Strain Measurement on Anti-G Garments using 3D Digital Image Correlation

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Abstract Anti-g garments protect fast jet pilots from g-induced loss of consciousness (G-LOC) which has contributed to many fatal incidents. The garments are mission-critical and expensive so prolonging service life with the required performance characteristics is of great interest. Strain distributions at some local areas within the garment are well-understood; however the strain field distribution over larger areas and its impact on failure is less known. A series of experimental tests using 3D Digital Image Correlation (3D DIC) were conducted on two types of garment to analyse the full-field displacements and strains to potentially optimise the garment design. The areas of interest were the anterior thigh and abdomen as they are common failure regions. 3D DIC is a viable method to obtain full-field strain data from pressurised anti-g garments and the results indicate that reinforcement features and garment geometry cause local strain concentrations in the anterior thigh areas.

Introduction When a fast jet aircraft undergoes high-speed manoeuvres there is an acceleration that acts on the pilot's mass. This acceleration creates hydrostatic forces within the pilot's cardiovascular system that pools blood in the lower extremities of the body. If this is sustained for more than approximately four seconds then, the pilot will experience grey out, black out and finally G-LOC [1] which has contributed to many fatal incidents. Anti-g garments are connected to a compressed air supply in the aircraft such that the inflation is approximately proportional to the g-force, which allows the garment to exert a compressive force on the pilot's thighs and abdomen to retain blood in the upper extremities of the body. The garment of interest featured low stretch properties which allowed for shorter inflation times due to the low inflation volume. However, the anterior thigh and abdomen experience maximum hoop stresses due to the larger diameters and are susceptible to failure. The strain values at some locations on the garment are well understood; however the strain distribution over most of the garment and its impact on garment failure has not been evaluated. Two types of garment have been investigated; the full coverage garment features a double layer construction, in which an inflatable bladder is restrained by a high tensile white nylon critical restraint layer which is then covered by a green aramid protective layer. The second garment was a skeletal garment with a single layer construction that allowed a significantly larger inflation volume. One full coverage garment that had been subject to solar exposure and a skeletal garment that had not been subject to solar exposure were available to investigate the viability of digital image correlation for evaluated strains in the textile of the garments.

Experimental The full coverage garment had the green protective layer on the left anterior thigh removed and a black speckle pattern was applied to the white critical restraint layer. In addition, a white speckle pattern was applied to the green protective layer on the right anterior thigh and abdomen. The skeletal suit had a white speckle pattern applied to the left anterior thigh and the abdomen. The speckle patterns were applied using a fine paint brush. The garments were fitted on to anthropomorphic test devices (ATD) as shown in Fig.1 which simulated the dimensions and weight of a pilot's abdomen and legs. The two ATD's with garments were secured in decommissioned Martin-Baker Type 12H Mk 2 ejection seats to simulate a cockpit environment. A compressed air source, controlled by an inflation rig, was connected to the suits for pressurisation. A Digitron 2020P differential manometer was used to achieve accurate pressure readings, as the pressure was increased in 6.9 kPa (1psi) increments from 0-81 kPa (0-11.75 psi). A 3D DIC system ISTRA 4D Q-400 from Dantec Dynamics [2] was used with two Allied Vision 1.2 Megapixel Stingray F-125 cameras with Schneider Kreuznach Cinegon 1.4/12 lenses to obtain full field displacement data.

Figure 1. Full Coverage Garment fitted to ATD secured to a Martin Baker Type 12H Mk2 ejection seat

Results A series of tangential X, Y and shear strain data sets for the common rupture areas on the full coverage and skeletal garment were obtained. The data was generated from the maps of displacement and evaluated using the ISTRA DIC software to process the stereoscopic images, the results were then mapped on to the contour [3] of the garment. The white critical layer on the full coverage garment experienced a local shear strain concentration as shown in Fig. 2a which was adjacent to a garment reinforcement feature that supported a locking mechanism. On the same area, the Y-direction strain was compressive adjacent to the safety harness location and the knee stitch line as shown in Fig. 2b. The skeletal garment exhibited a local Y-direction strain adjacent to the knee cut-out in the lower part of the observed region as shown in Fig. 2c and in the same area, there is a compressive X-direction strain as shown in Fig. 2d.

