ABSTRACT

In recent trends, metal matrix composites (MMC) have attracted the potential interest in engineering materials due to their superior mechanical properties than the conventional materials. The way of selecting the particular properties of the constituent materials to meet the specific demand is the most important motivation for the development of composites. In general, MMCs possess increased strength, higher service temperature, decreased part weight, and improved wear resistance compared to monolithic materials.

Aluminum and its alloys are the most popular matrix for metal matrix composites. Aluminum matrix reinforced with ceramic particles such as oxides, carbides, nitrides offer a large variety of mechanical properties depending on the chemical composition of the Al matrix. Hence, they have been widely used for high performance structural application in automotive, aerospace and defence industries. Among the various ceramics, Boron carbide (B₄C) possesses excellent physical and mechanical properties like high melting point and hardness, good impact and wear resistance, excellent resistance to chemical agents as well as high capability for neutron absorption. Because of its specific features, it has potential applications in power plants and nuclear industries.

The fabrication of durable and usable aluminum based MMC is challenging in several aspects. The joining of MMCs using conventional welding techniques has certain limitations on mechanical properties of composites due to
deleterious reaction between the reinforcing material and liquid state matrix. Hence, the solid state welding process is needed for joining of MMCs.

Based on the above considerations, the present investigation was carried out to fabricate boron carbide reinforced aluminum (6061) matrix composite with low cost option and welded using friction stir welding machine. Mechanical and metallurgical characterizations were performed on the fabricated as well as welded MMCs. The dry sliding wear characterization was also carried out on the stir zone of welded samples.

Aluminum matrix composites reinforced with B₄C particles of weight fraction 4% to 12% at a step of 2% was fabricated using the modified stir casting technique. The titanium containing flux K₂TiF₆ was used to overcome the wetting difficulty between B₄C and aluminum melt. The microstructure and mechanical properties of the fabricated composites were characterized using optical microscopy (OM) and scanning electron microscopy (SEM). Microstructural examination revealed the dispersion of B₄C particles homogeneously and well bonded with matrix. The presence of B₄C particles and its compound in the matrix are evidenced with X-ray diffraction and EDAX Analyzes. Mechanical properties like hardness and tensile strength were improved with the increase in weight percentage of B₄C particulates in the aluminum matrix.

The manufactured composites were friction stir welded using indigenously designed and developed FSW machine. In order to investigate the weldability of AA6061/B₄C/4-12p MMC, central composite design of experiments
and Analyzes of variance (ANOVA) were considered to control the number of experiments. Regression models were developed which can be used for predicting the ultimate tensile strength (UTS) and percentage of elongation (% E) of friction stir welded AA6061/B₄C MMC joints for any given set of process variables. The influences of friction stir welding parameters on UTS and % E of welded joint were analyzed from the developed models. FSW process parameters were optimized to maximize the UTS and % E of welded joint. The joint fabricated at optimized process parameters exhibited a maximum tensile strength.

Metallurgical characterization such as microhardness survey and microstructure of friction stir welded MMCs was performed at different (Low, medium, high and optimum) heat input conditions. A considerable increase in hardness was observed in the weld zone when compared to the base metal for all heat input conditions. The distinct phases present in the weldment were observed using OM and SEM. Photomicrograph revealed the presence of numerous fine particles with the substantial grain refinement of the matrix in the stir zone. Highly elongated grains of aluminum alloy were observed in the thermo mechanically affected zone. The fracture surfaces of welded joint at different heat input conditions mostly promoted a brittle failures.

The dry sliding wear properties of the welded composites were studied using a Pin on disc wear testing machine. The presence of fine grain along with B₄C particles in the nugget zone improved the wear properties. A regression model was developed to predict the wear rate of welded composite for the given set of FSW
process variables. Optimized FSW process parameters were estimated to minimize the wear rate. SEM Analyzes was carried out to examine the Worn Out surfaces of wear tested specimen of composites. The micrograph depicted presence of fine grooves and wear track relative to the % of reinforcement in the matrix. The higher % of B₄C content in the matrix offered good wear resistance.