39th Solid Mechanics Conference
Zakopane, Poland, September 1–5, 2014

P010

INFLUENCE OF THE FATIGUE LOADINGS ON THE RESIDUAL STRESS-STRAIN CHARACTERISTIC OF THE ENGINNERING MATERIALS

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1. Introduction

Mechanical properties of the material are usually determined on the basis of test carried out using material in the as-received state. Obtained results may be applied for the purposes of design of structures. However, during normal exploitation process those structures may be subjected to fatigue loadings. Cyclic loading may substantially influence the observed macroscopically mechanical properties of the material [1, 2]. As a consequence mechanical behavior of the structure may be different from designed one, especially under extreme loading conditions.

This work presents the analysis of the influence of the fatigue loadings on the residual tensile curves of selected engineering materials, i.e. AISI 1045 [3, 4] steel and TiAl6V4 titanium alloy.

2. Experimental method

The first analysed material was titanium alloy. The hour-glass specimens, applied during the tests, were machined from an extruded rod made of TiAl6V4 titanium alloy, and subsequently polished in order to get roughness equal to 0.3. Therefore it was possible to induce localization of the fatigue damages and subsequently to determine true stress and strain values exactly in the place of fatigue damage accumulation. The diameter of the specimen grip and the necking was equal to 8 mm and 4 mm, respectively, and radius of the hour-glass was equal to 20 mm. The transversal extensometer has been applied for the purposes of strain measurement.

The latter tested engineering material was AISI 1045 steel. The specimens were machined from a drawn rod. Cylindrical specimens were fabricated with tangentially blended fillets between the gauge section and the ends. The gauge length and diameter were 12 mm and 4 mm, respectively. The surface was polished after machining.

The same specimen geometry was used for all of the analyses presented in this paper, including the tensile and fatigue tests. Three specimens were used for each tensile test under given loading conditions. The average value of the three replicate measurements was analysed. Fatigue test, pre-fatigue and tensile tests were carried out applying Instron servo-hydraulic testing machine. The experimental procedure has been divided into three steps:

- first, stress-controlled fatigue tests were carried out and followed by the analysis of ratcheting, plastic deformations and rupture surfaces;
- next, the initial material damage due to fatigue loadings was introduced into steel to reach the desired CFD values, i.e., 0.0, 0.25, 0.50, and 0.75; and
- finally, tensile tests of the pre-fatigued specimens were conducted to analyse the residual stress-strain characteristics of the steel.

3. Results

The tensile curves for both as-received and pre-fatigued materials are shown in Fig. 1a for the AISI 1045 steel and Fig. 1b for the TiAl6V4 titanium alloy. The stress-strain characteristic of both materials evolve as a consequence of initial fatigue loadings in different manner. In the case of steel, after pre-fatigue at stress controlled mode at magnitude equal to 557 MPa, material hardening is observed as the CFD increases to 0.25 and 0.50. A further increase to a CFD of 0.75 produces the opposite effect, a decrease in the flow stress. Thus, two different phenomena must be considered during fatigue loading. The first factor is related to cyclic hardening effects observed during the first few cycles and the second effect is softening due to the development of the fatigue damage [3].

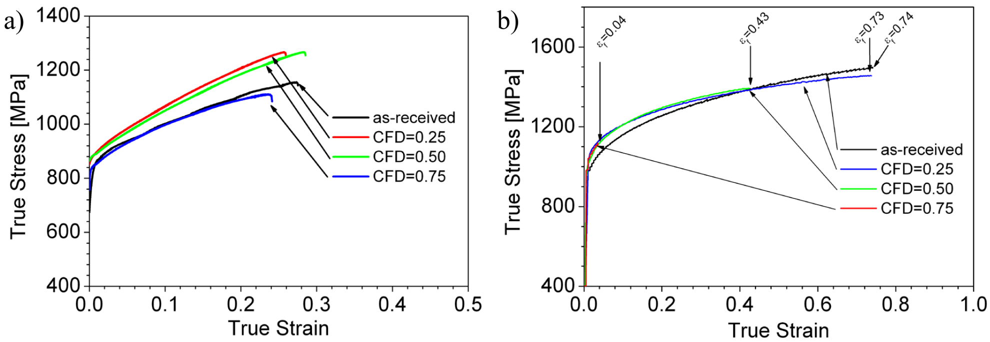

Fig. 1. Stress-strain curves of: a) AISI 1045 steel and b) TiAl6V4 titanium alloy.

Drop of the elongation due to pre-fatigue fatigue may be illustrated on the example of tensile tests of the titanium alloy initial loadings at amplitude equal to 557 MPa. Figure 2A and 2B shows fracture surface after tensile tests of the as-received material and after fatigue fracture, respectively. Initially the at CFD = 0.25 the fracture surface has ductile character (Fig. 2C), moreover the fracture strain equal to 0.74 is not strongly affected (Fig. 1b). The increase of the pre-fatigue cycles number to CFD = 0.50 induces drop of the elongation to 0.43 and ovalization of the fracture surface (Fig. 2D) which may be evidence of fatigue damage growth [3]. Further increase of CFD to 0.75 results in clearly observed decrease of the fracture strain to 0.04 followed by change of fracture mode to brittle (Fig. 2E).

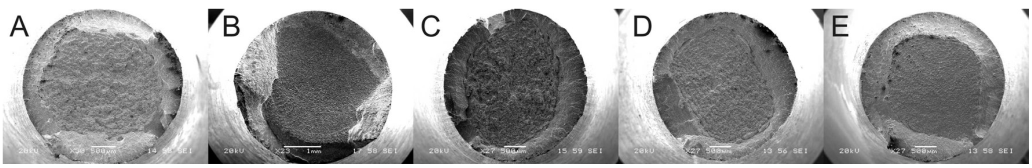

Fig. 2. Optical micrographs of the fracture surface.

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