Mechanical Forces Due to Lightning Strikes to Aircraft
A Pseudo-Stereo DIC Technique for Measuring Full-Field Displacement

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Abstract. One of the major considerations currently affecting the design of composite aircraft structures is the damage resulting from lightning attachment. Full-field measurements of the displacement of materials under lightning attachment would provide a greater understanding of the forces induced by the high current waveform. Furthermore the understanding of the forces involved would allow for the validation of finite element models to simulate the effects of lightning attachment, therefore aiding in the design of solutions to reduce damage to aircraft structures. The study aimed to develop a pseudo-stereo high speed digital image correlation technique in order to obtain full-field information during lightning attachment based on a 100kA initial strike over a 500μs duration, the most severe waveform experienced. The technique that was developed gave full-field measurements for a 550x550x2mm 6082-T6 aluminium panel under a 100kA lightning attachment. Two correlation measurements were recorded at 3000 and 5000 frames per second. The displacement results are comparative with the theory of a cylindrical pressure expansion arising from the acoustic shockwave on attachment to the material. Further developments to this system could allow for more reliable results and higher frame rates which can be used to develop finite element simulations based on measured physical data.

Introduction

On average a commercial airliner is struck once every 10,000 hours of flight, which is approximately once a year (Gagné. M and Therriault (2014)). For an aluminum airframe, protection from lightning attachment is straightforward due to high conductivity. However the introduction of composite airframes brings with it a much greater challenge to protect against lightning attachment, where significant damage can occur.

A lightning strike is a high amplitude direct current pulse having the electrical current waveform shown in Fig.1. The waveform is split into four components A-D. Each component induces a different mechanical response from the material with the high energy stages represented by Component A and Component D being responsible for the majority of the damage and delamination which occurs. The material undergoes complex deformations due to acoustic and magnetic shockwaves plus surface material vaporization arising from thermal expansion.

The aim of this project was to develop a pseudo-stereo digital image correlation system in order to obtain full-field displacement measurements for a material during lightning attachment to enable increased understanding of these processes.

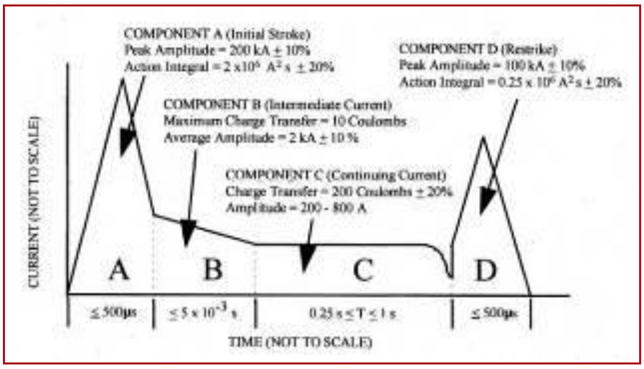

Figure 1 Standard electrical current waveform for simulated lightning strike testing on aerospace materials

Pseudo-Stereo System Development

Traditional digital image correlation systems use a stereo camera arrangement to obtain the two sets of images required for correlation. This project used a single camera to avoid synchronisation issues at the high sampling speeds required. An adapted four mirror arrangement similar to that used by Wang et al. (2008), was proposed by Faulder (2013) to enable a stereo DIC system to be replicated using a single camera for this purpose. The mirror arrangement is shown in Fig.2. The developed setup consists of a high speed camera and mirror arrangement positioned at a distance of 1.5 meters from the test panel (Fig. 3). The mirror arrangement splits the camera image into two sub images of the views from the two large mirrors shown. The large mirrors are aligned with a further mirror located under the panel (Fig.3 and 4) in order to produce two views of the panel underside in a single high speed camera image (Fig.5); whilst enabling the camera to be positioned away from the electromagnetic field induced during the test.

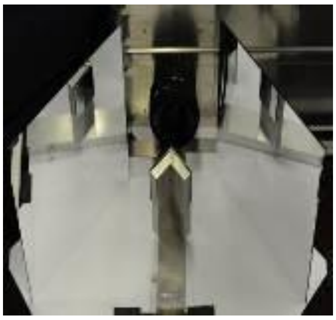

Figure 2: Four mirror set-up

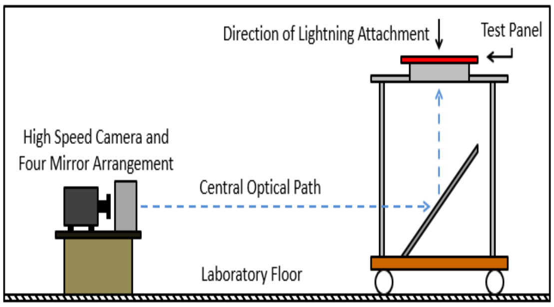

Figure 3: Experimental set-up

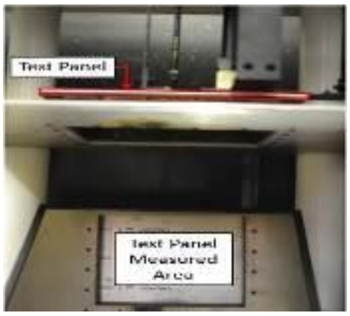

Figure 4: Test panel.

