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On the effectiveness of infrared thermography in the detection of the fatigue damage initiation in a composite plate with a hole

ADAM STAWIARSKI[1], MAŁGORZATA CHWAŁ[2], MAREK BARSKI[3*], PAWEŁ ROMANOWICZ[4]

1. Chair of Machine Design and Composite Structures; Cracow University of Technology [0000-0002-5700-4841]
2. Chair of Machine Design and Composite Structures; Cracow University of Technology [0000-0001-6626-607X]
3. Chair of Machine Design and Composite Structures; Cracow University of Technology [0000-0002-2247-5846]
4. Chair of Machine Design and Composite Structures; Cracow University of Technology [0000-0001-7475-1577]

* Presenting Author

Abstract: The necessity of monitoring the state of the structures is increasingly important especially in the composite structures because of the difficult estimation of the fatigue life. The number of non-destructive measurement and monitoring methods grows allowing for in details observation of the fatigue behaviour of the composite structures. In this study, the effectiveness and accuracy of the infrared thermography have been studied in the fatigue damage tests of the composite plate with a hole. The effectiveness of the early damage detection method associated with appropriate measured data analysis was analysed. The digital image correlation system has been also used to observe the fatigue behaviour of the analysed structure. Experimental tests have been preceded by the numerical finite element analysis of the composite structure to determine the expected damage initiation area. The practical aspects of the considered measurement technique were discussed in the context of the permanent structural health monitoring and utilization in the real SHM systems.

Keywords: fatigue damage, SHM system, infrared thermography, wave propagation

1. Introduction

The difficulties in the accurate prediction of the failure form and service life cause that composite structures are often designed with the use of the high value of the safety factors. The growing importance of the non-destructive testing methods and structural health monitoring systems is the consequence of the dynamic technological progress and optimization of the composite production processes [1-4]. The improvement of the accuracy of the damage detection is still of interest to researchers. However, quite often the accuracy improvement is associated with sophisticated techniques of data analysis, algorithms, or advanced procedures that quite often cause effectiveness decrease. In this paper, the effectiveness of the non-destructive passive infrared thermography was taken into account in the early damage detection under fatigue loading conditions. The fatigue of the GFRP composite plate with the hole was carried out with the use of visual non-destructive monitoring systems. The digital image correlation system coupled with infrared thermography monitoring allows for accurate determination of the fatigue damage evolution of the analysed structure.

2. Results and Discussion

Corresponding author: adam.stawiarski@pk.edu.pl

Composite plates with a circular hole in the middle made of GFRP laminates were considered. The fatigue tests were carried out with the utilization of the passive infrared thermography system monitoring the temperature distribution during the fatigue tests. The digital image correlation system was responsible for the visual, online determination of the displacement, and strain distribution. The temperature distribution, maximal temperature value and temperature histogram observed during the test were taken into account as straightforward markers of the fatigue damage initiation (Fig. 1). The temperature difference was also calculated to determine the relation between fatigue test parameters and the energy release intensity.

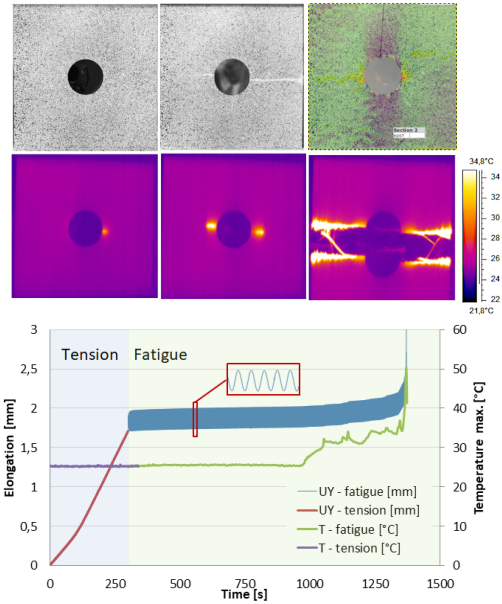

Fig. 1. The fatigue test results of the composite plate with hole registered by the infrared thermography and the digital image correlation systems.

The efficiency of the infrared thermography depends on the inspection parameters. In the cases of dynamic evolution of the damage, the accurate indication of the damage initiation depends on the infrared camera frame rate and sensitivity of the system. Nevertheless, the permanent monitoring of the structure by the infrared thermography system allows for detection of the failure form initiation before significant reduction of the strength capacity which may lead to catastrophic consequences.

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