutting speed as well as the tool material showing their importance. The % change with respect to Al2024 composite for the prepared composites are presented in Figure 4 (b).



a)



b)

Figure 4. Surface roughness using Tungsten carbide tool with cutting speed a) Surface roughness with respect to Al2024, b) %Change in surface roughness

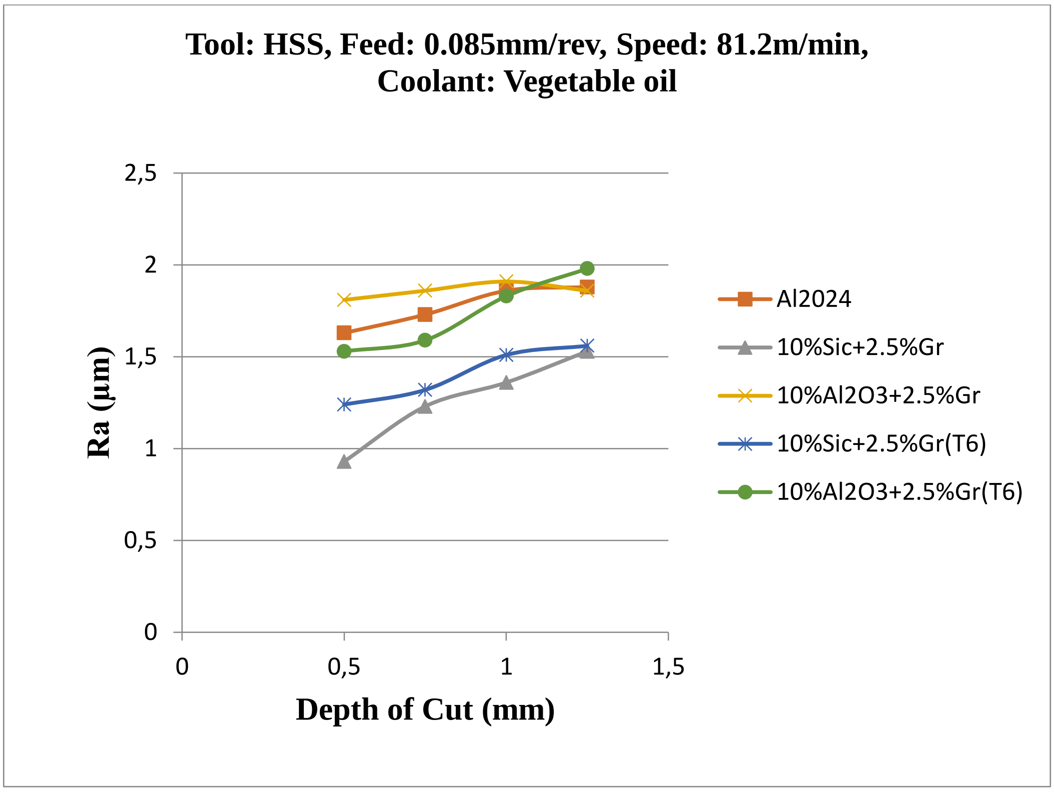


Figure 5. Surface roughness using HSS tool with depth of cut at feed 0.085 mm/rev

Figure 6 illustrate HSS tool provided surface roughness at 0.125 mm/rev feed rate on hybrid composite materials as-cast and age hardened. The comparison is again made with mild steel material. The drop in surface with increase in cutting speed is very sharp compared with the previous experimental results. Here too mild steel is having high roughness and as-cast 10% SiC + 2.5% Gr provide maximum lowest roughness.

In Figure 7 and Figure 8 the surface roughness provided by Tungsten tool at 0.085 and 0.125 mm/rev of feed rate for hybrid composites with and without age hardening is depicted. The Figure 7 shoes the roughness variation with depth of cut and Figure 8 is for cutting speed. Obviously increasing depth of cut produces more roughness while increasing cutting speed increases reduces the roughness. The trends are self-explanatory in all cases of composite materials.

