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FRACTURE TOUGHNESS INVESTIGATIONS OF METAL MATRIX COMPOSITES REINFORCED BY CERAMIC FIBRES

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1. Introduction

Characterisation of modern materials for engineering applications requires data from standard tensile or compressive tests in order to determine basic mechanical parameters. Besides of such parameters as: Young's modulus, proportional limit, yield point, ultimate tensile strength a knowledge concerning the stress intensity factor (SIF or K_I) is necessary. It is known that SIF describes material resistance to brittle cracking. The stress intensity factor is investigated using specimens having a notch containing a fatigue crack at its tip and by applying the following stages of the experimental procedure: (a) pre-cracking of fatigue zone, (b) testing under monotonic tension [1]. Several types of specimens are used, e.g. compact tension (CT); disk-shaped; single edge [2]. In many experimental cases, dimensions of specimens are limited by a material volume. Therefore, different sizes of specimens can be applied, i.e. standard [2] or miniature [3].

The objective of this paper is to determine the critical value of stress intensity factor of a metal matrix composite (MMC) reinforced by the Saffil ceramic fibres.

2. Details of experimental procedure

The 44200 aluminium alloy reinforced by a different percentage content of Al_2O_3 Saffil ceramic fibres, 10%, 15% and 20%, was selected for investigation. As reported in [4] the ultimate tensile strength and the Young's modulus of this type of reinforcement are equal to 1800 MPa and 300 GPa, respectively. All tests were performed using compact tension specimens (CT). With respect to a limited volume of the composite, the applied specimen was four times smaller than the typical one.

2.1 Specimen and validation process

The compact tension specimen, shown in Fig. 1, was designed on the basis of guidelines contained in the ASTM [2] and PN-EN standards [5].

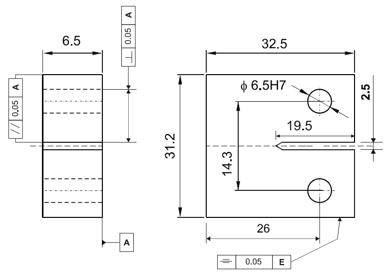
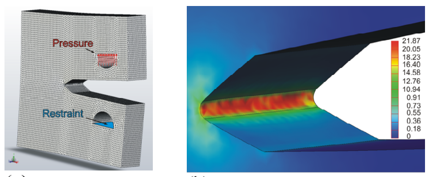


Fig. 1. Compact tension specimen (CT).



(a) (b)

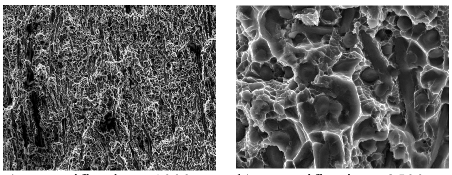
Fig. 2. Boundary conditions (a); the Huber-Mises-Hencky's effective stress at the tip of notch (b).

The specimen geometry was validated using finite element analysis (FEA). The loading and boundary conditions (Fig. 2a) were similar to those applied in the servo-hydraulic testing machine. The specimen was modelled using 3D solid body divided into 374088 3D elements and 528467 nodes, Fig. 2a. Selected results, e.g. Huber-Mises-Hencky's effective stress at the tip of notch, are illustrated in Fig. 2b. They show a typical concentration of the effective stress in a field close to the tip of notch.

2.2 Investigation of fracture toughness

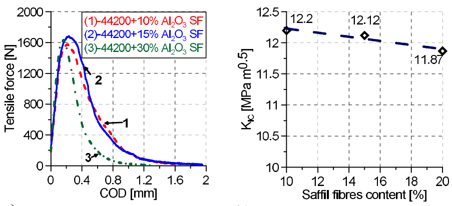
All fracture toughness tests were conducted using the 8802 Instron servo-hydraulic testing machine at room temperature. The specimens were mounted in the loading system by applying special grips. Crack tip opening displacement was measured by means of the clip on knife edge extensometer of 10 mm gauge length.

The crack propagated in perpendicular direction with respect to the opposite side of the specimen, independently on the content of Al_2O_3 Saffil fibres. Each specimen was observed at different magnification, i.e. macro- and micro-scales to distinguish features of the fracture surface. The results of macro-scale observations obtained at small magnification indicated several geometrical sections in the decohesion surface, i.e. plane of fatigue pre-cracking, and tension zone having two sloping fracture areas and tearing section.



a) magnification ×1000 b) magnification ×2500

Fig. 3. Microscope images of fatigue fracture surface of the 44200+20% Saffil fibres composite.



a) b)

Fig. 4. Tensile force versus COD (a), variations of K_{IC} as a function of Saffil fibres content (b).

The microscopic analysis of the fatigue fracture surface was performed at magnification equal to 18, 100, 1000 (Fig. 3a), 2500 (Fig. 3b). The results did not exhibit any typical features observed on the specimen surface after fatigue testing. Instead of them, a local delamination of the structure was observed in the case of composite with 20% Al_2O_3 Saffil fibre content, Fig. 3b. It occurred in the form of voids between the base material and fibres.

Variations of the tensile force versus crack tip opening displacement, exhibited the I-st mode fracture, Fig. 4a. The critical values of the stress intensity factor of the 44200 aluminium alloy reinforced by 10%, 15% and 20% of the Saffil fibres reached the following levels: 12.20, 12.12 and 11.87 [$MPa \times m^{1/2}$], respectively, Fig. 4b. Values of the K_{IC} decreased slightly with an increase of the Saffil fibre content.

3. Remarks

- A miniaturized compact specimen can be successfully applied to determine the K_{IC}.
- A pre-cracked zone in the composite did not has typical features usually observed on the specimen surface after fatigue.
- An influence of the Al_2O_3 Saffil fibres of the content within the range from 10% to 20% on the critical stress intensity factor was negligible small.

Acknowledgements

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