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Effect of Tool Materials and Aluminum Hybrid Metal Matrix Composite on Tool Cutting Forces

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Abstract – In this article, the effect of tool materials (HSS & Tungsten carbide) on machining of Aluminum hybrid metal matrix composite as-cast, age hardened and mild steel by measuring cutting forces is reported. The Aluminum hybrid metal matrix composites are Al20204+10%SiC+2.5%Gr and Al20204+10%Al_2O_3+2.5%Gr. These hybrid composites are used as they are casted and then as age hardened. These four work pieces are used to measure cutting force with HSS and Tungsten carbide tool. A comparison of these four composites are made with pure Al20204 and Mild steel work piece. The machining time is increased upto 15 minutes and the feed rate is changed from 0 to 0.15 mm/rev. the depth of cut and speed are maintained constant and vegetable oil is used as coolant. From the analysis it is found that the tangential and trust force increase with time and feed irrespective of any material. However, Tungsten carbide tool showed higher forces than HSS tool.

Index Terms – Cutting Force, HSS Tool, Tungsten Carbide Tool, Feed, Depth of Cut, Composite.

1. INTRODUCTION

Due to their many attractive features, aluminium matrix properties have attracted researchers around the world. Presently, these materials are striving to maximize their advantages by rapid marketing. The integration of three large-scale primary processing, characterisation, machining, can be seen as a way to expand the base of this technology [1–5]. On the other hand, the superior mechanical characteristics achieved by aluminium refurbishments influence their workmanship significantly. For manufacturing engineers, the machinability aspect is of great importance if work materials are to be used beforehand so that processing can be planed more efficiently [6–10].

Aluminium matrix composites (AMCs) are among the most promising materials for wear and structural applications due to their low density, low cost, and ease of composite fabrication. In recent years much interest has centered on the use of silicon carbide, graphite, or Al_2O_3 particles as reinforcements. Aluminium matrix composites in general and discontinuously reinforced AMCs, such as particulates of aluminium–alumina oxide silicon carbide in particular, have emerged as forerunners for a variety of general and special applications. This trend has been attributed to their superior specific strength and specific stiffness and high temperature capability, lower coefficient of thermal expansion, better wear resistance, improved dimensional stability, and amenability to the conventional metal forming techniques [8-12].

2. LITERATURE SURVEY

Experimentation on machinability of Al/SiC-MMC was performed by Manna and Bhattacharyya [11]. The impact on cutting force and surface roughness criteria of machining parameters such as cutting speed, feed and cutting depth were investigated. BUE (built-up edges) and chip formation were examined through SEM micrographs at different sets of experiments. Author concluded that flank wear rate is aversively proportional to reduction speed due to high cutting force generation and BUE formation. Lin et al. [12] analysed A359/SiC/2Op machinability. Continuous turning of round composite bars using tools with 25 mm polycrystalline diamond (PCD) inserts was chosen as the test process. The matrix test conditions involved cutting speeds of 300, 500 and 700 m min 'and feed levels of 0.1, 0.2 and 0.4 mm rev, while the cutting depth was kept steady at 0.5 mm.

Mechanical cutting force model is developed by Zhang et al. [13] for the turning process. To forecast cutting forces correctly, the edge of the cutting instrument is discreet and the chip load corresponding to each section of the distinct edge is determined using a method. Approach for measuring efficient tool angles is often established taking into account the effects of the machine corner radius and the shifting trajectory of feed. Ciftci et al. [14] researched a melt stirring – squeeze casting route to prepare SiC-reinforced MMCs comprising two amounts of SiC particles of specific mean particle sizes of 30, 45 and 110 lm (8 and 16 wt per cent); At specific cutting rates, at constant feed rate and cutting depth, machining tests were conducted on the composites using uncoated and triple layer coated carbide cutting equipment.

Kaczmar et al. [15] researched the methods and properties of MMC materials reinforced with particles of dispersion, platelets, non-continuous (short) and continuous (long) products. The most commonly employed approaches for producing composite materials and composite components are focused on casting techniques such as squeeze casting of porous ceramic performs using liquid metal alloys and approaches of powder metallurgy. Sahin et al. [16] examined different cutting conditions, machinability of 2024 aluminum alloy strengthened with Al2O3 particles utilizing variable particle size and fraction weight up to 30 wt. Percentage was performed by a vortex system. The tests were conducted using TiN (K10) coated carbide tools and TP30 coated carbide tools at various cutting rates.