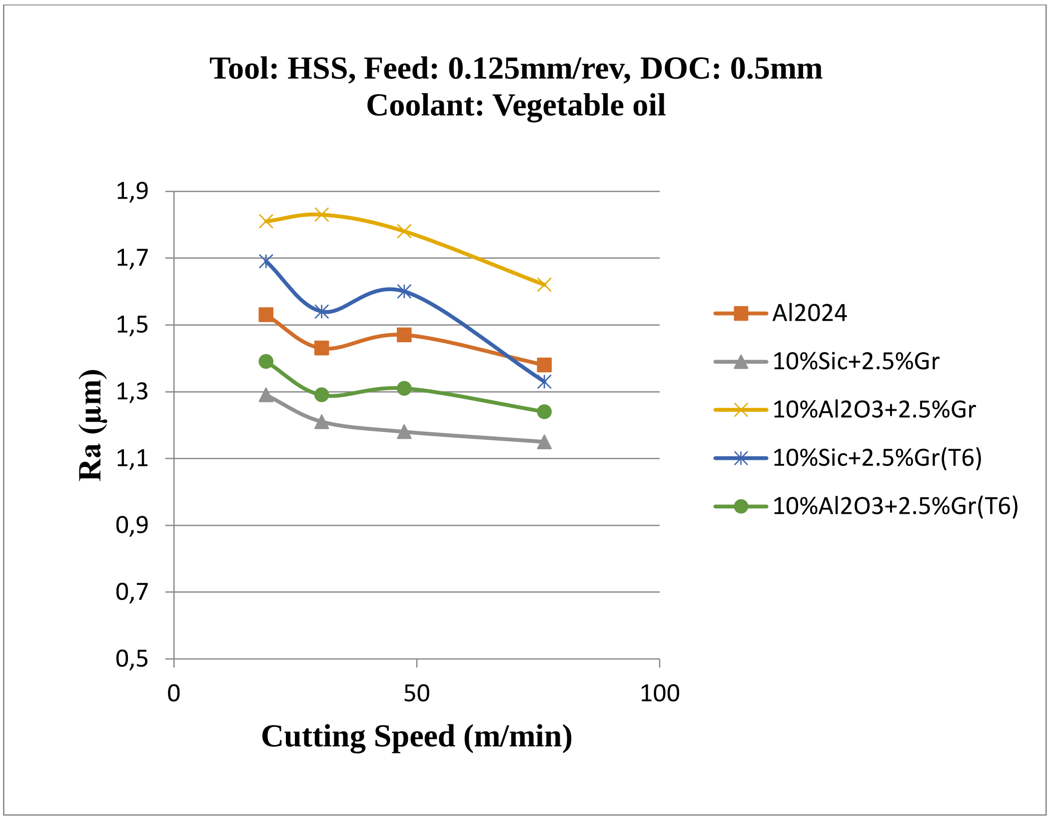


Figure 6. Surface roughness using HSS tool with cutting speed at feed 0.125 mm/rev

