MINI-COMPACT TENSION SPECIMENS FOR FRACTURE TOUGHNESS EVALUATION

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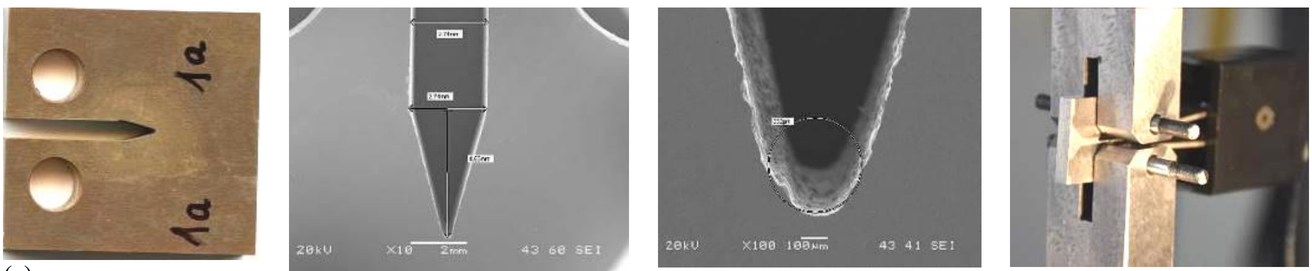
1. Introduction

Typical mechanical parameters such as the Young's modulus, yield point, ultimate tensile strength as well as fatigue limit are commonly used to indicate a possible applications of engineering materials. These parameters are required to carry out successfully all necessary static, dynamic or fatigue analyses. It has to be mentioned, that they are insufficient for investigations of crack growing. Therefore, the fracture toughness tests, that capture Stress Intensity Factor (SIF) [1] or Crack Tip Opening Displacement (CTOD) [2], are usually performed. They are carried out under plane strain state conditions [1, 2] using such parameters as Stress Intensity Factor and yield point i.e. $B \geq 2.5\ (K_{IC}/R^{0.2})^{0.5}$. When the SIF value cannot be calculated, then a proportion of the yield point to Young's modulus must be determined. Usually, it takes values starting from 0.0050 (for B equal to 7.5 mm) to 0.01 (for B equal to 0.65 mm) [1]. Various types of specimens can be used for such tests, e.g. arc, beam or compact [3, 4, 5]. Their thickness is usually equal to 13 mm [3]. In the case of smaller specimens it should be reduced up to 8 mm for mini-specimens [4], and 2 mm for micro-specimens [5]. Nowadays, many efforts of research groups are focused on modern material manufacturing and an effective failure reasons evaluation. Therefore, the main aim of the paper is to check an applicability of the mini-compact tension specimens for fracture toughness determination.

2. Details of experimental procedure

Two variants of mini-compact tension specimens were examined, Fig. 1a, d. The first one had a width, high and thickness equal to 32.5 mm, 31.2 mm and 6.5 mm, respectively, Fig. 1a, whereas the second one had all these dimensions 1.6 smaller, Fig. 1d.



(a) (b) (c) (d)

Fig. 1. Details of the mini-compact tension specimen; (a) general view (Cu+20% Al_2O_3 (fibres)); (b) and (c) the notch dimensions for SEM analysis; (d) grips, micro-specimen and extensometer mounted in the testing machine

Dimensions of the mini-specimens (Fig. 1a) were checked using Light and SEM microscopic techniques, Fig. 1b, c. Miniaturized gripping system was used to mount specimens in the testing machine, Fig. 1d. CTOD was determined using extensometer of 5 mm nominal gauge length and travel for axial strain equal to 2 mm. The miniaturized specimens made of the Mo-40%Al_2O_3+5Re composite, Ti-6A1-4V alloy, and titanium alloy were tested. The fatigue pre-cracking was conducted under cyclic force control. A length of the fatigue pre-crack was checked after final stage of the test by means of microscopic measurements carried out at five points uniformly distributed along the specimen width, i.e. 0; 25; 50; 75 and 100%. These results were subsequently used in the procedure of specimen quality assessment according to the required standards.

