FATIGUE DAMAGE OF AL/SIC COMPOSITES – MACROSCOPIC AND MICROSCOPIC ANALYSIS

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1. Introduction

Damage due to fatigue loading of typical metallic materials and composites has been investigated by many research centres [e.g. 1-4]. Since an observation of the fatigue damage evolution in its early stages is difficult, and the Wöhler procedure does not give sufficient information on degradation development during fatigue tests, the method proposed by Socha [2] was applied in this research for damage evaluation of the Al/SiC MMC. It is based on application of the inelastic strain or mean strain to define a damage parameter during subsequent cycles. According to this method three periods of damage process during HCF can be observed: (a) behaviour of undamaged material at the initial state of test; (b) development of fatigue damage due to single slip bands formation around hard particles [5] as well as voids and small cracks nucleation and stable growth; and (c) dominant crack propagation. Damage parameters for the second period were calculated on the basis of mean strain signals acquisition during tests.

Microstructural observations of specimens before and after fatigue were performed in order to evaluate an influence of the reinforced particles and voids distribution on damage development.

2. Experimental Results

The matrix material for the Al/SiC was prepared from a commercial Al powder with a purity of 99.7% and an average particle size of 6.74 μm (delivered by the Bend-Lutz Co). The reinforcing phase was made of the SiC powder of 99.8% purity and an average particle size of 0.42 μm (Alfa Aesar Co). The technological process included several stages. In the first stage of process the powders were mixed so as to obtain (Al+x vol.% + SiC) mixtures, where x ranged from 0% to 10% and was changed at an increment of 2.5. The mixtures were homogenized, for 6h, in a polyethylene vessel using a suspension of isopropyl alcohol and Al_2O_3 balls, then dried and granulized at room temperature on a sieve with the mesh size of #0.25 mm. In the next stage, the powder mixtures were subjected to isostatic consolidation at the pressure p = 245 MPa. The samples thus obtained were machined to give them the desired shape (cylindrical) and dimensions (radius r=40 ± 1 mm, length ~50 mm). The final stage of the technological process included direct extrusion of the prepared samples in the KOBO 100T horizontal hydraulic press, equipped with a reversely rotating die whose movement was transmitted onto the extruded material so that its deformation path varied.

Force controlled high cycle fatigue tests (20 Hz frequency) were carried out on the servo-hydraulic testing machine MTS 858. During the tests, sine shape symmetric tension-compression cycles were applied to keep constant stress amplitude equal to 65 and 70 MPa. Tests were performed at ambient temperature. Each cylindrical specimen manufactured from the Al/SiC rod was subjected to cyclic loading until fracture. A movement of the subsequent hysteresis loops along the strain axis was observed with an increasing number of cycle (Fig. 1). Simultaneously, a width of the subsequent hysteresis loops became almost unchanged. Such behaviour identifies the ratcheting effect. Only insignificant increase of inelastic strain amplitude was observed (Fig. 2).

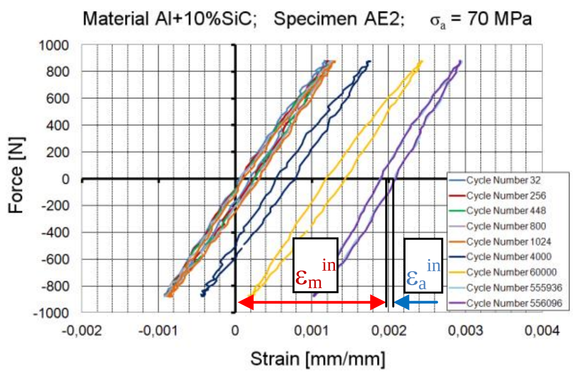

Fig. 1: Hysteresis loops for selected cycles

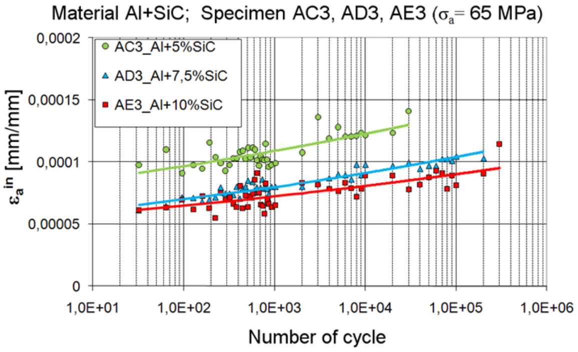

Fig. 2: Inelastic strain amplitude ε_a^{in} for selected cycles

Since ratcheting is the dominant mechanism of the composite deformation, the mean strain was taken into account during a damage parameter calculation in the stable growth period. Hence, the damage parameter can be defined in the following way:

$$D = \frac{\varepsilon_m^{in} - (\varepsilon_m^{in})_{\min}}{(\varepsilon_m^{in})_{\max} - (\varepsilon_m^{in})_{\min}}$$

It is worth to noticed that the rate of damage is relatively high at the beginning of the period. Afterwards, it becomes slower (Fig. 3).

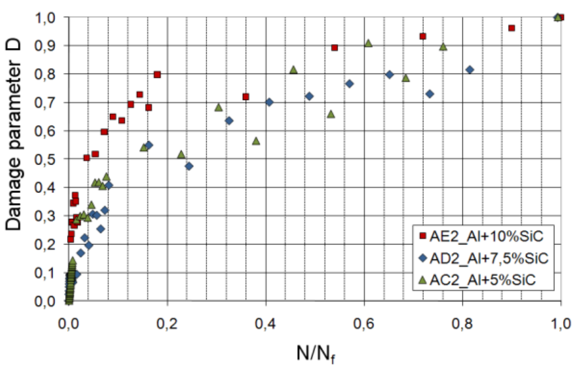

Fig. 3: An influence of SiC content on damage parameter variation (stress amplitude 70MPa)

Such a phenomenon indicates that the linear damage accumulation rule cannot be applied for the Al/SiC MMC. Moreover, it can be seen that the rate of damage parameter at the initial stage of fatigue increases with an increase of the SiC particle content.

3. Conclusions

An increase of the SiC content improved the fatigue and creep resistance, and moreover, it increased the rate of hardening during monotonic tensile tests. Hence, it can be concluded generally that the SiC reinforcement led to the material properties improvement. However, it has to be mentioned that a larger content of the SiC particles may lead to generation of their clusters which often include incoherent particles. Since is well known that the main part of the specimen loading is carrying out by reinforcements [5], such type of clusters do not contribute to tensile load transfer, and therefore, they can be treated as voids in the structure of a material.

4. Acknowledgements

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5. References

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