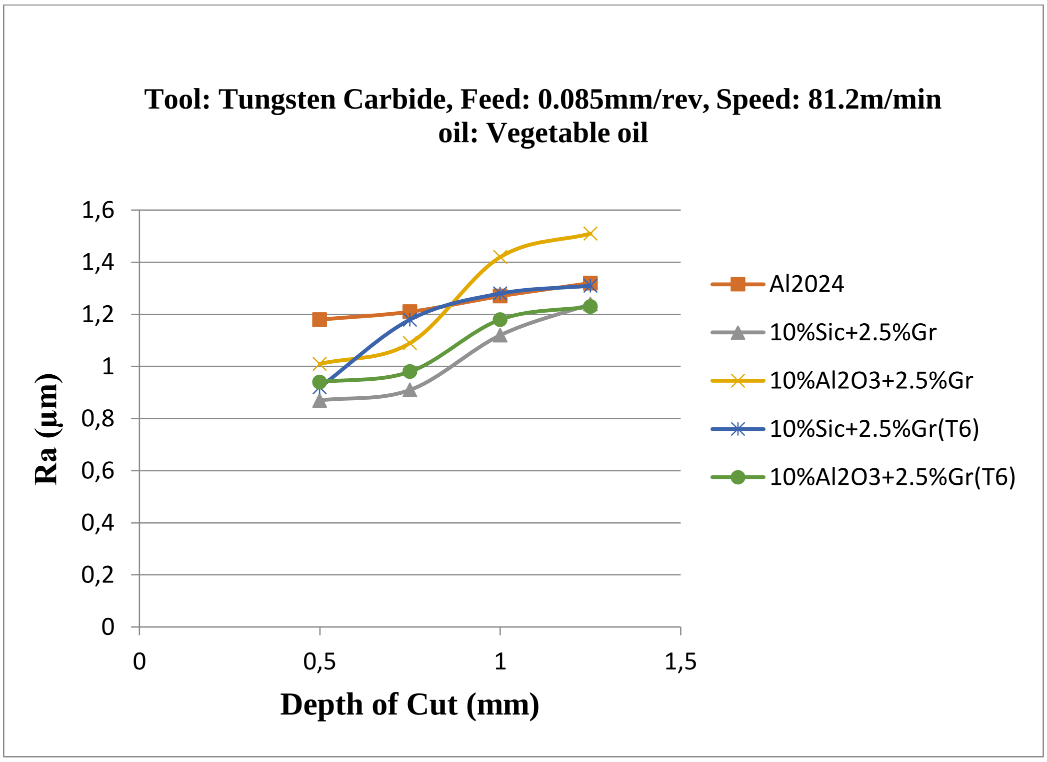


Figure 7. Surface roughness using Tungsten carbide tool with depth of cut at feed 0.085 mm/rev

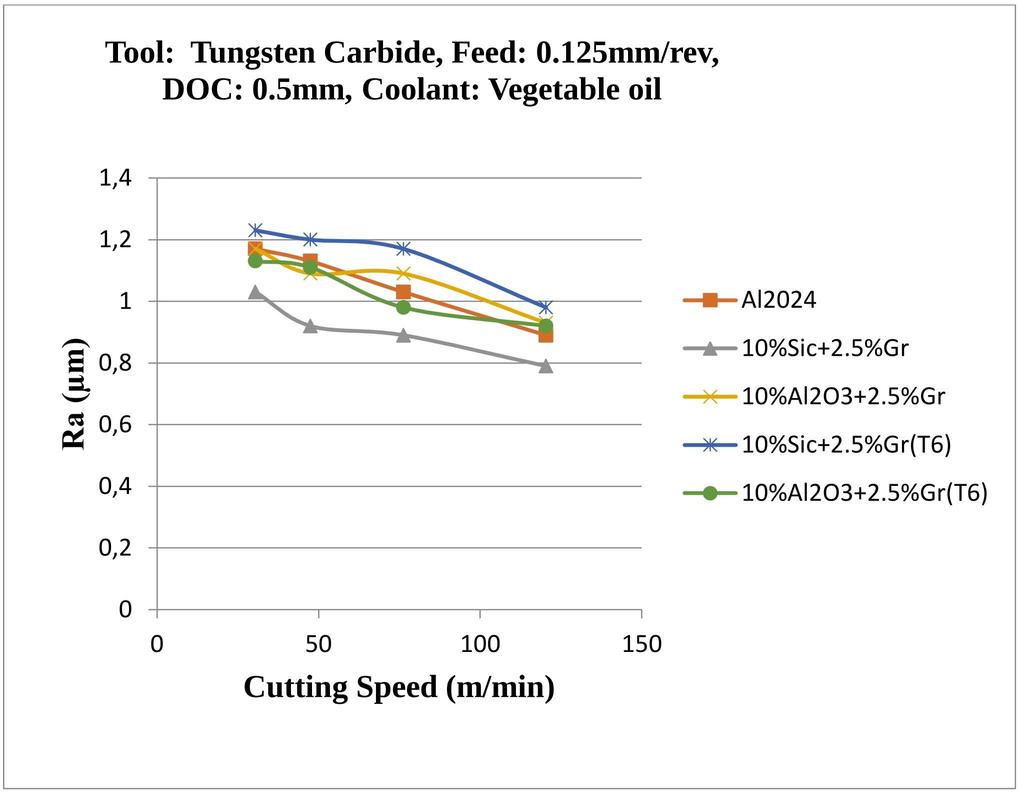


Figure 8. Surface roughness using Tungsten carbide tool with depth of cut at feed 0.125 mm/rev

Figure 9 and Figure 10 show the surface roughness analysis with respect to increase in feed rate from 0.006 to 0.125 m/min using HSS tool. The depth of cut is 0.5 mm and cutting speed is 47.5 m/min. It seems that with increase in feed the roughness does not has much impact but a slight increment can be seen after 0.085 mm/rev. this indicates that their exists an upper portion of feed rate increasing above this will cause the surface roughness to increase. Figure 10 is shown to indicate the surface roughness at 47.5 m/min of speed using vegetable oil as coolant and Tungsten carbide as tool. The trend is very similar and has a marginally higher value of roughness than the HSS tool at all increasing speeds.

