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COMPARISON OF ANALYTICAL MODEL OF SPRINGBACK ANGLE OF COMPOSITE PLATE WITH MEASUREMENT WITH AND WITHOUT RECRYSTALLIZATION EFFECT

POROVNÁNÍ ANALYTICKÉHO MODELU ZPĚTNÉHO ODPRUŽENÍ KOMPOZITNÍ DESKY S MĚŘENÍM S A BEZ REKRYSTALIZAČNÍHO EFEKTU

Abstract

Presented paper deals with comparison of two measurements done in our lab to achieve the value of the springback angle of composite plate with single curvature. Plate consists of carbon fiber and PPS matrix. Springback angle without recrystallization effect was measured earlier with the use of laser profilometer ScanControl LLT 2800-25 and optical distance measurement CHRocodile M4. Springback angle with recrystallization effect was measured later with the use of Fibre Bragg Grating optical sensor (FBG) and image processing. Results were compared with an analytical solution in developed software “Springback” with achieving good agreements.

Abstrakt

Článek se zabývá porovnáním dvou laboratorních měření, které byly provedeny za účelem změření velikosti zpětného odpružení kompozitní desky s jednou křivostí. Deska se skládá z uhlíkového vlákna a PPS matrice. Zpětné odpružení bez zahrnutí rekrystalizačního efektu bylo provedeno dříve pomocí laserového profilometru ScanControl LLT 2800-25 a sond na optické měření vzdálenosti CHRocodile M4. Zpětné odpružení s rekrystalizačním efektem bylo změřeno za použití optických sensorů s Braggovou mřížkou (FBG) a zpracováním obrazu. Výsledky byly porovnány s analytickým řešením, které bylo provedeno ve vyvinutém software “Springback” a bylo dosaženo dobré shody.

Keywords

Springback phenomenon; optical measurement; image processing; FBG sensors; thermoplastic matrix.

1 INTRODUCTION

Residual stresses and anisotropic behaviour of fibre reinforced composites during curing of laminate in closed form, lead to dimensional changes of composites after extracting from the form and cooling. One of these dimensional changes is so called springback of angle sections. Other dimensional changes are warpage of flat sections or displacement of single layers of composite for example. The forming tool can be quite expensive, so it is important well predict the springback angle.

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2 MEASUREMENT WITHOUT RECRYSTALLIZATION EFFECT

The principal aim of measuring was to capture thermal deformation of C/PPS specimen. The springback of C/PPS composite with $[[(0,90)/(\pm 45)]_4/(0,90)]_s$ lay-up was investigated. The measuring equipment, which was used, was temperature sensor PT100, CRZ Platinium thin film element, contactless infrared thermometer FLUKE 574, laser profilometer ScanControl LLT 2800-25 and optical distance sensors CHRocodile M4 (see Fig. 1). Specimens were warmed in an oven and then cooled down to the room temperature. At first, the measurements in the temperature range under the shrinkage effect were evaluated. The relative displacement between points, scanned by laser, was evaluated as an angular displacement of vertical part at each time step. Then the springback values were calculated and compared with the analytical solution [1].

Fig. 1 Experimental devices and optical sensors

3 MEASUREMENT WITH RECRYSTALLIZATION EFFECT

C/PPS composite plate with single curvature with the same lay-up described in chapter 2 was incised on the edges. Two metal tubes were bonded to the incisions. FBG sensor was bonded inside these tubes. FBG sensors are based on a periodic variation in the refractive index of the fiber core, which reflects particular wavelengths of lights and transmits all the rest. Specimen was put into oven with digitally controlled heating and warmed up to 175°C. Second FBG sensor has to be put to the oven for the temperature compensation. The value of elongation of the FBG sensor was obtained in each temperature step, which is related to the change in the angle of the specimen. The camera was placed in front of the oven and contrasting background behind the specimen inside. Door of the oven was opened in defined steps and the photos of the specimen were taken (see Fig. 2). The springback angle was evaluated in parallel from the figures using software for the image processing with the data obtained from FBG sensor.

