UNIVERSITI PUTRA MALAYSIA

PROPERTIES OF METAL MATRIX COMPOSITE OF ALUMINIUM - 11.8% SILICON REINFORCED WITH DIFFERENT PARTICULATES

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By

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Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirement for the Degree of Doctor of Philosophy

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DEDICATION

Thanking THE ALMIGHTY, for giving me the knowledge to complete my doctoral research successfully.

This research work is dedicated to my family.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

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Chairman : Associate Professor Shamsuddin Sulaiman, PhD

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A composite material is a materials system composed of a mixture or combination of two or more micro or macro constituents that differ in form and chemical composition and which are essentially insoluble in each other. Metal matrix composites are engineered materials composed of an elemental or alloy matrix in which an insoluble second phase reinforcer is embedded and distributed to achieve some property improvement. Particulate reinforced metal matrix composites constitute a major portion of these advanced materials. Aluminium-silicon alloys, as a matrix material, are characterized by lightweight, good strength–to-weight ratio, ease of fabrication at reasonable cost, high strength at elevated temperature, good thermal conductivity, excellent castability, good weldability, excellent corrosion resistance and wear resistance properties. Application of particulate reinforced composites in the aerospace, automotive, transportation and construction industries depends on the choice of cost affordable factor. In this research work, particulate

reinforced metal matrix composites are processed by vortex method, a melt stirring liquid metallurgy technique. Four different particulates namely, graphite, combination of tungsten carbide and aluminium silicate for hybrid composite reinforcement, quartz and titanium carbide are used as second phase reinforcers for reinforcement in the matrix. Aluminium-11.8% silicon alloy is selected as the matrix material and the particulates are mixed in different weight fraction %. Slab composite castings are made by pouring the composite mixture in grey cast, steel and copper permanent-molds. Process parameters like pouring temperature, particulate preheating temperature, impeller blade speed and shape are optimized and composite castings containing different weight fraction % of particulate are made by permanent-mold casting process. Effects on different weight fraction % addition of particulate on the particulate distribution in aluminum-11.8% silicon alloy composites are studied. The processed particulate reinforced composites are subjected to mechanical tensile testing and the properties are determined for different type of particulate reinforcements in the aluminium-11.8% silicon alloy matrix. Besides, hardness, density, impact strength-charpy, fracture toughness, electrical resistivity, electrical conductivity, thermal diffusivity, thermal conductivity, thermal expansion coefficient measurements are performed by using the appropriate equipments and machines. Metallographic studies of the processed particulate composites are conducted by optical microscopy and photomicrographs are captured at different magnifications to reveal and examine the particulate distribution in the aluminium-11.8% silicon alloy matrix. SEM observation of the fracture surfaces of tensile tested, charpy impact tested specimens are performed to study the fracture mechanics and surface characteristics with the aid of captured SEM fractographs. Interfacial bonding features of the processed composites are also analyzed with the help of SEM. Besides, slab castings without particulate addition are made and compared with the results based on the properties and microstructural features, particularly for the uniformity of particulate distribution in the aluminum-11.8% silicon alloy base matrix. It is found that the properties of the processed particulate reinforced aluminium-11.8% silicon alloy matrix composites are superior to the cast monolithic aluminium-11.8% silicon alloy based on the above-mentioned properties studies. Photomicrographs of the processed composites based on the metallographic studies have confirmed the uniformity of particulate distribution in the aluminium-11.8% silicon alloy matrix.