The findings of an experimental analysis of machinability, during turning, of silicon carbide particulate AMMC with fixed rhombic tools have been reported by Mama and Bhattacharayya [17] the impact of machining parameters such as the cuts velocity, feeding, and cutting profundity has been investigated during experimental. The combined impact of velocity cutting and feed on flank wear was noted. A new methodology was proposed by Jain et al. [18] to refine and test in Taguchi methods the machining parameters for the turning cycle on CNC Inconel-625. Lawel [19] concentrated on previous work on the application of non-ferrous metal production of vegetable oils related cutting fluids. The performance of many vegan oil cutting fluids based on several method criteria, such as thrust power, temperatures at the interface of the tool chip and flank wear. Any non-ferrous metals were illuminated during machining utilizing various tool materials. Jain [20] submitted a literature review of aluminum metal matrix composite machining (AMMC), especially particulate enhanced AMMC. This paper aims to provide a brief account of recent research on predicting cutting parameters and the surface area created by AMMC. By choosing the machining parameters correctly, AMMC processing can be economical.

The results reported by Seles et al. [21] after machining experiments on AISI 8640 steel with different cutting fluids indicate that the convection coefficient of synthetics are better than emulsion and neat oils. Higher convection coefficient of cutting fluids results in lower temperature in the chip-tool interface. Experiments with emulsions and synthetic fluids at 10% concentration proved higher cooling ability of synthetics. Tool life results obtained with synthetic and semi synthetic fluids in turning AISI 8640 steel at 400 m/min with P35 coated carbide tools indicate better results than emulsion, infers Machado et al. [22].

According to Rozzi [23] and Dhar et al. [24], application of conventional cutting fluids do not serve the purpose effectively particularly under high cutting velocity and feed. Besides, such cutting fluids pollute the environment in high production machining and grinding. Cryogenic cooling seemed to be quite effective in reducing the high cutting temperature, which impairs product quality and reduces tool life. Their work dealt with investigating the role of cryogenic cooling by liquid nitrogen jet on cutting temperature in turning plain carbon steel (C-40) under varying cutting velocity and feed.

The experimental and computational results of machining AISI 1060 steel by Paul et al. [25], Khan and Ahmed [26], Hong and Ding [27] indicate that cryogenic cooling enables substantial reduction in the cutting temperature depending upon the levels of the cutting velocity and feed and cutting tool geometry. It was also noted that the chip formation and chip-tool interaction become more favourable and the cutting forces decreased to some extent when liquid nitrogen jet was employed. Therefore, it appears that cryogenic cooling, if properly employed, not only provides environment friendliness but can also improve the machinability characteristics.

The research work carried out here is by producing composites material with Al2024 as base and adding Al_2O_3, SiC, and Gr as additive to access the machining performance of these materials under the influence of different operating conditions. The present research is intended to examine the effect on the strength resulting from cutting parameters such as rpm, feed and percentage of reinforcements, instrument temperature, surface finishing and wear by the maintenance of the continuous depth of cutting. For cooling the machining region, a vegetable oil based coolant is used.

3. METHODOLOGY

The process of the composite preparation is stir casting. The basic material Al 2024 is used and the matrix Al 2024 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 1 000 ° 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.

3.1. 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 specificity 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

3.2. 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 to measure cutting forces in turning. Figure 2 shows lathe machine and tool dynamometer used to measure cutting forces.

Figure 2 Lathe and Tool Dynamometer to Record Cutting Forces

4. RESULTS AND DISCUSSIONS

The physical and technical properties of the working object strongly affect the cutting forces. Higher cutting forces are triggered by tougher working materials. In laboratory tests the values of the three cutting force components have demonstrated an upward trend at lower speed levels. If the cutting speed rises, the cutting force components tend to decline when they plateau and are stable comparatively at higher speeds. The feed rate has the biggest effect on the specific cutting resistance and thus the cutting force components in a specific device configuration and work piece content. The narrower size of the nose reduces the cutting forces. However, small nose radius is not ideal for good surface finishing. Excessive nasal radius can also increase the likelihood of swelling due to the concentration of the temperature on the nose of the tool. Experiments show that the cutting force changes explanatory at lower speeds with the feed, and the change is slightly slower at higher speeds. The cutting depth has little impact on the particular cutting resistance. But the tangential component increases as much as the cut depth, i.e. when the cut depth is doubled, also the tangential part is doubled.

