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Changes in Fatigue Life Behaviour of Alloy A359 and A359-Based Composites Bulk-Reinforced with SiC Particles as a Function of the Reinforcement Content

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The results of mechanical tests carried out by the proprietary modified low cycle fatigue test (MLCF) on alloy A359 and A359-based composites bulk-reinforced with SiC particles (20% and 30% volume fraction of the reinforcement) were disclosed. The described method was based on previous results of own studies, successfully validated for a wide range of materials such as steel, cast iron with spheroidal and flake graphite, ADI included, cast steel and non-ferrous metal alloys. From the results of mechanical tests it was concluded that MLCF method is particularly useful in all those cases when some heterogeneities are expected in the tested material. The effect of these inhomogeneities is practically totally eliminated, since fatigue life is estimated on one sample only and not, as in the case of the conventional LCF method, on at least several samples. Micro-structural research was also conducted to assess the observed effects. The results of microstructural examinations and fatigue tests enable drawing a conclusion that alloy reinforcement with SiC particles significantly improves the fatigue life behaviour of the resulting composite, but when certain content of the reinforcement is exceeded the fatigue life is reduced.

Keywords: *Fatigue, Composites, Microstructure.*

1. Introduction

Metal matrix composites (MMCs) are a very interesting group of materials, due to their light weight and attractive useful properties [1, 2]. Moreover, composites based on aluminium alloy matrix reinforced with SiC particles can be subjected to multiple remelting, if the Si content in alloy matrix equals minimum eight percent by weight. This composition prevents the formation of Al_4C_3 at the metal matrix/reinforcement interface, which is of crucial importance since Al_4C_3 precipitates in aluminium matrix of the composite adversely affect the mechanical properties of this material [1, 2]. The mechanical properties including fatigue life are also tested and determined before new materials are introduced to practical applications. Up to now, most commonly, the data on fatigue characteristics have been derived from the well-known fatigue tests carried out in a high- or low-cycle regime (HCF and LCF, respectively) [3-5]. As a result of these tests, complete Wöhler diagrams are obtained, but for both HCF and LCF, the accuracy of the measurements increases with the increasing number of samples available in the test. In this study it was decided to select as a test material the A359 (AlSi9Mg) aluminium alloy and respective composites based on this alloy, reinforced with 20 vol % and 30 vol % of SiC particles. Attention was focused on fatigue behaviour and microstructure effects.

2. Procedures and results

2.1 Chemical composition

The chemical composition of the tested materials is given in Table 1.

Table 1 Chemical composition of tested materials.

A359 (Al - residue)						
Si	Fe	Cu	Mn	Mg	Zn	Ti
8.58	0.12	0.03	-	0.46	-	0.11
A359 + 20 vol% SiC (Al - residue)						
9.20	0.12	<0.01	0.02	0.54	<0.01	0.10
A359 + 30 vol% SiC (Al - residue)						
9.30	0.18	0.01	0.02	0.56	<0.01	0.11

2.2 Fatigue life assessment and microstructure examination

The fatigue life was determined by an original modified low cycle fatigue method (MLCF) described in detail in [3, 5]. The fatigue tests were stress-controlled. The results are presented in diagrams (Fig. 1-3) and compared in Table 2.

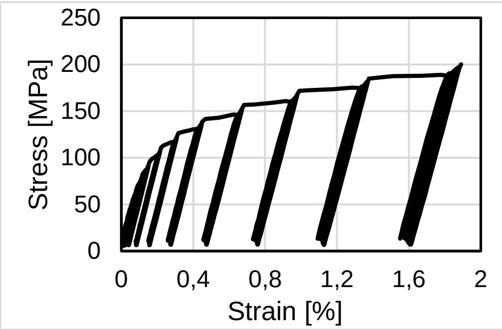


Fig. 1 The stress-strain diagram for A359 alloy.

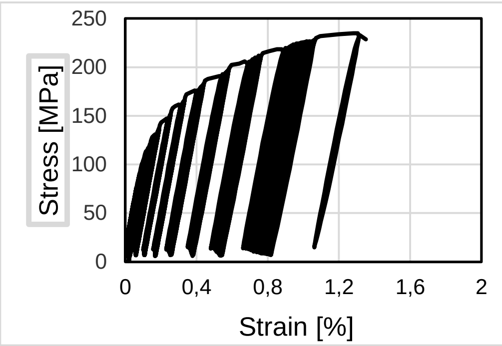


Fig. 2 The stress-strain diagram for A359 alloy reinforced with 20 vol % SiC.

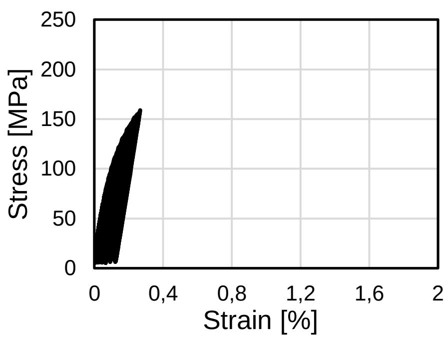


Fig. 3 The stress-strain diagram for A359 alloy reinforced with 30 vol % SiC.

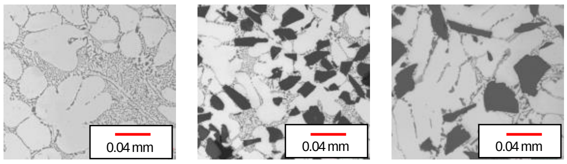
Figures 1, 2 and 3 present the stress-strain relationship for A359 alloy, A359 alloy reinforced with 20 vol % SiC and A359 alloy reinforced with 30 vol% SiC, respectively. Attention deserves the fact that the highest fatigue strength was obtained for A359 alloy reinforced with 20 vol % SiC (Fig. 2, Table 2), and the lowest for A359 alloy reinforced with 30 vol % SiC (Fig. 3, Table 2). Microstructures of the investigated materials are shown in Fig. 4. It was characterized by the optimal content and distribution of SiC particles in alloy matrix. The most preferred type of microstructure was obtained in the composite containing 20 vol% SiC (Fig. 4b).

Table 2 Selected fatigue parameters.

Material	b	c	ε_{max}	K' MPa	n'
A359	-0.16994	-0.42018	0.01469	455.7	0.23257
A359 +20 vol% SiC	-0.11867	-0.28059	0.02242	636.8	0.21238
A359 +30 vol% SiC	-0.09231	-0.13129	0.04922	-	-

where: b – Basquin's exponent, c – fatigue ductility exponent, ε_{max} – maximum strain, K' – cyclic strength coefficient, n' – cyclic strain hardening exponent.

The particles were smaller than in the composite containing 30 vol% SiC. The composite with 30 vol% SiC was also characterized by a non-uniform distribution of the reinforcement particles in alloy matrix (Fig. 4c), which was the main cause of the reduced fatigue life.



a b c

Fig. 4 Microstructure of A359 alloy (a), A359 + 20 vol % SiC (b), A359 + 30vol % SiC (c), 500x

3. Concluding remarks

Based on the obtained results it was concluded that the best microstructural and fatigue characteristics were obtained in the composite containing 20 vol % SiC.

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