DEVELOPMENT AND MICROMECHANICS OF IN-SITU Al-Mg_2Si COMPOSITES

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ABSTRACT

In-situ Al-XMg_2Si (X = 0.0, 5.0, 10.0, 15.0 and 2.0 wt.%) composites have been developed through gravity casting technique. The effects of Mg_2Si concentration on phase formation, thermal stability, density, microporosity, microstructural morphology, hardness, tensile strength, compressive strength, fracture behaviour, dry sliding wear behaviour and micromechanics of Al-Mg_2Si composites have been studied. Additionally, the performance of the Al-Mg_2Si composites has been analyzed through the material selection technique (Digital logic method) and the simulation of a disc brake rotor for two-wheelers (Pulsar 150) has been performed through finite element analysis considering the optimum Al-Mg_2Si composite as a disc brake rotor material.

Inductively coupled plasma (ICP)- Mass spectrometry (MS), differential scanning calorimetry (DSC), thermogravimetric analysis (TGA), optical metallography, X-ray diffraction (XRD), field emission scanning electron microscopy (FESEM) and FESEM-equipped with energy-dispersive X-ray spectroscopy (EDS) have been performed to characterize the developed composites. Standard hardness, tensile, and compression tests have been carried out to ascertain the hardness, strength, and ductility of the developed composites. The tensile fractured and compressive internal fracture surfaces have been examined under a scanning electron microscope to study the failure mode in correlation with microstructure and properties. Dry sliding wear test of developed Al-Mg_2Si composites specimens (wear testing pins (Φ = 7 mm and L = 22 mm) has been carried out using a pin-on-disk wear testing machine. The pins have been loaded against a rotating steel disc (EN 31, Hardness = 60 HR_C, HV 695) with four different normal loads (19.6 N, 29.4 N, 39.2 N, and 49 N). The dry sliding wear test has been performed at room temperature in an open-air environment (relative humidity ≈55%) with a fixed rotating speed, sliding distance, wear track diameter, and total sliding time of 200 rpm (sliding speed = 2.1 m/s), 3768 m, 0.1 m and 1 hour, respectively.

FESEM-EDX analysis confirms the addition of commercially pure Mg and Si in commercially pure Al forms in-situ Mg_2Si. The primary Mg_2Si phase volume fraction and size increase with the increase in Mg and Si concentration in the Al-Mg-Si system. Additionally, hollows (aluminium entrapment) in the primary Mg_2Si particles are also increased. The bulk hardness, yield strength and compressive strength of the Al-Mg_2Si composites increase and ductility decrease with increasing Mg_2Si concentration in the Al-Mg_2Si composite. The Al-Mg_2Si composites have a mixed mode of ductile and brittle

fracture under tension. Further, brittle fracture increases with the increase in Mg_2Si concentration in the Al-Mg_2Si composites under tension and compression. Dry sliding wear of Al-Mg_2Si involves adhesion (associated with subsurface cracking and delamination) and micro-cutting abrasion, abrasive wear (involving micro-cutting and microploughing), drilling effect, and adherent oxide formation. The wear resistance of the commercially pure aluminium significantly increases due to Mg_2Si addition and wear resistance is increased with the increase in Mg_2Si concentration up to 15.0 wt.% and then decreases at 20.0 wt.%. The wear mechanism is changed with the change in Mg_2Si concentration in the Al-Mg_2Si composite.

Micromechanics of in-situ Al-Mg_2Si composites has been studied through the representative volume elements (RVEs) technique. The deformation plasticity (Ramberg-Osgood) model has been considered to investigate the micromechanics of in-situ Al-Mg_2Si composites. Needle-like eutectic Mg_2Si particles and sharp corners of primary Mg_2Si particles, interconnected regions of primary Mg_2Si clusters, and matrix (Al)-reinforcement (Mg_2Si) interfaces are the stress concentration and preferable failure initiation region, under tension and compression. The Al phase nearby the eutectic and Mg_2Si phases sharp corners and narrow Al phase region between two Mg_2Si islands and between two-grain boundary regions are the strain localized and preferable void initiation regions under tension and compression.

The digital logic method has been employed to understand the performance of developed Al-Mg_2Si composites by comparing them with other traditional disc brake rotor materials such as grey cast iron and stainless steel. The technical performance index and relative cost analysis reveal that the Al-15Mg_2Si and Al-20Mg_2Si composite have more or less the same performance index and better effective cost index compared to stainless steel and grey cast iron. Disc brake rotor simulation reveals that the Al-20Mg_2Si composites are structurally safe for rotor application and have excellent heat dissipation compared to stainless steel. Therefore, Al-20Mg_2Si composite can be a potential replacer of the existing motorcycle disc brake rotor materials.