Experimental Procedure

Two tests were conducted at 100 kA for each lightning attachment. The camera was set to record at 3000 and 5000 frames per second in the first and second test respectively. Images were post processed and separated into the two sub-images for correlation.

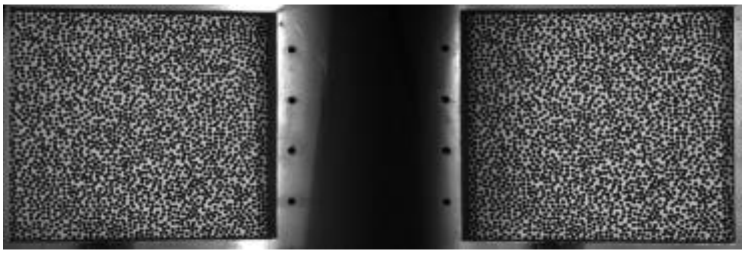

Figure 5: Image captured using the pseudo-stereo set-up.

Experimental Results

Results for tests recorded at 3000 frames per second are presented in Fig. 6.

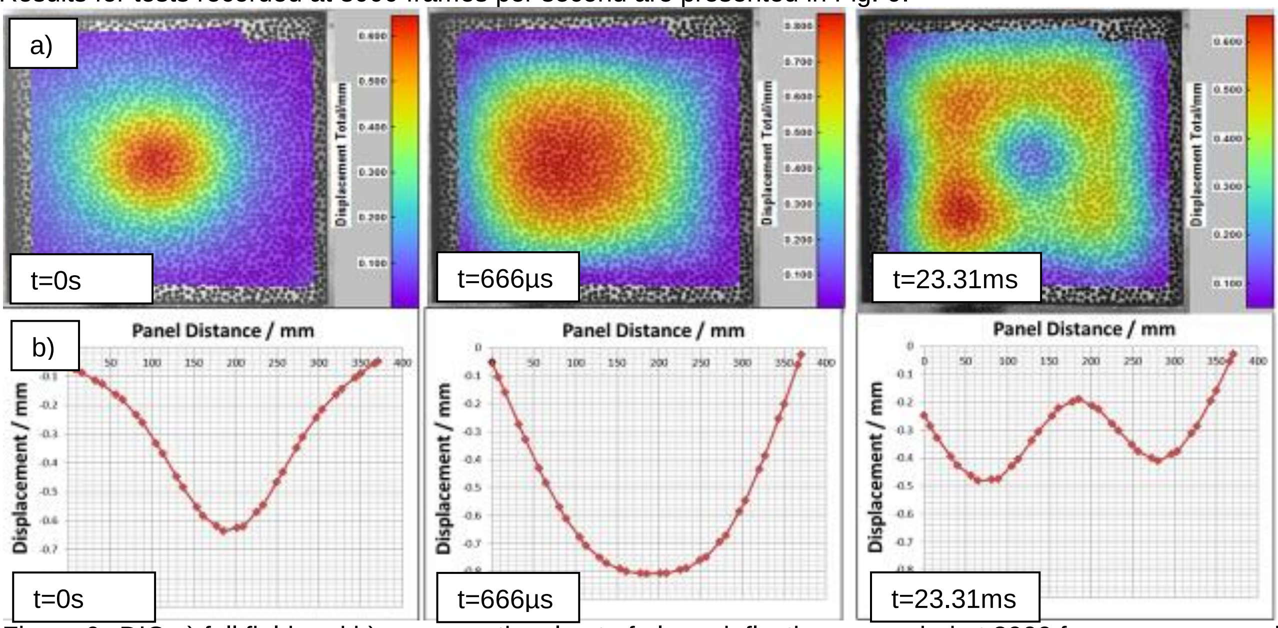

Figure 6: DIC a) full field and b) cross sectional out of plane deflections recorded at 3000 frames per second

Conclusion

The developed pseudo-stereo system was an effective method for monitoring the behavior of an aluminium panel during lightning attachment. The digital image correlation produced full-field deflection measurements

References

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