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Thermal imaging and Thermoelastic Stress Analysis of impact damage of composite materials

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ABSTRACT

The infrared thermography, together with Thermoelastic Stress Analysis and Pulse heating thermography, is used in evaluation of impact damage in fiberglass composite materials. The controlled impact of fiberglass specimen was recorded by a high frame rate infrared thermal camera. The elastic deformation, together with the damage, was evaluated and compared with the post-impact analysis performed by methods of Thermoelastic Stress Analysis and Pulse heating thermography. The applicability and limitations of presented infrared based methods were addressed. Combination of both methods, Thermoelastic Stress Analysis and Pulse heating thermography, is suggested as appropriate for detecting damage including fiber fractures and delamination.

1. Introduction

In last few decades, in the field of engineering and structures, infrared (IR) thermal imaging cameras based on Focal Point Array (FPA) technology have enabled fast development of experimental methods based on thermography. Cooled middle-wave IR cameras (FPA temperature approx. -200 °C), with frame rates above 100 Hz, enabled acquisition of fast events such as impact or stresses caused by structural vibrations. Methods such as Thermoelastic Stress Analysis (TSA), Lock-in thermography, Pulse heating or Flash thermography, became standard non-destructive testing methods. The image based stress distribution patterns, resulting from the TSA, enabled a full-field visualization of surface stresses making the method comparable to strain gauge acquisition, with a difference that instead of point wise data, surface stresses are acquired.

Thermoelastic Stress Analysis [1–9] is a method suitable for evaluating stress distribution of cyclically loaded structures or specimens. Thus, cyclic mechanical loading, magnetic field, or ultrasound is required as excitation needed to cause stresses at frequencies where quasi-adiabatic state is reached. The adiabatic condition achieved at frequencies above 10 Hz for metallic materials, is required to fulfill the thermoelastic equation (Section 4). By using fast IR cameras (acquisition frequency more than 100 Hz) and applying the thermoelastic equation, only stress distribution can be evaluated [10]. The thermoelastic equation cannot give precise stress level readings without involving the loading signal data, i.e. the additional hardware component, called Lock-in, is required [1–3]. Lock-in links the load force (or displacement) signal with acquired thermal flashes, enabling better evaluation of stress peaks. The signal can be load force from the load-cell, displacement from the actuator, or displacement obtained by integrating structural accelerations picked up by an accelerometer [11].

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