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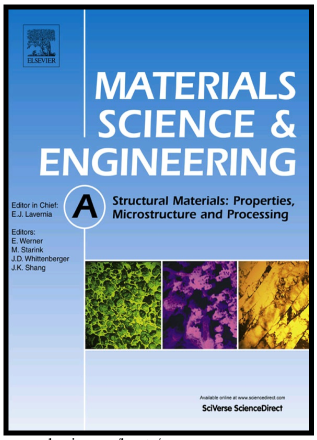

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In-situ experimental and numerical studies of the damage evolution and fracture in a Fe-TiB_2 composite

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Abstract

A joint experimental and modelling study of plastic strain and ensuing damage in a novel metal matrix composite (Fe-TiB_2) is presented. Damage is observed and quantified using SEM images processing and Acoustic Emission (AE) analysis. The use of AE confirms that the surface damage observed is strongly correlated to damage in the bulk of the material. The primary mode of damage is particle fracture. Very little particle decohesion is observed, indicating an exceptionally good cohesion of the steel/particle interface. Damage is initiated soon after the composite yield point is reached and increases significantly with strain. Macroscopic failure of the tensile specimen occurs when about 25% of the particles are fractured. This corresponds to about 21% engineering strain.
Using in-situ SEM tensile tests with quantitative digital image correlation (DIC), full-field strain measurements are obtained and particle fracture quantified. The results of fields measurements are compared to results of a FFT based homogenization method with boundary conditions retrieved from the experiment. A good agreement is found between the DIC-measured and FFT-predicted results. Estimated values of the particle fracture stress are obtained.

Keywords: Metal Matrix Composite Fe–TiB_2, damage, In-situ, DIC, AE, FFT, homogenization

1. Introduction

Lightweight structures for transportation have become a major area of development for improved energy efficiency and decreased CO_2 emissions. A solution is to develop taylored materials with improved specific properties. Novel steel-based composites reinforced with titanium diboride particles have been developed by ArcelorMittal in this context. This material consists of a significant volume fraction (~13%) of titanium diboride (TiB_2) particles dispersed in a ferritic steel matrix. It is obtained during solidification directly from the melt through a near eutectic solidification route [1, 2]. The phase diagram indicates that, depending on composition, the TiB_2 phase will precipitate in the melt (primary particles) and the eutectic TiB_2 phase be formed by the eutectic reaction. This leads to a relatively homogeneous distribution of particles, with little clustering, and since the particles are formed in situ, strong interfacial bonding. These should both favour good mechanical properties and resistance to damage [3].

These composite steels were designed for high stiffness associated with low density. This is achieved by selecting a high modulus low density particulate phase, so as to obtain a maximum value for the specific stiffness (E/ρ). It was also necessary that these steels be produced on an industrial scale using a process such as continuous casting. Therefore, the steel composition had to

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