The approach angle determines the chips 'width and thickness. The thickness of the chip is reduced at smaller angles, resulting in increased special cuts. It is therefore advantageous to use a larger approach angle from the point of view of the tangential cutting force and force. The approach angle also greatly affects axial and radial components. The main cutting force increases due to the greater plastic deformation due to the difference in the side rake angle, from positive to negative.

In these experiments the cutting forces are recorded and carried out at various machining times and feed. The cutting forces (tangential and thrust force) and coefficient of friction are analysed for different working-material mixtures. Figure 3-12 shows the cutting force and the friction coefficient value obtained at different machining intervals using work pieces as cast and heat treated as well.

In Figure 3 the tangential force on HSS tool with machining time is seen to increase consistently for all materials applied. The working conditions for each graph is mentioned at the inset of figures. Mild steel being the toughest produces more tangential force component with time. Al2024 composite has shown the lowest while the remaining lie between mild steel and Al2024. In Figure 4 the thrust force with machining time is depicted for different composite materials. The trend of this and previous figure are same i.e. with increasing time the force time. In Figure 5 and Figure 6 the tangential force and thrust force on Tungsten carbide tool material with machining time is provided. The trend of these two forces on tungsten tool is similar to HSS tool. However, the only difference is that the HSS tool faces lowest tangential force when the work material is with 10% SiC. Mild steel remains at the top with high tangential and thrust force. The thrust force is lower on pure Al20204 composite.

