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Investigation on Cutting Force, Flank Wear, and Surface Roughness in Machining of the A356-TiB_2/TiC in-situ Composites

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ABSTRACT

This article reveals the experimental investigation on the machinability of A356-TiB_2/TiC in-situ composites prepared by a mixed salt reaction system. The fabricated composites are characterized by Energy dispersive analysis (EDAX), X-ray Diffraction (XRD), scanning electron microscopy (SEM) and micro-hardness analysis. Multi-coated tungsten carbide tool was used to examine the influence of TiB_2/TiC reinforcement ratio on machinability behaviour of composites. The variations in cutting speed, feed rate and depth of cut upon cutting force, surface roughness and flank wear were examined. The experimental results revealed that the enhancement of a reinforcement ratio causes the decrease in cutting force and increase in flank wear and surface roughness. Higher flank wear is observed, when machining the A356-TiB_2/TiC composites at higher cutting speed due to the generation of high temperature at the machining interface. The increment in surface roughness, flank wear and cutting force is experienced at higher depth of cut and feed rate. Further, the mechanisms of chip formation and surface generation under different machining parameters are addressed. The outcome of this experimental investigation helps to utilize the turning process for machining the in-situ composites at economic machining rate without compromising the surface quality.

KEYWORDS

Chip Formation, Cutting Force, Flank Wear, In-situ Composites, Machinability, Surface Roughness, Surface Texture, TiB_2/TiC

1. INTRODUCTION

Aluminium matrix composite has high strength, low weight, good wear resistance, excellent formability, high thermal conductivity and low thermal expansion (Chen et al., 2000). These materials successfully applied in centrifugal pumps, control valves, heat exchangers, nozzles and barrel liner for guns (Lewis, 1991). A356 alloy has good castabilty and strength to weight ratio. These properties make them to use in various fields, including torpedoes, missile bodies and automobile components like engine cylinders and pistons. (Amneesh et al., 2016; Shyam Kumar et al., 2015; Srinivasu et al., 2015). TiB_2 and TiC are boride, and carbide-based reinforcements and has superior hardness, stiffness and resistance. These reinforcements will act as good grain refining agents for aluminium alloy (Kennedy & Wyatt, 2000). TiB_2 and TiC reinforcements refine aluminium grains and enhanced the interfacial bonding strength between reinforcements and matrix, which causes improvement in mechanical properties (Birol, 2006).

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Machining of the composite material and achieve the geometrical accuracy is a paramount task. Turning is a basic operation is to covert fabricated composites into the desired size and shape (Devinder, 2012; Singh & Singh., 2013). During turning operation, composite material offers variable forces on cutting tool edge. Due to presence of ceramic reinforcement phase, this reinforcement shears the cutting edge and causes the tool wear. This worn-out tool increases an area of contact and spoils the surface texture of a machined surface (Mishra & Sahu, 2014). It is essential to understand the mechanism of chip formation and surface generation and address the challenges associated with the machining of the composites (Hiremath & Auradi, 2016). In-situ composites are attracted many scientists due to its superior mechanical properties. These properties are achieved by reinforcing of small size, dirt and oxide-free reinforcements, which are generated by exothermic chemical reaction. (Tjong and Ma, 2000). Al_2O_3, AlN, TiB_2, TiC, ZrB_2, and Mg_2Si ceramics can be reinforced into aluminium alloys via in-situ synthesis (Pramod et al., 2000). Fabrication of the in-situ reinforcement by reacting with the inorganic halide salts were well documented from the literature. Mahamani, (2011) described that the mechanism of flux assisted synthesis method to fabricate the TiB_2 reinforced composites. The role of the exothermic reaction in developing of high interfacial strength, improved wettability and the cluster-free reinforcement formations are discussed. Dinaharan et al., (2011) synthesized zirconium diboride reinforced composites via K_2ZrF_6-KBF_4 reaction system. Experimental results revealed that the hardness, ultimate tensile strength and wear resistance of composites is improved by an increase in the volume fraction of ZrB_2 particles within the matrix. Mahamani et al., (2015) presented the dual reinforced in-situ composites fabricated through K_2TiF_6-KBF_4-K_2ZrF_6 reaction system. Presence of micro size TiB_2 and sub-micron size ZrB_2 reinforcements in the matrix improved the mechanical properties. Jerome et al., (2010) discussed the synthesis of Al-TiC composites produced by fabricating the composite by reacting with the K_2TiF_6 and graphite with aluminium melt. Analysis of results shows that the addition of reinforcement enhanced the wear performance of aluminum composites.

The machinability issues on aluminium ex-situ composites are widely reported in the various literatures. (Krishnamurthy et al. 2011; Thirumalai Kumaran and Uthayakumar 2014; Kannan and Kishawy 2008). Machining behavior of the in-situ aluminium matrix composite has received limited attention in the reported literature. Anandakrishnan & Mahamani (2011) conducted turning studies on AA6061-TiB_2 reinforced composite considering machining parameters as cutting speed, feed rate and depth of cut. Results of the experimental work indicated that the increase as the volume fraction of reinforcement increases the tool wear and surface roughness. Kumar et al., 2014 examined the chip formation in machining of in-situ Al–4.5%Cu/TiC composites under dry turning by using uncoated ceramic inserts. Scanning electron microscopic analysis of the cutting tool shows that the less built-up edge formation at higher cutting speed. Further, it is founded from analysis; the reinforcement ratio offers considerable influence in the chip formation and also noticed that the chip shape was changed from ductile C-type to be segmental, with an increase in reinforcement ratio. Ozcatalbas, (2003) described the chip formation mechanism in machining of in-situ Al_4C_3-Al composites at various turning conditions. Analysis of results discloses that the higher volume fraction of reinforcement reduces the formation of a built-up edge across the rake face of a tool. Further, the cutting force is sensitive with respect to the feed rate, and also it represents that surface roughness of the composites was increased by an increase in tool feed rate during turning of composites. Fabrication of dual reinforced composite offers the more complimentary balance between the intrinsic advantages (John et al., 2009).

Hybridization is a way to explore the advantages of reinforcements. In the present investigation titanium diboride (TiB_2) and titanium carbide (TiC), reinforcements generated through mixed salt reaction and this combination has a potential for improvement in mechanical properties and wear resistance to elevated temperatures. Therefore, it is expected that the reinforcing TiB_2 and TiC ceramics into A356 matrix would serve many automobile applications. Hence, the mechanism of the chip formation and surface generation at various turning conditions and reinforcement ratio facilitates for obtaining the economic machining rate without compromising the surface quality. Further, the literature review exposes that the machinability issues on A356-TiB_2/TiC composites

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