3. Results

Experimental data from tests of the mini-compact specimens for all materials in question were analysed on the basis of force variations versus COD (Fig. 2), and features of fracture zones, Fig. 3. A quasi-linear relationship can be observed for the Mo–40%Al_2O_3+5Re composite, Fig. 2. However, calculation of the SIF value was not possible for this material. In the case of the 44200 aluminium alloy with Saffil fibres a brittle cracking was obtained, Fig. 3b. The critical value of SIF was equal to 12.2 MPa $m^{1/2}$. In the case of Ti-6Al-4V alloy tested in the parent and weld material zones (Figs. 2, 3c, d) variations of force versus COD represented plastic behaviour. The CTOD values determined for those zones were equal to: 0.0703 mm; 0.0872 mm, respectively. An inspection of the fatigue zone dimensions of the CT specimen representing weld region enabled identification of the unstable grow of the crack, Fig. 3d.

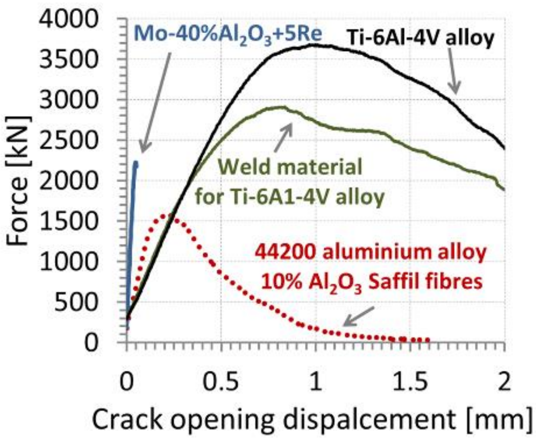
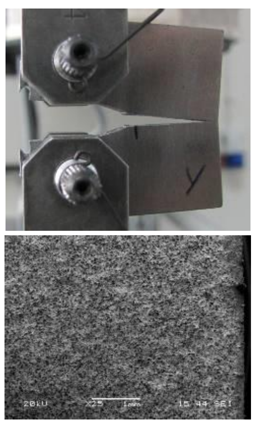
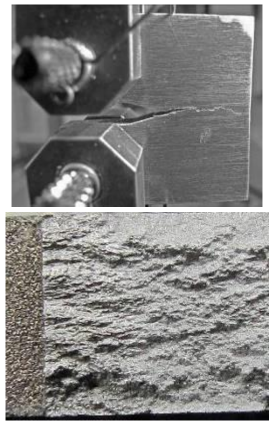


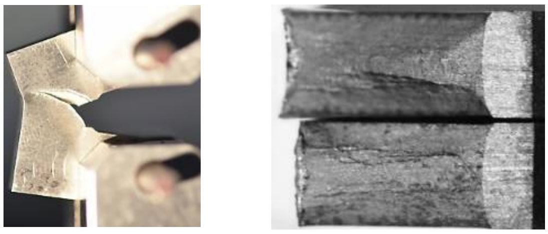
Fig. 2. Force versus crack opening displacement



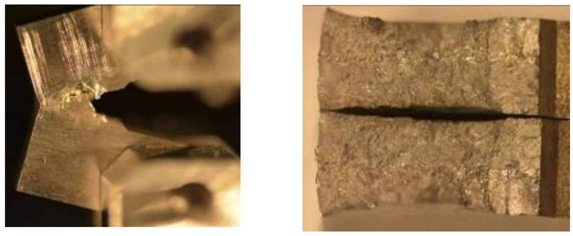
(a1, 2)



(b1, 2)



(c1, 2)



(d1, 2)

Fig. 3. Mini-compact specimens: (a) Mo–40%Al_2O_3+5Re; (b) 44200 aluminium alloy 20% Al_2O3 Saffil fibres respectively; (c) Ti-6A1-4V alloy; (d) weld zone for the titanium alloy

4. Summary

The paper presents the results showing that besides of the classical compact specimens also application of the mini-compact specimens enables reasonable determination of the Stress Intensity Factor and Crack Tip Opening Displacement for various engineering materials.

References

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