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Stable crack growth in composite laminates under various stiffness of the loading system

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Abstract

The work is devoted to experimental study of stable and unstable crack growth processes in composite materials. The eccentric tension tests of the compact specimens of glass-epoxy composite laminates in conditions of various stiffness of the loading system were carried out. Different measurement techniques of crack opening displacement were used in work. During the analysis of results of a tension test of compact specimens with crack, descending sections of the loading curves were considered by analogy with postcritical deformation stage, which could be found in test of smooth specimens of different materials. It is shown that behavior of composite specimens with crack under tension depends on the loading system parameters: crack grows process is stable when stiffness of the loading system is enough, crack opening displacement rate increase under reduction of stiffness of the loading system. This effect should be take into account during modeling and analyzing of fracture processes of composite materials, strength and survivability assessment of composite structures in real loading conditions.

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Keywords: stable crack growth, composite laminates, loading system stiffness, postcritical deformation stage, compact specimen tension tests,.

1. Introduction

The crack growth process in composite materials has been the object of a large number of studies over more than two decades. It connected with extensive use of composite materials in different technical fields, especially in aeronautical engineering, and high requirements for structural integrity. From the point of view of safety and

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survivability of critical structures in emergencies, the possibility of stable crack growth processes are extremely important [Gdoutos et al. (2012), Lomakin et al. (2016)]. Because of the fact that crack growth corresponds to descending section on the loading curve under tension of specimen with notch or initial crack, this process could be consider by analogy with postcritical deformation stage [Vildeman et al. (1997), Bazhukov et al. (2013), Lomakin et al. (2016)]. Postcritical deformation stage connected to the accumulation of damages, structural failure and fracturing processes and each point on this stage can correspond to the moment of the loss of load-carrying ability because of transition from stable to non-equilibrium process of damages accumulation, which depends on stiffness of the loading system. During the transition from the stable stage of damage accumulation process to unstable regime, interaction of the deformed body with the loading system plays the key role. Consequently, based on loading conditions, each point on the descending section of loading curve can correspond to the moment of the loss of load-carrying ability because of transition to non-equilibrium stage of the damage accumulation process [Vildeman et al. (1997, 1998, 2008), Tretyakov et al. (2016)].

This work is devoted to developing of scientific foundations of the prediction, risk assessment and accident prevention related to accumulation of structural damages and crack growth processes in glass-epoxy composite laminates under different loading conditions, in particular stiffness of the loading system.

2. Test procedure and materials

For studying of crack growth processes in glass-epoxy composite laminates, the eccentric tension tests of compact specimens at room temperature were carried out. The specimens were manufactured of plate with thickness of 2.3 mm, width of 20 mm and length of 300 mm, sketch of compact specimen is shown on Fig. 1, manufactured specimen is shown on Fig. 2, a.

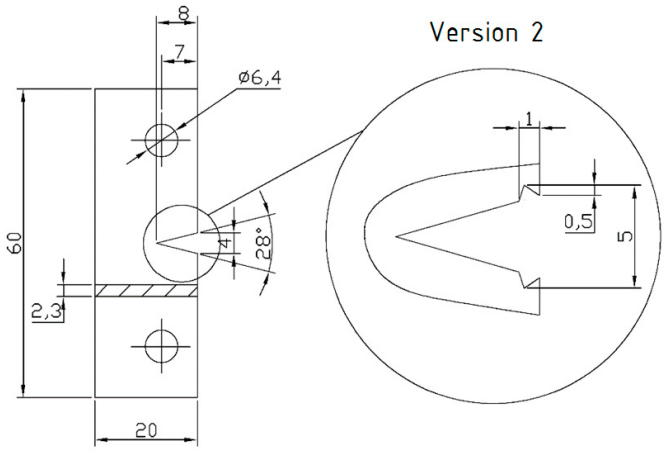

Fig. 1. The sketch of compact specimen of composite laminates for tension test.

The universal servohydraulic test system Instron 8801 (±100 kN, 30 Hz) were used in tests. Different methods of measure of the crack opening displacement were used in the work: crack opening displacement gauges (COD) Instron 2670-122 (Fig. 2, b), axial dynamic extensometer Instron 2620-601 (Fig. 2, c), non-contact video system for analyze of displacement and strain fields based on digital image correlation (DIC) technic [Lomakin et al. (2015), Tretyakova et al. (2016)]. The COD gauge was mounted on the base of 5 mm; the axial extensometer was mounted on the base of 6 mm.