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Influence of Particle Size on Machinability Behavior in Turning of AA6061-AlN Composites

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ABSTRACT

Machinability of the composites and achieving the dimensional accuracy in addition to surface finish at an economic machining rate is still the topic for numerous researchers. The current article describes the variation in machinability characteristics of AA6061-AlN composites under various sizes of reinforcements. Cutting speed, cutting depth and feed rate are preferred to perform the turning test. Cutting force, surface roughness and flank wear are identified to appraise the machinability characteristics. For an identical machining condition, the nano particle reinforced composite has less surface roughness and minimal flank wear and a greater cutting force than the other composites. An increment in cutting speed raises the flank wear and declines the surface roughness and cutting force for all composites. The findings from the experimental investigation help to utilize the turning process for machining the composites with various sizes of reinforcement at the economic rate of machining without compromising the surface quality.

KEYWORDS

Aluminum Composites, Aluminum Nitride, Cutting Force, Flank Wear, Machinability, Micro Particle, Nano Reinforcement, Particle Size, Surface Roughness, Turning

1. INTRODUCTION

In a couple of decades, the role of aluminum matrix composite is unavoidable in the transport, military and air vehicle sectors owing to its amazing properties and the prospective for weight reduction. Utilization of the composites brings out the lower fuel expenditure, energy consumption, noise and airborne emissions in turn enhance the competitive advantage of the aforesaid sectors (Surappa, 2003; Adalarasan & Santhanakumar,2017). Aluminum nitride (AlN) has covalent bond with hexagonal structure. Further, the AlN has exceptional thermophysical properties, superior interfacial adherence with aluminum matrix, greater thermal conductivity and coefficient of thermal expansion. AlN materials extensively used in gas and electronic package industries, wherever elevated temperatures are associated (Liu et al. 2009). Al-AlN composites are employed in producing microelectronic devices (Lii et al. 2003). AA6061 is a precipitation hardened alloy and possess intermediate strength and corrosion confrontation. Magnesium and silicon are major alloying elements of the AA6061 alloy. It is used in assembly of aircraft structures like wings and fuselages, automotive components and marine applications (Amneesh et al. 2016). Yu et al. (2011) reported a way to synthesize in-situ Al–AlN composite by nitriding a powder mixture of AA6061–2% Mg–1% Sn at 560 °C and found that Al–AlN composite offered better mechanical properties than the monolithic alloy. Ayse et al., (2013)

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developed AlN-Si-Al composites by pressure less infiltration technique. Their investigation report disclosed that the extreme thermal conductivity and thermal expansion coefficient of the fabricated composite. Fale et al., (2013) proposed a novel method to manufacture the Al-AlN composites by reacting the NH4Cl and CaO with aluminum melt. Kumar & Murugan (2012) fabricated the AA6061-AlN by stir casting process and studied the mechanical properties of the composites under various reinforcement ratios. Result of the experimental work indicates that the AA6061-20% AlN composite has the enhancement of 48% yield strength, 32% ultimate tensile strength, 51% hardness (VHN) and reduction of 54% ductility than the unreinforced AA6061 alloy. Among the various methods to produce the composites, stir casting method has numerous advantages including simple, flexible, inexpensive, appropriateness for mass production and production of multi-face profiled composite parts (Hashim et al. 1999). Akbari et al. (2013) discussed a novel method to fabricate the Al-Al_2O_3 nano composite by integrating the high energy ball milling cum stir casting process. Further, they described the mechanism for attaining the homogeneous distribution and lower porosity by controlling the stirring speed.

The variation of reinforcement size on mechanical properties is well documented in the literature. Akbari et al. (2013) observed the increment in the hardness, tensile and compressive strength by reducing the Al_2O_3 size from 50 μm to 20 nm. High degree strengthening effect and grain refinement of nano size Al_2O_3 into the A356 alloy brings tremendous improvement in the aforesaid mechanical properties. Wasik et al. (2017) also noted the similar enhancement in mechanical properties by declining the size of the SiC particle from 60 μm to 2 μm. Ghods et al. (2015) found that the improvement of flexural strength of Al-AlN composite by declining the reinforcement particle size from 1 μm to 50nm.

The knowledge on machinability of the material enables to develop the process plan in an effective and economic way (Alabdullah et al.2017). The wide spread application of the composite material is restricted due to its poor machinability. Attaining the dimensional accuracy and surface finish at economic machining rate is still the subject for many researchers (Sekhar & Singh, 2015). The conversion of the composite sample into the desired component requires some additional processing. Among the various additional processing, machining is unavoidable process to convert the composite sample into preferred components (János et al 2016; Ashwin et al 2018). The ceramic phases embedded into the composite samples offers faster tool wear, residual stress formation, poor dimensional control and surface finish. Finer surface finish of the machined component improves the fatigue life, corrosion and thermal resistance (Maity & Pradhan, 2017). Machinability assessment under various machining parameters and reinforcement ratio are widely reported in the literatures (Anandakrishnan & Mahamani 2011; Ismail et al. 2018). Said et al. (2013) performed a chip formation study in milling of Al-SiC/AlN composites. Crescent shaped elemental chips are formed during machining. Scanning electron microscopic study of chip shows that the micro cracks at outer side of chip as a mark of greater shear stress. Tomadia et al. (2017) developed a mathematical model to envisage the surface roughness by means of regression analysis in terms of coating type, cutting speed, feed rate, cutting depth and volume content of reinforcements in milling of Al-Si/AlN composites. The variance analysis indicates that the coating type has momentous consequence in generating surface roughness. Kannan et al. (2009) found that the consequence of the particle size on machining force in turning the Al-Al_2O_3 composites. Result of the investigation indicates that the feed force and cutting force are raised by enhancing the particle size from 9.5 μm to 25 μm. The literature review indicates that the study on influence of particle size on machining characteristics requires further attention. A number of investigations are further required to address the machinability behavior of the composites to promote the industrial application. Therefore, the current paper deals the influence of the particle size on machining characteristics of the AA6061-AlN composites. High energy ball milling cum stir casting process was employed to disperse the macro, micro and nano size AlN reinforcement into AA6061 matrix. The chip formation and morphology of the machined surface are investigated apart from cutting force, flank wear and surface roughness.

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