# Determination of Optimum Parameters for Multi-Performance Characteristic in Turning of Al 6061-6% $ZrB_2$ in-situ Metal Matrix Composite Using Grey Relational Analysis

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## ABSTRACT

*In-situ aluminum matrix composite is the innovation of high performance material technology and it has superior interfacial integrity and thermodynamic stability between the matrix and reinforcement. During synthesis, the $ZrB_2$ particle is formed by exothermic reaction within the aluminum melt. As a result, small, fine and oxide free reinforcements are formed. Excessive temperature released from in-situ chemical reaction will facilitate the homogeneous distribution of particles in entire shape of the composites. Making the engineering components from this composite material require machining operations. Therefore, addressing the machinability issues of the composite is very important. This paper proposes an approach to optimize the machining parameters in turning of Al 6061-6% $ZrB_2$ in-situ Metal Matrix Composite (MMC) with multiple performance characteristics by using grey relational analysis. The effect of in-situ $ZrB_2$ reinforcement particles on machinability behavior need to be studied. The machining parameters, namely cutting speed, feed rate and depth of cut are optimized with considerations of multiple performance characteristics including surface roughness, tool wear and cutting force. It is concluded that the feed rate has the strongest effect. The confirmation experiment indicates that there is a good agreement between the estimated value and experimental value of the Grey relational grade.*

*Keywords:* *ANOVA, Cutting Mechanism, Grey Relational Analysis, in-situ Metal Matrix Composite, Multiple Responses, Optimization, $ZrB_2$ Reinforcement*

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# 1. INTRODUCTION

Metal matrix composites have attracted the attention of many researchers for its superior hardness, wear resistant, formability, corrosion resistance and elevated strength with minimal weight. Machinability issues of ex-situ metal matrix composites are highly focused in literatures (Muthukrishnan et al., 2008; Pramanik et al., 2008; Manna & Bhattacharyya, 2003; Ozben et al., 2008). Coarse, uninformed distribution and agglomeration of reinforcements present in the matrix are obstacles for machinability behavior of metal matrix composites (Daniel et al., 1997). In-situ composites have overcome these problems because of the formation of reinforcements by exothermal chemical reaction. The 6061 aluminum alloy has been used in automotive industry for the fabrication of parts which includes wheel, panels and vehicle structure (Demir & Gunduz, 2009). ZrB2 is known to have many superior properties such as high melting temperature, hardness, corrosion resistance, oxidation resistance and electrical conductivity, being used for aircraft / rocket components working at special high temperature, cutting tools and cathode material for aluminum refinement furnace (Guo et al., 2006; Yu & Yang, 2005). Production of in-situ metal matrix composite by flux assisted synthesis was widely reported in the literatures (Naveenkumar et al., 2010; Zhang et al., 2008; Zhao et al., 2005; Sivaprasad et al., 2008; Yue et al., 1999; Kumar et al., 2007; Lu et al., 1997). Most of published work focused on synthesis, characterization and wear studies of Al-ZrB2 in-situ composites (Naveenkumar et al., 2010; Zhang et al., 2008; Zhao et al., 2005). Very few researchers were studied the machinability behavior of in-situ composites.

Ozcatalbas (2003a) carried out an experimental investigation on machinability behavior of Al-Al4C3 in-situ composites. The micro crack propagation at particle-matrix interface facilitates the fracturing through the chip cross section this effect reduce the cutting force. The homogeneous microstructure and high hardness of the composite reduce the buildup edge formation that improves the surface roughness.

Ozcatalbas (2003b) investigated the chip and buildup edge formation in machining of the in-situ Al-Al4C3 composites. The morphologies of chip routes were determined by using the quick stop device. It was observed that the small size particle and high hardness of the composite cause discontinuous chip formation and increasing the chip cutting ratio.

Rai et al. (2006) conducted the experiments on machining of Al-TiC in-situ composite. They reported the chip formation and cutting force measurements during shaping operation. High volume fraction of the TiC particles causes discontinuous and favorable chip formation without any build up edge formation. The cutting force was minimized due to the propagation of micro cracks at particle-matrix interface. Size and morphology of the TiC particle present in the composite have been found to influence surface roughness.

Anandakrishnan and Mahamani (2010) investigated machinability of the in-situ Al6061-TiB2 composites. They reported the effect of speed, feed and depth of cut on flank wear, cutting force and surface roughness. It was observed that presence of small and fine TiB2 particles have offered significant influence on machinability.

Now a day's optimization of machining parameters plays an important role in high quality and cost effective products. Surface roughness is the most critical quality measure for the mechanical machined components. Frequent tool wear causes the poor surface finish, increase in tool cost and manufacturing time. Cutting force is an important measure to assess the friction between the tool and work piece. Wrong selection of machining parameters reduces the machining efficiency and quality of the products (Tosun, 2006). Optimization of multi criteria problems are a great need of producers to product precision parts with low costs. Many methods such as Taguchi and Response Surface Methodology have been employed for optimization of the machining

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