Abstrak tesis dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

KAJIAN SIFAT BAGI ZARAHAN YANG DIPERKUAT ALUMINIUM-11.8% SILIKON ALOI BERASASKAN KOMPOSIT MATRIK

Oleh

THOGULUVA RAGHAVAN VIJAYARAM

Mei 2006

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Bahan komposit merupakan sistem bahan yang terdiri dari campuran atau kombinasi dua atau lebih mikro atau makro kandungan yang berbeza dari segi bentuk dan komposisi kimia dan kebiasaanya tidak bercampur antara satu sama lain. Besi matrik komposit adalah kejuruteraan bahan komposit yang mengandungi elemen atau aloi matrik dimana satu bahan penguat yang tidak bercampur pada fasa kedua dimasukkan bagi meningkatkan sifat bahan tersebut. Sebahagian besar kandungan bahan penguat komposit besi matrik mengandungi bahan termaju. Alloy Aluminium – Silikon sebagai bahan matrik adalah diklasifikasikan sebagai ringan, nisbah kekuatan kepada berat yang baik, senang difabrikasikan pada kos yang berpatutan, kekuatan yang tinggi pada suhu tinggi, pengalir termal yang baik, sangat mudah ditempa, mudah di kimpal, penghalang hakisan karat yang baik dan kandungan tahan hakis permukaan yang tinggi. Penggunaan komposit bahan penguat di dalam industri

aeroangkasa, automotif, pengangkutan dan pembinaan bergantung kepada faktor pilihan kos yang mampu ditanggung oleh industri berkenaan. Di dalam kajian ini, bahan penguat komposit besi matrik di proses dengan menggunakan kaedah 'vortex' iaitu satu teknik metallurgi di mana pencairan cecair melalui pengaulan dilakukan. Empat bahan berbeza yang digunakan dalam fasa kedua penguatan matrik adalah terdiri dari graphite, kombinasi tungsten karbida dan aluminium silikat bagi campuran komposisi penguat, quartz dan titanium karbida. Sebanyak 11.8% alloy silikon telah dipilih sebagai bahan matrik dan kandungan bahan ini dicampur dalam nisbah peratusan berat yang berbeza. Komposit ketulan acuan dihasilkan dengan kaedah menuang campuran komposit ke dalam acuan kelabu, keluli dan kuprum yang tetap. Parameter proses seperti suhu penuangan, suhu prapemanasan bahan, kekuatan kelajuan mata pisau dan bentuk dilaraskan pada keadaan terbaik dan acuan komposit yang mengandungi nisbah peratusan berat bahan yang berbeza dibuat menggunakan proses acuan yang tetap. Kesan pada nisbah peratusan berat tambahan pada setiap bahan dalam aluminium 11.8% silikon alloy dikaji. Komposit penguat yang telah diproses, kemudian diuji dengan ujian tegangan mekanikal dan kandungan kekuatan bahan tersebut ditentukan bagi bahan penguat yang berbeza di dalam matrik aluminium 11.8% silikon aloi. Selain itu, ujian kekerasan, ketumpatan, kesan kekuatan-charpy, ketahanan keretakan, ketahanan pengaliran elektrik, konduktor elektrik, diffusiti termal, pengukuran konduktor termal telah dijalankan menggunakan peralatan dan mesin yang bersesuaian. Akhirnya metallograf dijalankan keatas zarahan bahan komposit yang telah diproses dan fotomikrograf diambil pada skala pembesaran yang berbeza bagi menunjukkan dan menguji pengagihan zarahan bahan dalam matrik aluminium-11.8% silikon aloi. Melalui pemerhatian SEM pada permukaan retak dari ujian kekuatan, satu ujian kekuatan-charpy dilakukan ke atas spesimen bagi mengkaji keretakan mekanik dan sifat – sifatnya dengan bantuan dari fraktograf SEM yang telah diambil. Ciri-ciri struktur persamaan di antara permukaan bagi komposit yang telah diproses juga dianilisis dengan bantuan SEM. Selain itu, ketulan proses acuan tanpa zarahan bahan tambahan dihasilkan dan dibandingkan dengan hasil keputusan dari properti dan ciri-ciri struktur mikro khasnya pembentukan zarahan bahan dalam matrik aluminium-11.8% silikon aloi. Hasil dari kajian ini menunjukkan properti bagi hasil proses dari komposit bahan penguat matrik aluminium-18% silikon aloi adalah lebih baik dari acuan monolithic aluminium-11.8% silikon alloy. Fotomikrograf keatas komposit yang telah diproses berdasarkan kajian mettalograf membuktikan pembentukkan zarah-zarah di dalam aluminium-11.8% silikon aloi matrik.

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