Conclusion The use of 3D DIC is a viable method to obtain full-field strain data from pressurised anti-g garments. The abdomen area on both garments experienced uniform strain distributions; however the anterior thigh areas for both garments experience local strain concentrations due to reinforcement features and garment geometry.

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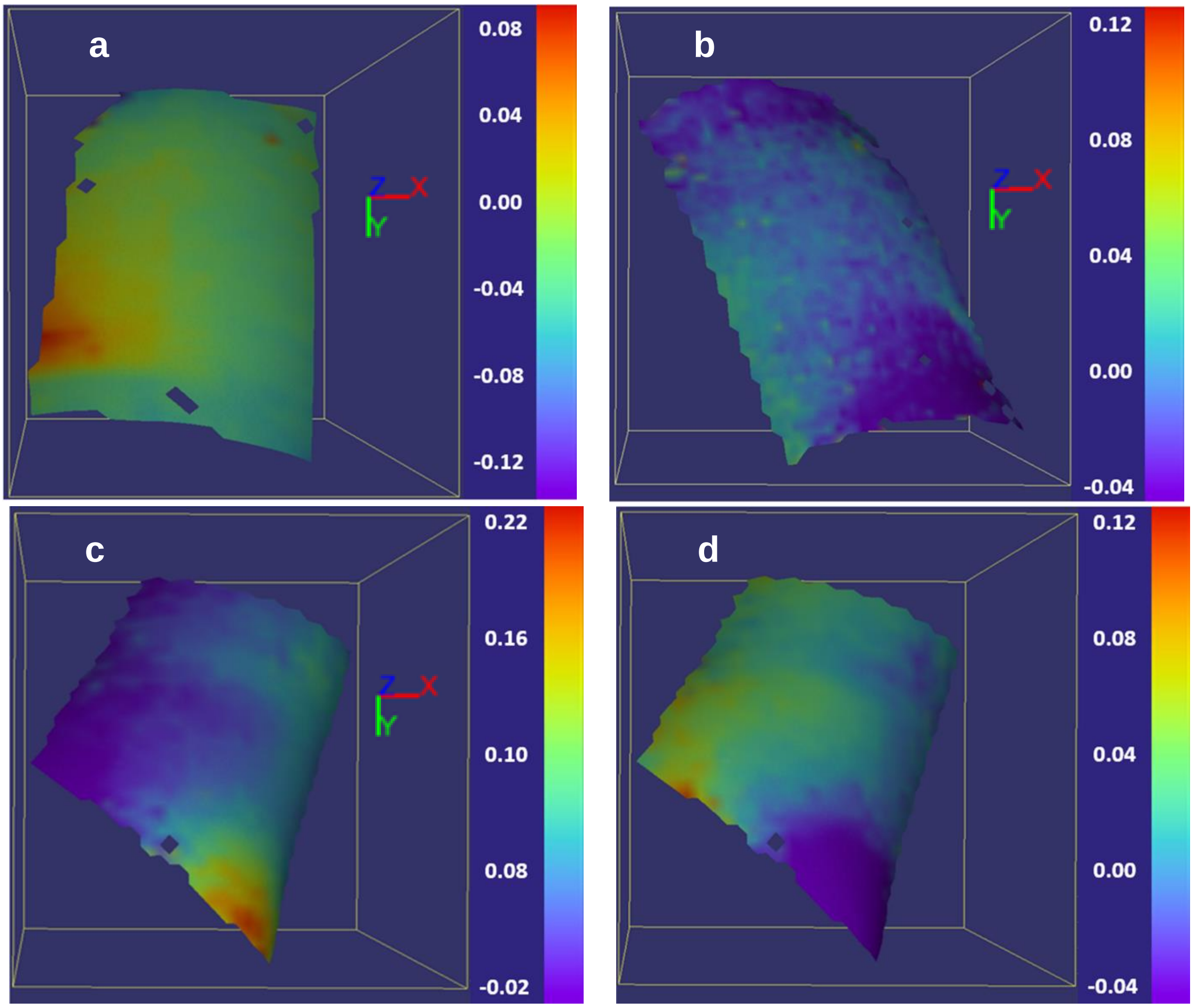

Figure 2. Full field tangential strain distributions at the maximum pressure level of 81 kPa (11.75 psi). Shear strain (a) and Y-strain (b) on the white critical layer of the full coverage garment. Y-strain (c) and X-strain (d) on the green protective layer of the skeletal garment.

References

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