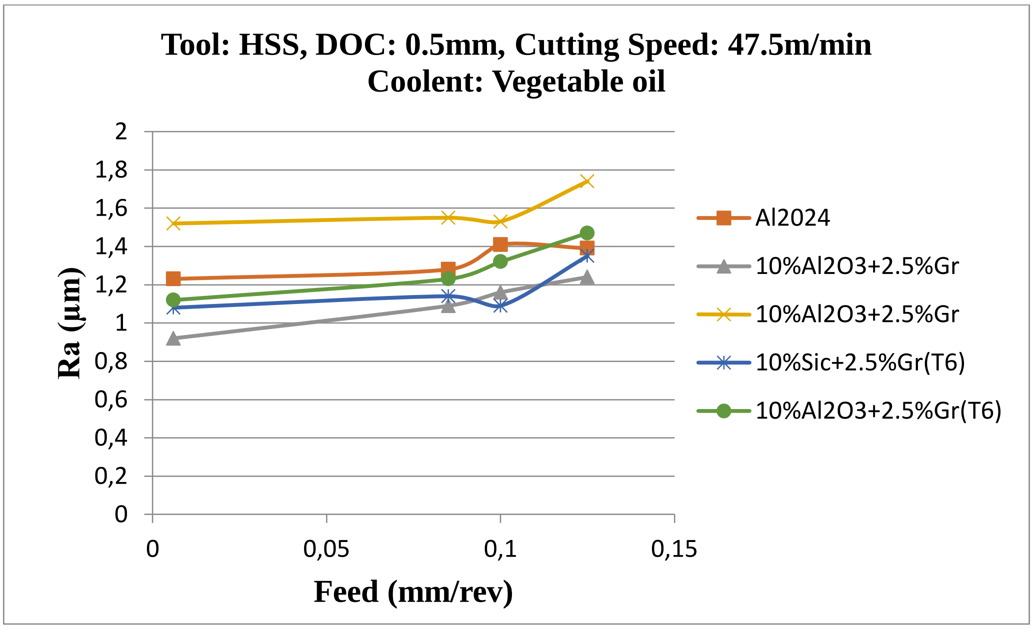


Figure 9. Surface roughness using HSS tool with feed rate at 47.5 m/min speed

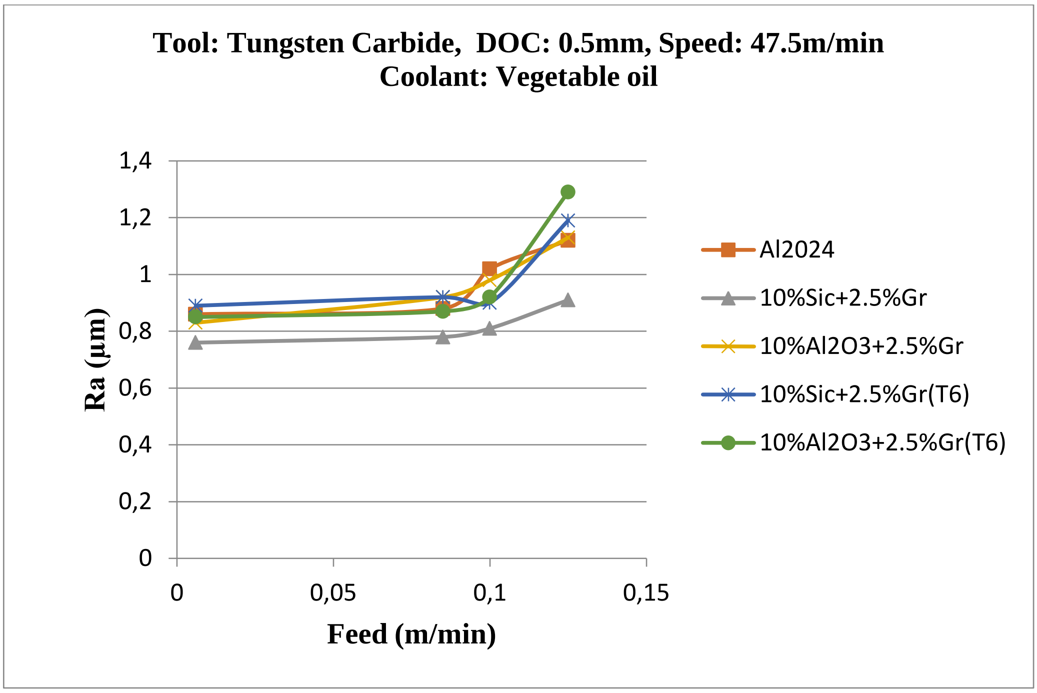


Figure 10. Surface roughness using Tungsten carbide tool with feed rate at 47.5 m/min speed

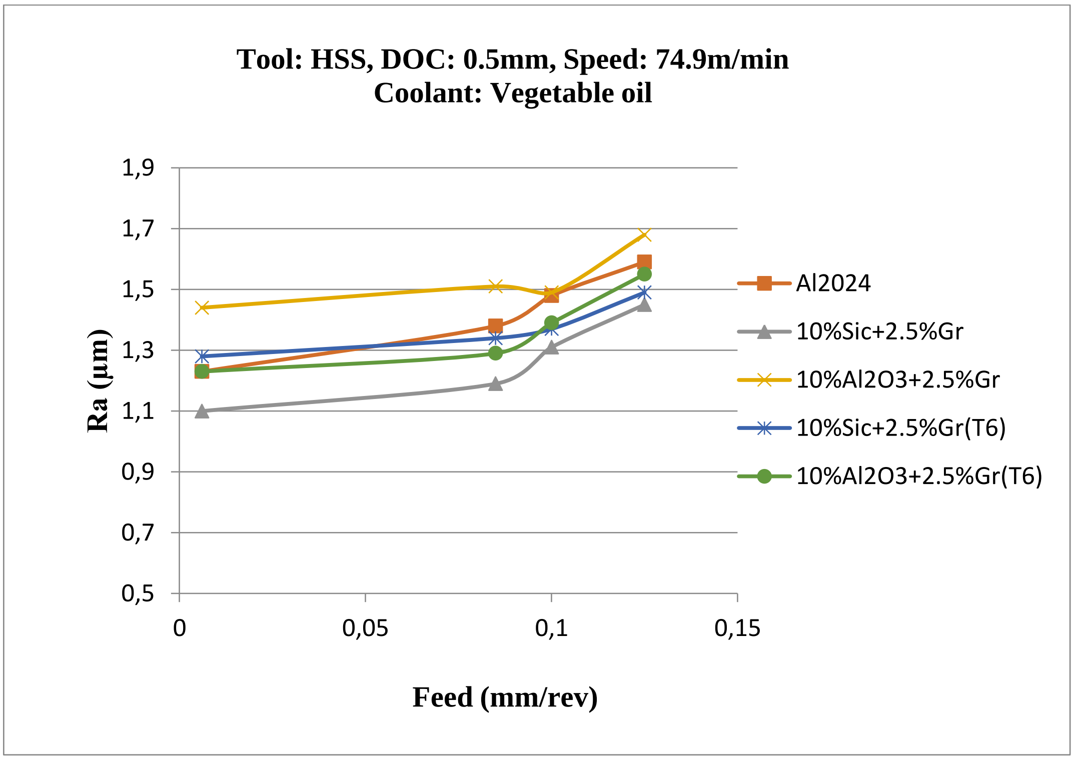


Figure 11. Surface roughness using HSS tool with feed rate at 74.9 m/min speed

Figure 11 and Figure 12 show the feed rate effect on surface roughness for HSS and Tungsten carbide tool respectively. The hybrid materials are anyways kept same with depth of cut being 0.5mm. The feed rate at this speed is showing a rising trend of surface roughness with increase in feed rate irrespective of any material taken. Mild steel being at the highly affected and 10% SiC+2.5% Gr being less affected. For the cluster of hybrid composite the HSS tool provides more roughness than the Tungsten carbide tool.

