ASSESSMENT OF DAMAGE PROPAGATION IN CARBON-FIBRE COMPOSITE UNDER CYCLIC LOADING

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Summary: *Carbon-fibre composite is very popular material in aircraft industry. Application of this material is limited by low fragility and low impact resistance. In flight airplane can be initialy damaged by hailstorm or bird strikes. Vibrations of the engine and turbulence during flight may cause propagation of this damage. This study describes the of laser profilometry to investigate post damage under cycling loading.*

Keywords: *carbon-fibre composite, damage propagation, laser profilometry*

1 Introduction

Carbon fibres embedded in thermoplastic (polyphenyle sulfide) matrix are very popular material in aircraft industry. Application of polymeric matrix brought advantages of high chemical resistivity and good fatigue performance [1, 2]. Service life of ligthweight structures used especially in aviation industry can be influenced by different effects [3]. Aerodynamics loads and engine vibrations cause low-amplitude cycles [4]. Wayward strikes may appear during the ground maintenance, may be caused by inflight collisions or severe meteorological conditions. Article deals with evaluation of laser profilometry as a method for ground maintenance procedures.

2 Materials and Methods

2.1 Specimen description

Carbon fibre composite with polyphenyle sulfide matrix samples were prepared for this purpose. Final specimens were cut from base plate by using water jet cutter. Specimens got rectangular shape with dimensions of $250 \times 25\,\mathrm{mm}$. The material is consisted of quasi-isotropic 8-ply of carbon fabric. The fibres volume fraction is higher than $90\,\%$. Thin glass fibre cloth protect the core against mechanical and chemical influence. The surface is covered by this fibre. The base material was manufactured by LATECOERE Czech Republic s.r.o. Plates with thickness $2.5 \pm 0.05\,\mathrm{mm}$ were delivered.

2.2 Initial damage

The drop tower was designed as a part of the project SGS12/163/OHK2/2T/16 with maximal impact energy $50\,\mathrm{J}$. Spherical indenter with diameter $20\,\mathrm{mm}$ was used to initial damage. We used impact energies of $10\,\mathrm{J}$, $20\,\mathrm{J}$ and $15\,\mathrm{J}$. The impacts were beated in $30\,\%$, $50\,\%$ and $70\,\%$ of the length of the samples.

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2.3 Static loading

Quasistatic loading test was performed to obtain tensile strength of as delivered specimen and impacted specimen. No decrease of tensile strength caused by initial damage was measured. In the both cases values of the tensile strength were $27 \pm 0.5\,\mathrm{kN}$.

2.4 Fatique loading

For fatique testing Mikrotron (Russenberger Prufmaschninen, AG) resonant testing machine was employed . It was set up at chosen stress level of force value $6\,\mathrm{kN}$ and amplitude $5\,\mathrm{kN}$. Thermal imaging camera SC7600 (FLIR Systems, Inc.) was used to prevent exceeding the $50\,\%$ of glass transition temperature. Lower frequency limit was set to avoid specimen rupture [5]. Because of the profile scaning the fatigue experiment was interupted six times at predefined number of cycles.

