The industrial applications of a rapid reflection photoelastic coating

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Introduction

Reflection Photoelastic Stress Analysis (RPSA) is an experimental technique used in industries to assist in a variety of design and manufacture processes. Users can benefit from immediate qualitative and quantitative information, for example about maximum shear strains in complex geometries. Recent developments and commercial availability in automated collection and analysis of photoelastic data has given potential for RPSA to be a truly effective method. However, current RPSA methods are hindered by complicated coating application processes with large timescales for data collection. This research demonstrates the possibility of overcoming these drawbacks by designing a new coating material that is thin (~50 µm), possesses a high sensitivity to strain and the potential to reduce the overall RPSA timescale by an order of magnitude. The transition from laboratory testing to industrial application is presented.

Benefits of a rapid photoelastic coating

Common reflection photoelastic materials utilise thermoset resins as either an adhesive for a polycarbonate sheet or as a mouldable coating for use on complex geometries. Application processes are difficult to perfect and often produce undesirable qualities that affect a coating's photoelastic response. Such effects include non-uniform adhesive layers creating residual stresses or air bubbles in transparent coating, distorting captured photoelastic images. Another inconvenient attribute of thermoset resins is their long cure times, often upwards of twenty-four hours.

This research investigated the potential of UV curable resins to produce rapid, energy efficient and low-cost chemical reactions when compared to thermosets. A developed UV curable formulation, labelled WF31, was measured to achieve a maximum cure conversion in 20 s irrespective of the dosage of UV-C light. This would allow industries flexibility in the choice of curing apparatus – powerful light sources are not a requirement. When cured, WF31 was uniform in appearance allowing for unobstructed full-field measurements to be conducted. The coating could also be removed easily without damage to the substrate it was adhered to. Two-part epoxy coatings often had to be removed by force resulting in damage to the component being analysed.

Development of experimental procedure

The apparatus used to measure photoelastic data was the GFP1600 grey-field polariscope[1], in conjunction with the DeltaVision acquisition and processing software. This system provided automated full-field magnitude and directional data with a sub-fringe resolution of retardation better than 0.1 nm. In order to translate the measured retardation into desirable strain information, the coating must first be calibrated so that its strain-optic coefficient is known. This was achieved by manipulating the strain-optic law shown in equation 1

$$(\varepsilon_1 - \varepsilon_2) = \frac{\delta}{2dK} \tag{1}$$

where ($\varepsilon_1 - \varepsilon_2$) is the principal strain difference, δ is retardation, d is the coating thickness and K is the strain-optic coefficient. An effective experimental procedure was required to calculate an accurate value of K for WF31.

Aluminium beams (300 x 25 x 6) mm were manually coated using a K-bar that spread a ~50 µm thick layer of WF31 across an area of 25 cm^2. Strain gauges were also applied to the beam to measure the principal strains. The aluminium beams were then subjected to an elastic tensile loading scenario with a maximum stress of 250 MPa in 30 MPa intervals. At each loading interval, the GFP1600 acquired and processed images containing the induced retardation the photoelastic coating inflicted on the interacting polarised light used to illuminate the sample. The sample was illuminated uniformly with two circular polarised light sources placed either side of the GFP within the same plane as the imaging lens. Illuminating uniformly, paired with a reflective backing such as silver paint, was shown to improve the GFP's signal-to-noise ratio by 60 % when compared to non-uniform illumination. In order to extract the photoelastic data that accurately represented principal strain difference, GFP images of loaded samples were first subtracted with the information held within zero-load images of the samples. Performing this processing facility removed the effects of coating residual stresses and the effects of uncalibrated light sources outputting elliptical polarised light rather than circular.