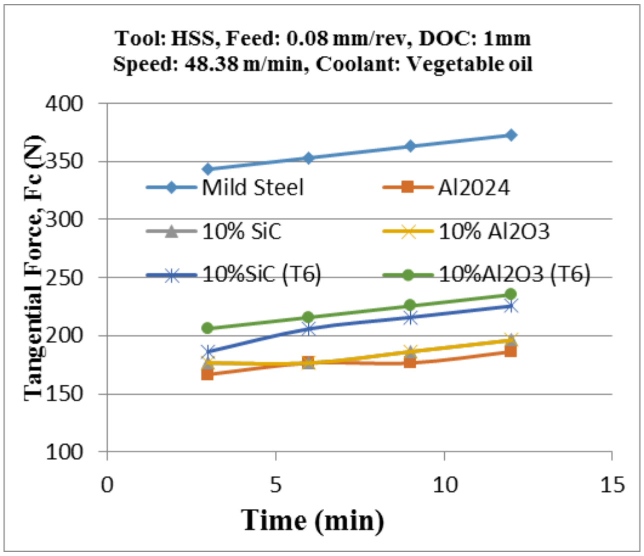

Figure 3 Tangential Force Increasing with Time for HSS Tool

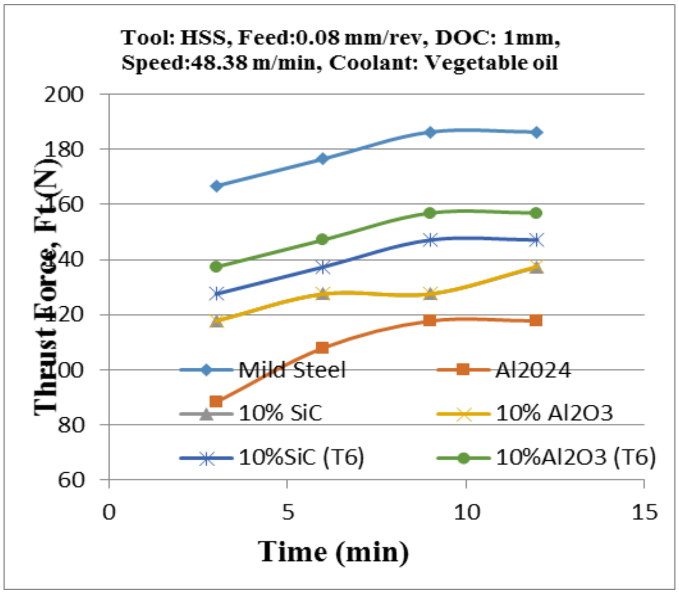

Figure 4 Thrust Force Increasing with Time for HSS Tool

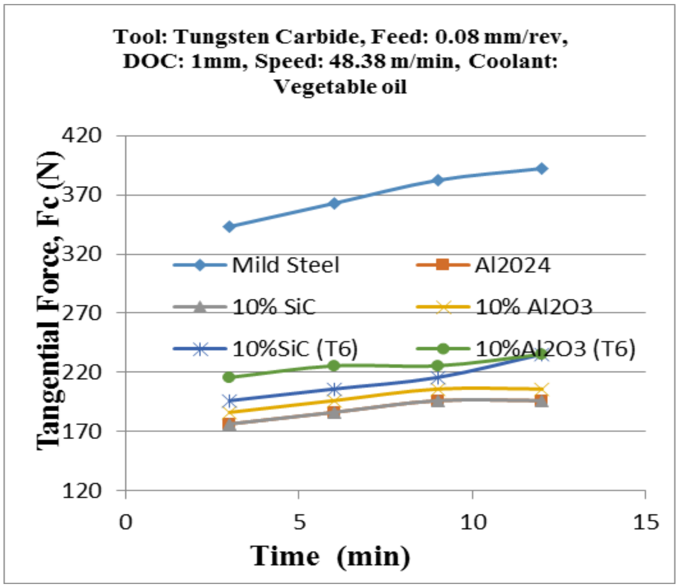

Figure 5 Tangential Force Increasing with Time for Tungsten Carbide Tool

The coefficient of friction between tool and work piece made of seven different material compositions where the machining was carried using HSS tool and Tungsten carbide tool is depicted in Figure 7 and Figure 8 respectively. The friction coefficient is highest for Mild steel and lowest for Al2024 and Al2024 with 10% Al_2O_3. The depth of cut is fixed at 1 mm and speed 48.38 m/min. the coolant oil used for this analysis is vegetable oil. The friction coefficient is maximum for mild steel and lowest for 10% Al_2O_3 at all machining time irrespective material used.