Fig. 2 Measurement with recrystallization effect and measured specimen with FBG sensor

4 COMPARISON WITH ANALYTICAL SOLUTION

Comparison of both results with the analytical solution was done in developed software called "Springback" which was based on Matlab code rewritten into Java with GUI. The analytical solution is based on classical lamination theory (CLT) and equations for through-thickness characteristics of the composite plate (see [2, 3] for details). The springback can be calculated as

$$\Delta\gamma = \Delta\gamma_t + \Delta\gamma_c = \gamma \frac{\left(\alpha_x - \alpha_z\right)\Delta T}{1 + \alpha_z \Delta T} + \gamma \frac{\phi_x - \phi_z}{1 + \phi_z}, \tag{1}$$

where:

$\Delta\gamma_t$ – temperature part of angle change $\left[\circ\right]$,

$\Delta\gamma_c$ – recrystallization part of angle change $\left[\circ\right]$

α_x – coefficient of thermal expansion in longitudinal direction $\left[\mathrm{K}^{1}\right]$,

α_z – coefficient of thermal expansion in trough-thickness direction $\left[\mathrm{K}^{1}\right]$

ΔT – change in temperature $\left[\circ\right]$

Φ_x – coefficient of recrystallization shrinkage in longitudinal direction $\left[-\right]$,

Φ_z – coefficient of recrystallization shrinkage in through-thickness direction $\left[-\right]$.

Eq. (1) is derived for the flat plate. For the case of plate with single curvature there is light modification of this equation (see [2] for details). Comparison of both results with the analytical solution can be seen in Fig.3.-It is evident that a good agreement was achieved.

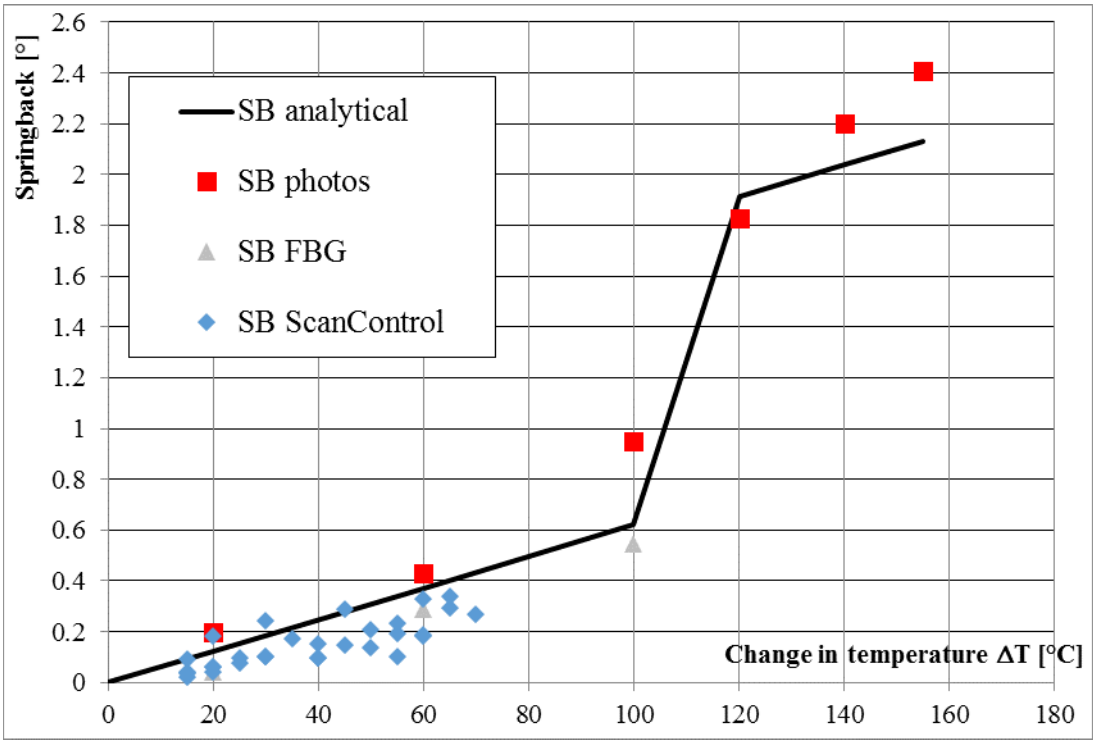

Fig. 3 Comparison of both measurements with analytical solution obtained by "Springback" software

5 CONCLUSIONS

Two types of springback measurements were done - one with the recrystallization effect and the second one without it. Both experimental measurements and the analytical solution were mutually compared and the good agreement between measured data and calculated results has been found.

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