[1] www. stressphotonics.com

Calibration of the coating

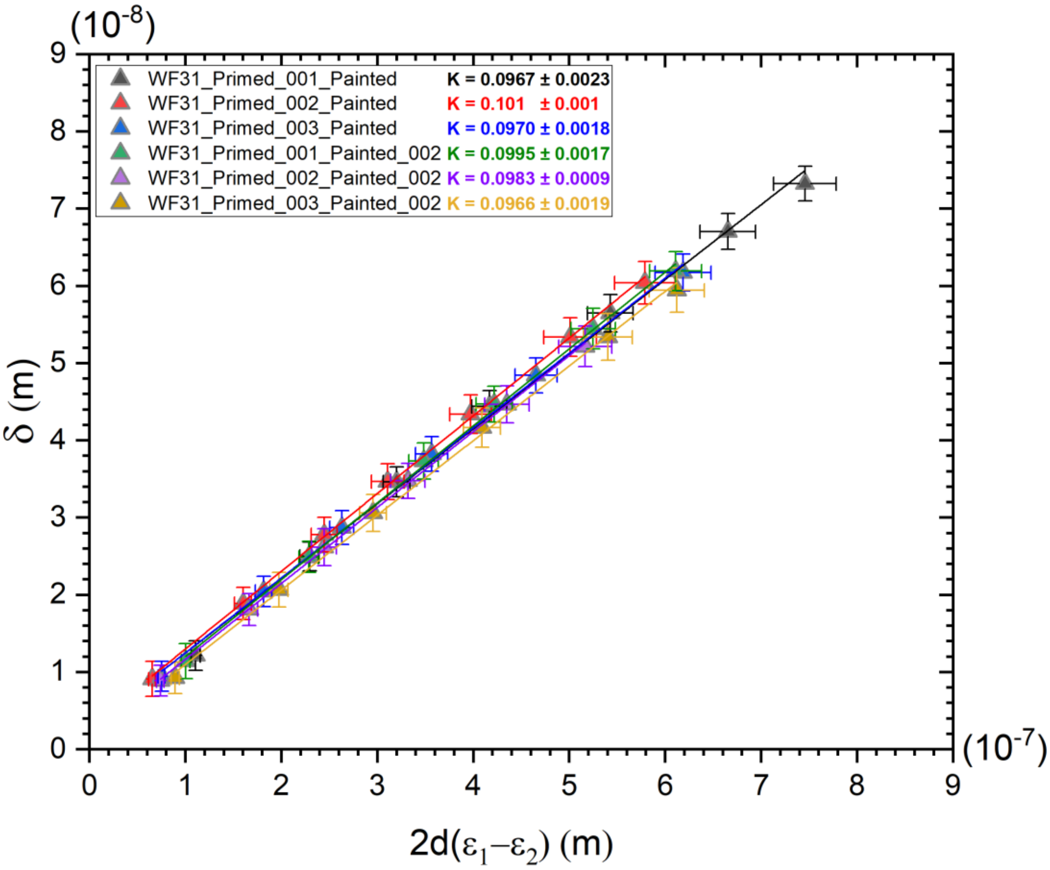

Fig 1: Calibration of six individual coatings. Their calculated strain-optic coefficients are presented in the legend.

By combining the strain gauge data, GFP1600's retardation data and the thickness of the coating (once removed and measured with a micrometre) figure 1 was used to calculate the value for *K* for WF31. The combined *K* value for WF31 was calculated to be 0.098 ± 0.002 – a medium-high sensitivity photoelastic coating.

Industrial applications

The research aims to transition from a research environment to an industrial setting. A case study will be presented to determine the overall effectiveness of the rapid coating for a relatively large aerospace application, compared to existing commercially available photoelastic coatings. Comparisons will be made to measure the reduction in the total time for coating application, data collection and coating removal. Additional research will be presented to determine if the UV curable formulation is applicable to components possessing complex geometries subjected to varying loading scenarios in an industrial setting. A focus on the coating's effectiveness to be sprayed, for quick and easy application, will be reviewed. Furthermore, methods to correct for thickness differences will be explored. An introduction of a coloured dye into the coating will produce a tint which affects the how the light enters the GFP. A relationship between the differences in intensity of red and blue light will be used to measure the thickness of the coating.

Conclusion

A rapid photoelastic coating has been developed which has a strain optic coefficient of comparable performance to existing coatings but is much faster and easier to apply in a laboratory setting. An investigation for the applicability of the rapid coating in an industrial setting has been described and the results of this will be presented at the conference.