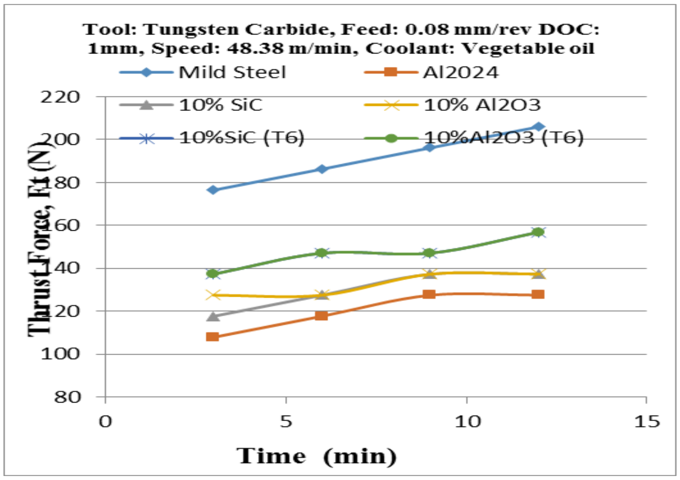

Figure 6 Thrust Force Increasing with Time for Tungsten Carbide Tool

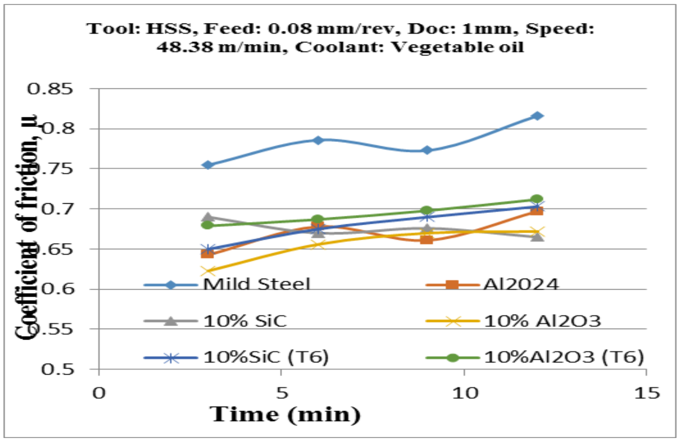

Figure 7 Coefficient of Friction Increasing with Time for HSS Tool

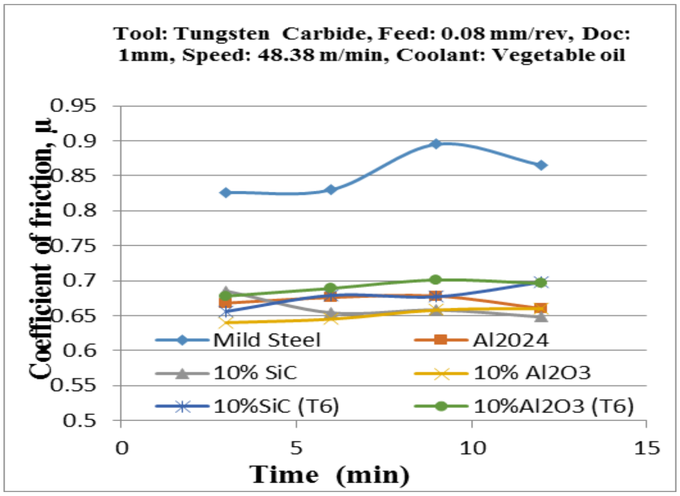

Figure 8 Coefficient of Friction Increasing with Time for Tungsten Carbide Tool

The effect of feed rate of the tool on the tangential and thrust force when it is made of HSS and Tungsten carbide is shown in Figure 9 to Figure 12 respectively. The depth of cut is kept same for both the tools at 0.5mm and speed 78.4 m/min. irrespective of any parameter changed mild steel is observed to be always at the top at all feed rates. Mild steel is comparatively stronger than Al20204 hence the machining requires more force for the operation of chip removal. Hence the Al2024 with either 10% SiC or Al_2O_3 additive the does not impact much on the tool.

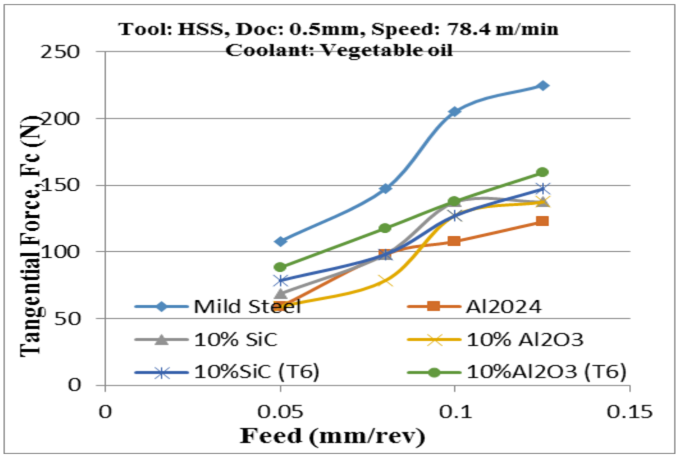

Figure 9 Tangential Force Increasing with Feed for HSS Tool

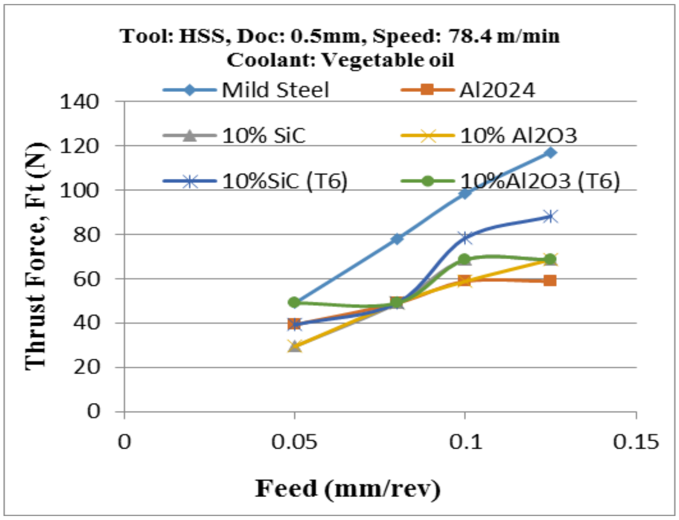

Figure 10 Thrust Force Increasing with Feed for HSS Tool

In Figure 11 and Figure 12 the tangential and thrust force on tool using Tungsten carbide tool is depicted at different feed rates. As tungsten carbide is more brittle than HSS tool the forces acting on this too are marginally greater than the HSS tool. The material mild steel is still the worst to affect the tool life due to more reaction between the material and tool. But a noticeable difference between the acting forces with respect to machining time and feed rate is the non-linear behaviour. With machining time the forces are linearly increasing while with feed the increase is non-linear.