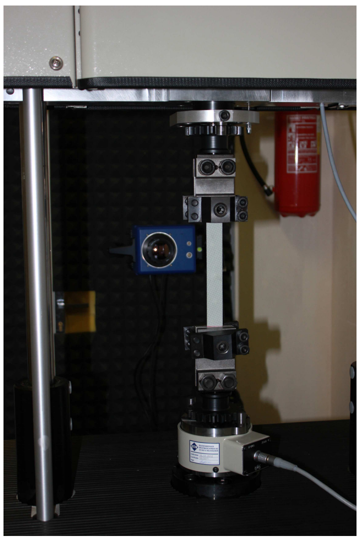

Figure 1: Experimental device for dynamic loading and thermal imaging camera

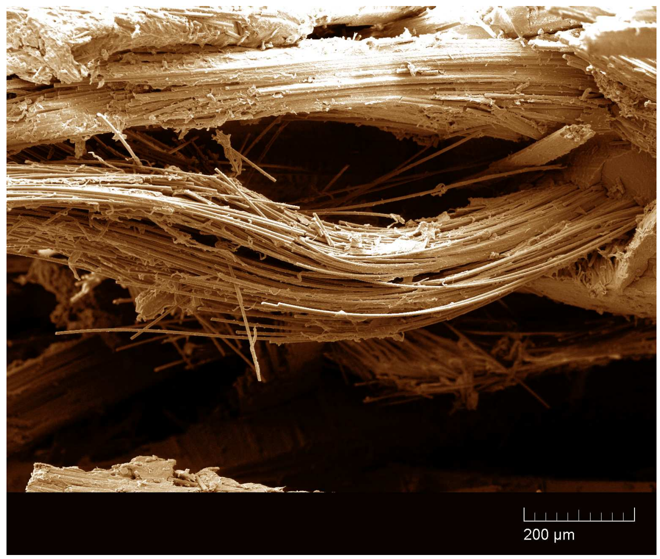

Figure 2: Fibre crack visualization (SEM)

2.5 Profile measurement

Profilometry measurement was performed using laser scanner ScanControl LLT2600-25 (Micro-Epsilon Messtechnik). Maximum width of scanning area was $40\,\mathrm{mm}$ with 1024 measured points. Altitude resolution of the scans was $4\,\mu\mathrm{m}$. The scanner was controlled by single axis linear stage. Minimum step was $10\,\mu\mathrm{m}$ and on-axis accuracy $\pm 0.5\,\mu\mathrm{m}$. Scanning time was approximately 15 minutes.

2.6 Damage propagation assessment

The scanned data of profile changes were analysed using custom algorithm in MATLAB (Mathworks, Inc) computational environment. To find the position of the sample in scanning area edge detection algorithm was used. Global surface changes from the initial damage were considered and object were transformed to unitary coordination system. The initial damage with cyclic loading caused overall influenced curvature of the surfaces. Surfaces were fitted by the second order curves and transformed to the new reference level. On straightened surfaces were quantified local impacted zones. Changes in impact depth, sample thickness and area of influenced zones were chosen as degradation parameters. Influenced zone was evaluated by deviation of the surrounding area. Thickness of specimen was counted between the bottom of the upper surface and the top of the lower surface. Thickness of the specimen was counted from the difference between the bottom of the upper surface and the top of the lower surface.

