EFFECT OF PARTICULATE SIZE AND WEIGHT FRACTION ON THE MECHANICAL PROPERTIES, FRACTURE AND FATIGUE CHARACTERISTICS OF ALUMINIUM-GRAPHITE AND ALUMINIUM-ZIRCON PARTICULATE COMPOSITES

by

U. T. SUBRAMONIA PILLAI

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TO MY

PARENTS

CERTIFICATE

This is to certify that the thesis entitled "Effect of Particulate Size and Weight Fraction on the Mechanical Properties, Fracture and Fatigue Characteristics of Aluminium-Graphite and Aluminium-Zircon Particulate Composites" by U.T. Subramonia Pillai submitted to the Indian Institute of Technology, Delhi, India, for the award of the degree of Doctor of Philosophy in Chemical Engineering Department is a record of bonafide research work carried out by him under our supervision and guidance. The thesis work, in our opinion, has reached the standard fulfilling the requirements for the Doctor of Philosophy Degree. The research report and results presented in this thesis have not been submitted in part or in full to any other University or Institute for the award of any degree or diploma.

(Dr. K.D.P. Nigam)
Assistant Professor
Department of Chemical Engg.
Indian Institute of Technology,
New Delhi- 110016 (India).

(Dr. R.K. Pandey)
Assistant Professor
Department of Applied Mechanics
Indian Institute of Technology
New Delhi- 110016 (India)

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ABSTRACT

The Al-alloys containing dispersion of second phase ceramic particles, have wide potentiality as viable engineering materials for a number of applications. The Al-base particulate composites thus obtained have been prescribed for applications such as bearings, pistons, cylinder liners etc. The present investigation is concerned with the studies on Al-Graphite and Al-Zircon particulate composites. The effect of weight per cent of particulate phases (Graphite, Zircon) as well as the particulate sizes has been investigated on the strength, ductility, fracture toughness and fatigue crack growth rate of the cast and the forged Al-Graphite and Al-Zircon composites.

Chapter 1 gives an introduction to metal-matrix particulate composites with particular reference to Al-base particulate composites. The superior tribological properties of Al-base composites have been outlined and their engineering applications have been discussed.

Chapter 2 provides the review of available literature on particulate composites and methods for manufacturing the Al-base composites. The effect of particulate on properties like strength, ductility, fracture energy etc. are given and the micromechanism of void formation, growth and coalescence in two phase materials is discussed. A review of the fracture toughness parameters (K, CTOD, J integral) has been presented. From the literature review

it emerges that a need for studying the effect of wt.% of particulate phases and particulate sizes in Al-Graphite and Al-Zircon composites on the properties like strength, ductility, fracture toughness and fatigue resistance to provide an optimum composition of composites for obtaining the best possible combination of these properties.

Chapter 3 deals with the method of fabrication of Al-Graphite and Al-Zircon composites with different wt.% of particulate phases (1.5, 3.0 and 4.5 in case of graphite and 10, 15, 20 and 30 in case of zircon) and with different particulate size ranges (75- 125, 125- 180 and 180- 250 μm). The microstructural examinations, particle size analysis, interparticle spacing analysis etc. for the composites have been described. The evaluation of mechanical properties has been given and the fractographic studies from the tensile fracture surfaces have also been presented.

Chapter 4 provides experimental details concerning the fracture mechanics tests. The test methods for evaluating toughness parameters, CTOD, J and K_Q are reported. The experimental values of fracture toughness for the composites are presented, and the fractographic studies of fracture surfaces from the fracture toughness specimens are detailed.

Chapter 5 gives an experimental account of the measurement of fatigue crack propagation rate in the composites using fracture mechanics approach. Also the micromechanism of fatigue crack propagation in these composites has been investigated using SEM.

Chapter 6 presents the discussion of the results obtained in chapter 3 for Al-Graphite and Al-Zircon composites. The effect of different parameters (such as particulate wt. per cent, particulate size, interparticulate spacing on the tensile properties of cast and the forged composites are discussed. The effect of filler phase and the particulate size on strength and ductility of composites has been described. Also, the influence of deformation in the forged composites has been compared with the cast composite's with particular reference to the properties of strength and ductility. A comparison and contrast of strength-ductility relationship between the graphite and zircon composites has been made and the volume fraction ranges for the particulate phase to provide the optimum properties in these composites have been discussed. The micromechanism of tensile fracture has also been compared between the graphite and the zircon composites.

Chapter 7 is concerned with the discussion of results of fracture toughness measurements reported in chapter 5. The CTOD and J toughness values measured on the composites have been related with composite parameters like wt.% of particulate phase, particulate size etc. The size of fracture process zone has been computed using void coalescence model for both the composites and related with the micromechanism of fracture. A comparative evaluation of graphite and zircon composites has been made on the basis of toughness of the composites for a given volume fraction of particulate phase, the toughness per unit strength and the crack size factor. The fracture toughness values in the graphite and zircon composites with different wt.% of particles and particulate sizes have been rationalized in the light of observed micromechanism of fracture in these composites.

Chapter 8 presents the fatigue crack growth rate as a function of stress intensity range, ΔK and CTOD range, ΔCTOD in the graphite as well as zircon composites. The evaluation and comparison of fatigue growth rate constants c and n (by stress intensity approach) and c' and n' (by CTOD approach) using Paris' equation have also been presented. The fatigue crack growth rates have been compared at different ΔK and ΔCTOD levels for the composites of different composition and particulate sizes. The fatigue crack growth rate is found to increase with increasing wt.% of particulates phase as well as increasing particulate size in the composites. The forged composites show higher crack growth rate than the cast composites. The micromechanism of crack propagation has been described and compared between the two composites. The two composites have also been compared under different heads like da/dN as a function of applied stress intensity range, da/dN as a function of tensile strength and da/dN as a function of fracture toughness.

The conclusions based on the present investigations are reported in Chapter 9.

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