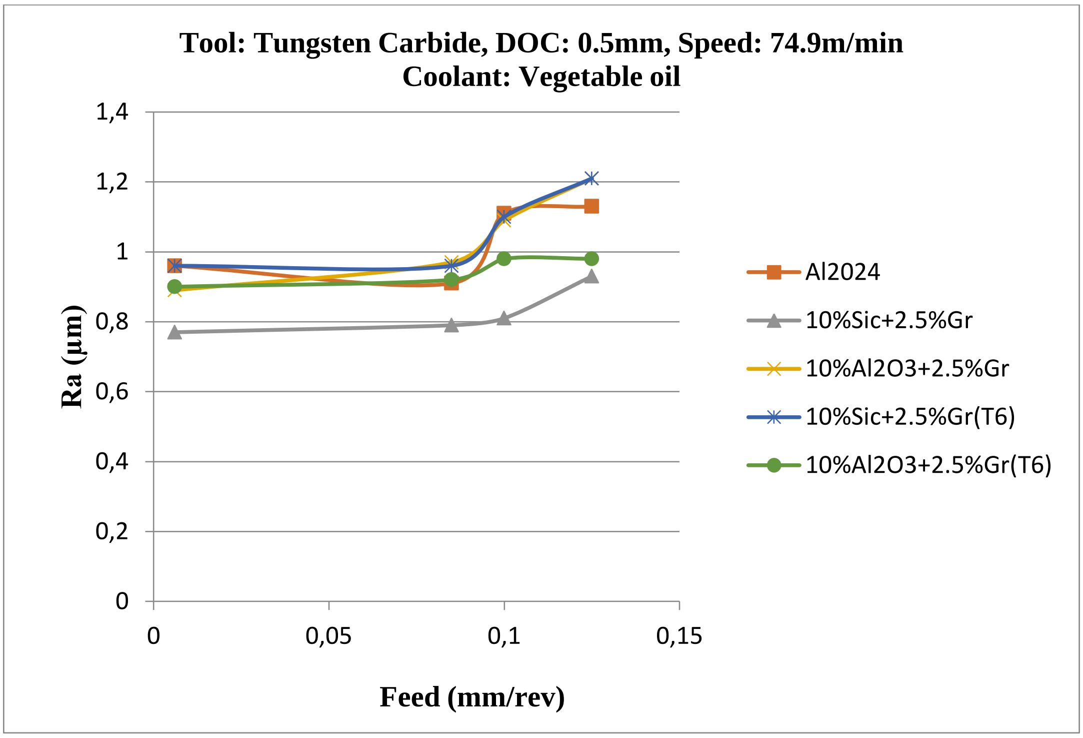


Figure 12. Surface roughness using Tungsten carbide tool with feed rate at 74.9 m/min speed

4. Conclusion

The surface roughness during the machining operations has a prime importance in obtaining the final product. In this article the effect of HSS tool and Tungsten carbide tool at different cutting time, feed rate, depth of cut, and speed of rotation on different hybrid materials with and without age hardened is analysed. The following important conclusions are drawn from the analysis:

- The feed rate at speed of 74.9 m/min is showing a rising trend of surface roughness with increase in feed rate irrespective of any material taken.
- At speed of 47.5 m/min the roughness is not much affected by any tool used.
- Surface roughness increases with depth of cut for all hybrid materials and with the increase of cutting speed the roughness reduces without showing any particular effects of material.

References

[1] Masuko, M., Suzuki, A., Sagae, Y., Tokoro, M. &Yamamoto, K. (2006). Friction characteristics of inorganic or organic thin coatings on solid surfaces under water lubrication, Tribol Int., 39(12), 1601–1608.

[2] Axinte, D.A. & Belluco, W.& Chiffre, L. (2001). Reliable tool life measurements in turning—an application to cutting fluid efficiency evaluation, Int J Mach Tools Manuf., 41(7), 1003–1014.

[3] Su, Y., He, N., Li, L., Iqbal, A., Xiao, M.H., Xu, S.& Qiu, B.G. (2007). Refrigerated cooling air cutting of difficult-to-cut materials, Int J Mach Tools Manuf.,47(6), 927–933.