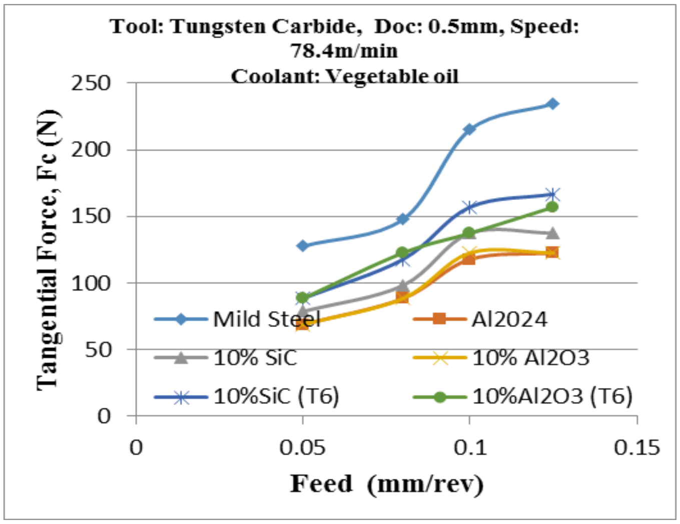

Figure 11 Tangential Force Increasing with Feed for Tungsten Carbide Tool

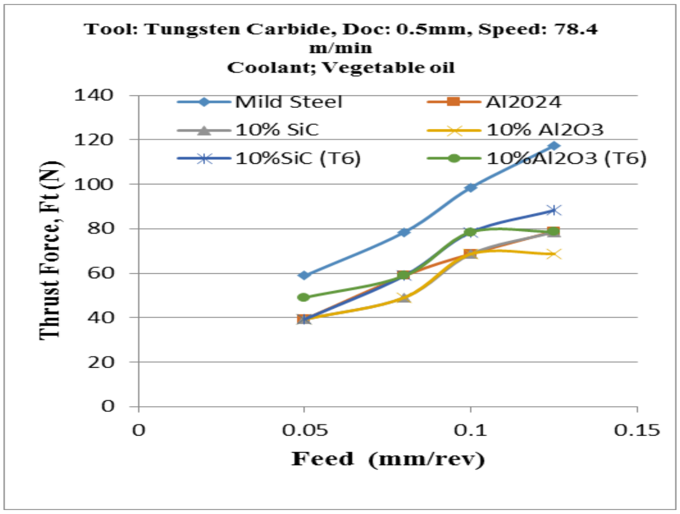

Figure 12 Thrust Force Increasing with Feed for Tungsten Carbide Tool

5. CONCLUSION

The productivity and economy of production by machining is substantially influenced by the life and quality of the cutting tools and the produced surface. The effect of tool material, work piece material, machining time and feed rate are studied in this work. With cutting time, the components of the tangential force and thrust force increased. Mild steel is machined with HSS tool and its tangential force is higher by about 20-50% than composite materials using vegetable oil as coolant. Cutting forces improved with rise in fed rate and machining time. The work piece had a slightly different behaviours on the forces. Mild steel had a worst cutting force impact while Al20204 with some times 10% SiC or Al_2O_3 has given lower cutting forces.

REFERENCES

[1] Masuko M, Suzuki A, Sagae Y, Tokoro M YK. Friction characteristics of inorganic or organic thin coatings on solid surfaces under water lubrication. Tribol Int 2006;39:1601–8.

[2] Axinte DA, Belluco W DCL. Reliable tool life measurements in turning—an application to cutting fluid efficiency evaluation. Int J Mach Tools Manuf 2001;41:1003–14.

[3] Su Y, He N, Li L, Iqbal A, Xiao MH, Xu S QB. Refrigerated cooling air cutting of difficult-to-cut materials. Int J Mach Tools Manuf 2007;47:927–33.

[4] Dhar NR, Paul S CA. Role of cryogenic cooling on cutting temperature in turning steel. J Manuf Sci Eng 2002;124:146–54.

[5] Mukhopadhyay D, Banerjee S RN. Investigation to study the applicability of solid lubricant in turning AISI 1040 steel. J Manuf Sci Eng 2007;129:520–6.

[6] Afzal A, Mohammed Samee AD, Abdul Razak RK, Khan SA, Khan H. Optimum spacing between grooved tubes: An experimental study. J Mech Sci Technol 2020;34:469–75. https://doi.org/10.1007/s12206-019-1244-7.

