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Production, characterization and analysis of mechanical properties of a newly developed novel aluminium-silicon alloy based metal matrix composites

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Abstract

In this paper, a novel in situ ceramic composite consisting of Al_2O_3-SiC-C has successfully been prepared from waste fly ash material obtained from thermal power plant. The EDAX and X-ray studies have confirmed nearly complete conversion of SiO_2 to SiC by thermal reduction in a plasma reactor. Particle size ranging between 5 μm-30μm with different shape and aspect ratios are observed. Al-Si alloy based AMC are prepared with untreated and treated fly ash having 14.3% & 13.2% of volume respectively. Mechanical properties like hardness, impact energy, compression strength and tensile properties such as UTS, YS are more for AMC prepared with thermally treated fly ash in comparison to AMC prepared with untreated fly ash and Al-Si alloy.

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Keywords: Fly ash; Plasma treatement; Carbo thermal reduction; Ternary insitu cermaic composite; Al-Si alloy based MMC;

1. Introduction

During past few decades, researchers have focused on finding lightweight, eco friendly, high quality, good performance and low-cost materials (Feest 1986). In accordance with this trend, Metal matrix composites (MMC) have created growing interest among researchers and industrialists. Amongst different classes of composites, MMCs

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are the precursor. Since last twenty years MMCs have altered from a topic of scientific and intellectual interest to a material of broad technological and commercial implication (Miracle 2005). In recent years Aluminium based MMCs have received increasing attention as engineering materials because of their lightness, higher specific strength and wear resistance. Choice of a suitable combination of matrix with reinforcement materials has become an interesting area for manufacturing science in MMCs (Ashby et al.1980). Aluminium-silicon alloys, as a matrix material, are chosen for their good strength-to-weight ratio, ease of fabrication at reasonable cost, good thermal conductivity, high strength at elevated temperature, excellent corrosion resistance as well as good castability and wear resistance properties. Thus, these alloys are suitable for aerospace, automotive and military applications. Majority of eutectic or near eutectic Aluminum-silicon alloys are used to produce pistons and are, therefore, known as 'piston alloy', which provides the best overall balance of properties (Day et al.1970**)**. The traditional material such as cast iron as engine component is replaced by lightweight Al–Si alloy castings which help in savings fuel and reduces vehicle emissions .However, the main weaknesses of aluminium alloys lie in a fact that they exhibit low wear resistance and creep resistance. Therefore, ceramic particles are added to reinforce aluminium alloy matrices to overcome these problems (Pedersen et al.2006, Suresh et al.1993, Pramanik et al.2006, Zhang et al.1995,Yan and Zhang 1995,Zhang et al.1995) .Al_2O_3 and SiC powder are two commonly used reinforcing agents in Aluminium metal matrix composites (AMCs) and the addition of these reinforcements to aluminium alloys has become the subject area for research work (Sahin 2003, Hanumanth and Irons 1993).In the automotive and aircraft industries, Al_2O_3 or SiC reinforced aluminium alloy matrix composites are applied for pistons, cylinder heads, etc., where the tribological properties of the material are very important (Mostaghaci 1989, Gibson et al.1985, Dellis 1991, Rohatgi 1991, Dinwoodie 1987, Joshi et al.1995, Kocazac et al.1993). Therefore, the development of AMC is emphasized for meeting the requirements of various industries. The mixtures of hard second phase particles in the alloy matrix to produce AMC is also considered to be beneficial and economical (Chadwich and Heath 1990). Fly ash particles are potential discontinuous dispersoids used in metal matrix composites, since they are low-cost and low-density reinforcement available in large quantities as a waste by-product in thermal power plants. The fly ash contains the most important chemical constituents like SiO_2, Al_2O_3, Fe_2O_3 and CaO. It constitutes quartz, mullite, magnetite, hematite, spinel, ferrite and alumina (Rohatgi 1994). Addition of fly ash particles to Al matrix improves the hardness, wears resistance, damping properties, stiffness and reduces the density (Rohatgi et al.1997, Keshavaram et al.1984, Sobczak et al.1998). Aluminum–fly ash composites have potential applications as covers, pans, shrouds, casings, pulleys, manifolds, valve covers, brake rotors, and engine blocks in automotive, small engine and the electromechanical industry sectors. The fly ash reinforced AMCs are also termed as 'Ash alloys' (Rohatgi 1993).With the increase in the content of fly ash in Al or its alloys, the mechanical properties such as hardness, modulus of elastics, 0.2% proof stress, tensile strength, compression strength and impact strength are enhanced (Rohatgi et al.1998). It is reported that addition of fly ash in narrow range has enabled superior mechanical properties of AMC as compared to AMC prepared with wider size range fly ash particles (Rohatgi et al.1998).The ductility of the composite decreases with increase in the weight fraction of reinforced fly ash and decreases with increase in particle size of the fly ash. However, for composites with more than 15% weight fraction of fly ash particles, the tensile strength is reported to be decreasing (Rohatgi 1998).

From foregoing discussion, it is evident that use of a waste material such as fly ash in Al and its alloy is beneficial and has dispensed with the use of costly ceramic particles such as SiC or Al_2O_3 in to Al or its alloy matrices. In the present investigation a novel insitu ternary ceramic mixture composite of Al_2O_3-SiC-C is developed by carbo thermal reduction of fly ash in a plasma reactor. Addition of in situ mixture to Al alloy matrix is thought to improve properties of AMCs further. Present work will highlight results of the newly developed AMCs prepared with novel in situ ternary ceramic mixture.

2. Experimental procedure

2.1 Thermal treatment of fly ash

The waste fly ash material, obtained from thermal power plant, is screened below 240 mesh size. The average size