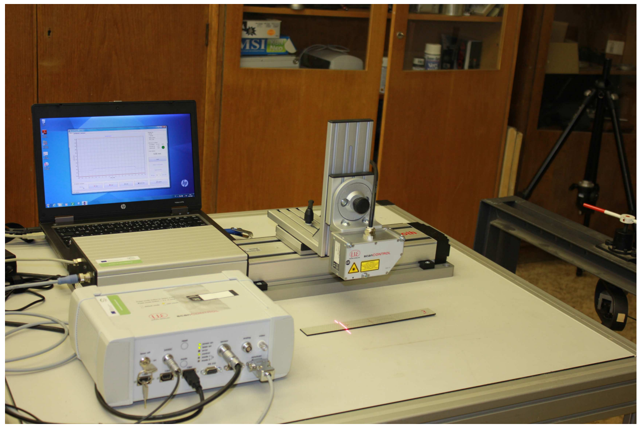

Figure 3: Profilometry device equipped with ScanControl LLT2600-25 laser scanner

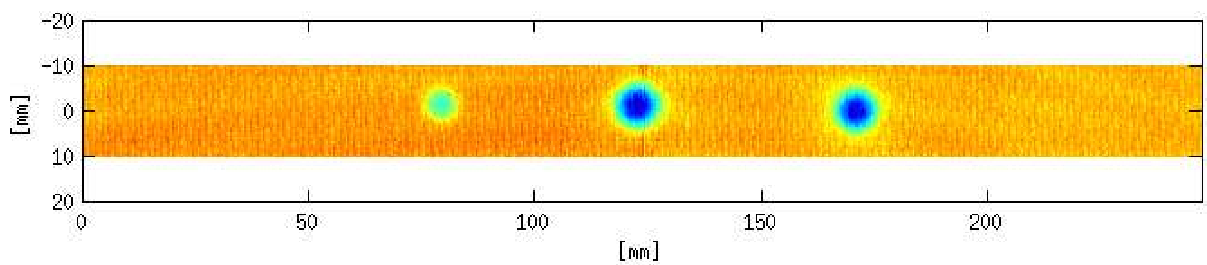

Figure 4: Reconstruction and visualization sample surface after scanning process

3 Results

Based on reconstructed profiles from laser measurements influenced zones were identified. Changes in specimen parameters described micromechanical response to the fatigue loading. The process of damage propagation in three selected samples is depicted in fig. 5. The depth of damage decreased with number of cycles. The area and thickness of specimens slightly increased. Damage propagation exhibits similar evolution among the tested set of samples.

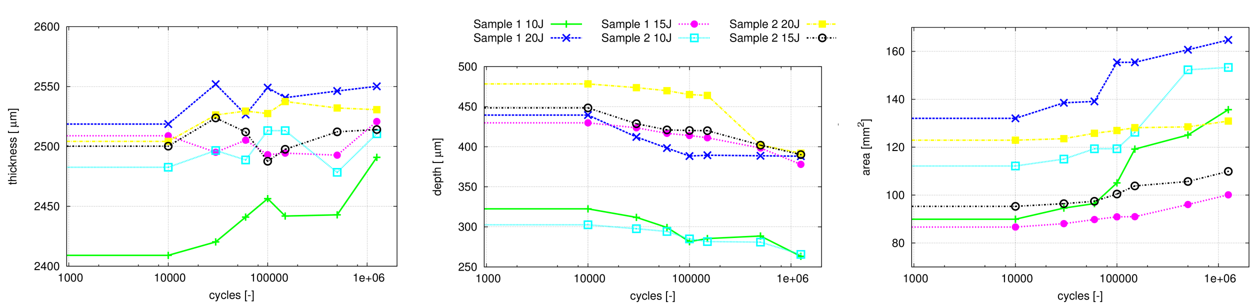

Figure 5: Results of the experiment

4 Conclusions

In this study of time-lapse profilometry was for evaluation of post impact damage propagation in C/PPS composite under cyclic loading used. Significant changes of chosen parameters provide information about damage accumulation in composite specimens. The area of influenced zone increases with number of cycling. The depth of the impact corresponds to impact energy. Thickness of the specimen decreased. Generally laser profilometry is a suitable method for NDT testing and evaluation of surface damage but the reliability of the method is strongly influenced by resolution of available laser scanner.

Acknowledgment

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References

[1] Minster, J. et al. *Microindentation into an epoxy composition to assess the influence of aging on mechanical properties*. J. Appl. Polym. Sci. 123, S2090-S2094 (2012).

[2] Minster, J. et al. *Time-dependent mechanical characteristics measured through the use of a microindentation technique*. Mech. Time-Depend Mater, 14 (3), S243-S251 (2010).

[3] Aoki, R. et al. *An Experiment Study of Impact-Damaged Panels under Compression Fatigue Loading*. Int. Appl. Mech., 40 (5), S487-S505 (2004).

[4] Baklanov, S.V. *Low-frequency vibroisolation mounting of power plants for new-generation airplanes with engines of extra-high bypass ratio*. Journal of Sound and Vibration 308, S709S720 (2007).

[5] Pirner, M. et al. *Dynamic response as a tool for damage identification*. Developments in the Science and Technology of Composite Materials, S633-S642 (1990).