[4] Dhar, N.R., Paul, S. &Chattopadhyay, A.B. (2002). Role of cryogenic cooling on cutting temperature in turning steel, J Manuf Sci Eng., 124(1), 146–154.

[5] Mukhopadhyay, D., Banerjee, S. &Reddy, S.K.N (2007). Investigation to study the applicability of solid lubricant in turning AISI 1040 steel, J Manuf Sci Eng, 129, 520–527.

[6] Afzal, A., Mohammed Samee, A.D., Abdul Razak, R.K., Khan, S.A.& Khan, H. (2020). Optimum spacing between grooved tubes: An experimental study, J Mech Sci Technol., 34, 469–475.

[7] Afzal, A. &Abdul Mujeebu, M. (2019). Thermo-Mechanical and Structural Performances of Automobile Disc Brakes: A Review of Numerical and Experimental Studies, Arch Comput Methods Eng., 26, 1489–1513.

[8] Afzal, A., D. Mohammed Samee, A.D. & Abdul Razak, R.K. (2019).Experimental Investigation of Thermal Performance of Engine Coolant Oil and Water in Helical Coil Heat Exchanger, J Eng Res., 8, 333–351.

[9] Afzal, A, SMohammed Samee, A.D., Javad, A., Shafvan, S.A., Ajinas, P.V. & Ahammedul Kabeer, K. M. (2018). Heat transfer analysis of plain and dimpled tubes with different spacings, Heat Transf Res., 47(3), 556–568.
[10] Pinto, R.N., Afzal, A., D'Souza, L.V., Ansari, Z.&Mohammed Samee, A.D. (2017). Computational Fluid Dynamics in Turbomachinery: A Review of State of the Art, Arch Comput Methods Eng., 24, 467–479.
[11] Aksoy, M., Inan, A. &Cakir, D. (2005). Study of tool wear & surface roughness in machining of homogeniused Sic- reinforced aluminium metal matrix composite, Journals processing technology, 164-165, 862-867.
[12] Sahin, Y. &Sur, G. (2004). The effect of Al2O3, TiN and Ti based CVD coating on tool wear in machining metal matrix composites, Surface & coating technology, 179, 349-355.
[13] Venkatesh, R., Hariharan, A.M. (2009). Machiniability studies of Al/Sic/(20p) MMC by using PCD insert (1300 grade), Proceedings of the world congress on engineering (WCE 2009), 1-3 July, London, U.K.
[14] Gopi, K.R, Shivananda H N,& Sandeep S. (2016). Investigation of microstructure and mechanical properties of ECAP-processed AM series magnesium alloy,Journal of Materials Engineering and Performance, 25(9), 3737-3745.
[15] Manna, A. & Bhattacharayya, B. (2003). A study on machiniability of Al/Sic MMCs, Journal of materials processing technology, 140(1), 711-716.
[16] Krishnamurthy, L., Shridhara, B.K. &Abdul Budan, D. (2007). Comparative study on the machinability aspects of Aluminium Silicon Carbide &Aluminium Graphite Composites, International journal on material and manufacturing processes, 22(7-8), 903-908.
[17] Gopi, K.R, Mohandas, K.N, Reddappa, H.N.R. & Ramesh, M.R. (2013). Characterization of as cast & heat treated aluminium 6061/zircon sand/graphite particulate hybrid composites, International Journal of Engineering and Advanced Technology, 2(5), 340-345.
[18] Sahin, Y. &Acilar, M. (2003). The effect of Al2O3, TiN and Ti based CVD coating on tool wear in machining metal matrix composites, Composites Part A: Applied Science and Manufacturing, 34, 8, 709-718.
[19] Rajashekar, Naveed, M.A. & Khar, A.R. (2013). Studies on effect of heat treatment on mechanical properties of hybrid Aluminium matrix composites, International Journal of Innovative Research in Science, Engineering and Technology, 2(11),1-8.
[20] Shivaprakash, Y.M., Jayashree, P.K., Gowrishankar, M.C., Gurumurthy, B.M., Hiremath, A.R. & Sreenivasa Prasad, K.V. (2016). Experimental studies on heat treated AA6061+GCI composite. Indian Journal of Science and Technology, *9*(39), 1-8.