[7] Afzal A, Abdul Mujeebu M. Thermo-Mechanical and Structural Performances of Automobile Disc Brakes: A Review of Numerical and Experimental Studies. Arch Comput Methods Eng 2019;26:1489–513. https://doi.org/https://doi.org/10.1007/s11831-018-9279-y.

[8] Afzal A, D MSA, K ARR. Experimental Investigation of Thermal Performance of Engine Coolant Oil and Water in Helical Coil Heat Exchanger. J Eng Res 2019;8:333–51.

[9] Afzal A, Samee A. D M, Javad A, Shafvan S A, P V A, Kabeer K. M A. Heat transfer analysis of plain and dimpled tubes with different spacings. Heat Transf Res 2018;47:556–68. https://doi.org/http://dx.doi.org/10.1002/htj.21318.

[10] Pinto R, Afzal A, D'Souza L, Ansari Z, Mohammed Samee AD. Computational Fluid Dynamics in Turbomachinery: A Review of State of the Art. Arch Comput Methods Eng 2017;24:467–79. https://doi.org/https://doi.org/10.1007/s1183.

[11] A.Manna, Bhattacharayya, "A study on machiniability of Al/Sic MMCs", journal of materials processing technology, 140(2003) 711-716.

[12] J.T.Lin, D.Bhattachacharyya, c. lane, "Machiniability of a silicon carbide reinforced aluminium metal matrix composite", elesevier 1995, wear 181-183pp.

[13] Guicia Zhang, Changsheng Guo, "Modeling of cutting force distribution on tool edge in turning process", 43rd proceedings of the north American manufacturing research, volume 1, 2015 page 444-465.

[14] Ibrahim ciftci, Mehmet Turker, "Evaluation of tool wear when machining Sic reinforced Al2014 alloy matrix composites", materials & design 25(2004) 251-255.

[15] J.W.Kaczmar, K.pietrzak, W.Wlosinski, "The production & application of metal matrix composite materials", journal of materials processing technology, 106(2000) 58-67.

[16] Y.Sahin, M.Kok, H.Celik, "Tool wear & surface roughness of al2o3 particles reinforced aluminium alloy composites", journal of materials processing technology, 128(2002) 280-291.

[17] A.Manna, Bhattacharayya, "A study on machiniability of Al/Sic MMCs", journal of materials processing technology, 140(2003) 711-716.

[18] M.Kok, "Production & mechanical properties of al2o3 particles reinforced 2024 aluminium alloy composites", journal of materials processing technology , 161(2005) 381-387.

[19] Hemanth Jain, Jaya Tripathi, Ravindra.B, "Optimisation & evaluation of machining parameters for turning operation of Inconal 625", materials today proceedings 2(2015), 2306-2313.

[20] Salete Martins Alves, "Vegetable based cutting fluid – an environmental alternative to grinding process"

[21] Sales et al., Not Always the Cutting Fluid with Higher Cooling Ability Guarantee Lower Cutting Tool Temperature, Maq Metals, Aranda Publisher, No.407, Dec. 1999, pp.46-61
[22] Machado A.R., Motta M.F, Dasilva M.B, Performance of Synthetic and Soluble Oil When Turning AISI 8640 steel, Journal of Manufacturing Science and Engineering Vol.119, No.4, (A), pp.580-586
[23] Rozzi. J. "Final Report: Low cost Machining without Cutting Fluids", National Centre for Environmental Research
[24] N.R. Dhar, S.Paul, A.B. Chattopadhyay, Role of Cryogenic Cooling on Cutting Temperature in Turning of Steel, Journal of Manufacturing Science and Engineering. Vol.124, issue, February 2002, pp.146-154
[25] S. Paul, N.R. Dhar, A.B. Chattopadhyay, Beneficial Effects of Cryogenic Cooling Over Dry and Wet Machining on Tool Wear and Surface Finish in Turning AISI 1060 Steel, Journal of Materials Processing Technology, vol. 116,issue 1, 2001. pp 44-48
[26] Ahsan Ali Khan Mirghani I Ahmed, Improving Tool Life using Cryogenic Cooling, Journal of Materials Processing Technology, Vol.196, issue 1-3, 2008, pp.149-154
[27] Shane Y.Hong, Yuchang Ding., Cooling Approaches and Cutting, International Journal of Machine Tools Manufacturer Vol.41.issue 10, August 2001, pp.1417-1437.

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