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

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Why Anti-G Garments...

- Reduces the risk of Gravity induced Loss Of Consciousness (GLOC) in high performance aircraft capable of higher speeds, greater manoeuvrability and higher Gz performance
- Allows the pilot to focus on mission accomplishment and minimizes the risk of loss of Situational Awareness (SA).
- Mission sustainment and training effectiveness is increased

Operation benefits

- Pilot fatigue decreased through reductions in:
  - Anti-G Straining Manoeuvre
  - Dehydration - 3% increase in dehydration halves tolerance at 7Gz*
- Cost of loss of life and aircraft
- Duty of care demands safety is taken into account when making equipment decisions
- Reduced Weight/ thermal burden

Maximising pilot performance

- Full coverage G-suits provide improved GLOC performance.
- Norwegian tests suggest no GLOC incidents since introduction of FCAGT vs. 23% of pilots experiencing GLOC previously
Current Approach

- UNDEFINED state
- Basic mathematical model
- Swatch level testing for repeatable intrinsic properties (flame resistance, uv degradation, washing cycles)
- Perform verification and validation of performance by real test set up
- Correlate the swatch level test results to the garment level as an undefined function but validated and consistent

Future Approach

- DEFINED state
- Accurate mathematical model
- Swatch level testing for repeatable intrinsic properties (flame resistance, uv degradation, washing cycles) variance with time, environment
- Predict performance by simulations by understanding the stress/strain distribution
- Correlate the swatch level test results to the garment level as an defined functions
- Perform verification and validation of performance by analysis and real test set up

Informed Design decisions

More assured requirement specifications
Enhanced Approach

- Understand the effect of 1D swatch test values variance on the garment performance
- Understand the 2D and 3D stresses/strain generated in the garment
- Understand the effect of geometry, stitch and layering of the garments
- Relate the swatch level parameters with a DEFINED function to the garment performance
- Perform multiple field analysis like thermal combined with cyclic pressurization & depressurization on the Anti-G
- Measure and analyse the effect of restraints applied on the pilot
- Ability to vary the test conditions to simulate the fabric, swatch and garment performance

Production Acceptance Test (PAT)

Solar Exposure 88 MJ/m²/yr 1, 3, 5, 7 & 10yr

Operating Temperature Transients

Humidity 240 hrs

Post-Solar Endurance Approx 10k/yr

PAT Every 10K

Proof Pressure

Burst Pressure
Aims and Objectives

To generate full-field experimental strain data on the common failure regions of two types of anti-g garment

1. Identify viable technique to obtain full-field data on large surface areas
2. Install ejection seats and pressure equipment from RFD into the Laboratory
3. Prepare garments and integrate setup with 3D DIC equipment
4. Complete experiments and process data
3D Digital Image Correlation

3D DIC is a full-field, non-contact technique that measures the in-plane and out-of-plane deformations on a large range of materials and loading conditions.

- Apply a speckle pattern to the area of interest.
- Calibrate the system, each facet in the grid contains a unique speckle pattern.
- A reference image is taken in the specimen's undeformed state.
- As the specimen is loaded, the system tracks the movement of the facets and computes displacement.
Experimental

1. Ejection seats and pressure equipment delivered to laboratory
2. Speckle patterns applied to areas of interest
3. Fit garments on to the ATD’s and secure in to ejection seats
4. Set up pressure line with control system and digital manometer
5. Integrate setup with 3D DIC equipment and calibrate system
6. Conduct 3D DIC experiments and process the data
Specimen Preparation

**Full Coverage Garment**
- Green outer protective material removed from right leg and black speckle applied
- White speckle applied to thigh and abdomen

**Skeletal Garment**
- White speckle pattern applied to the green outer protective material of the thigh and abdomen area
3D DIC Experiments

Pressure Increments

- 0-81 kPa (0-11.75 psi) in increments of 6.9 kPa (1 psi)
- Matched to pressure levels used by RFD

- Green - 0 kPa
- Red - 81 kPa

- Green - 0 kPa
- Red – 81 kPa
Results – Full Coverage Garment

White Critical Layer

- **Shear Strain** Map
- 8% local shear strain at 81kPa

Green Protective Layer

- **Y-strain** map
- 4% Y-direction compression at safety harness and knee stitch line
Results – Skeletal Garment

Outer Protective Layer

- **Y-strain** map
  - 22% Y-strain in channel adjacent to knee cut out

- **X-strain** map
  - 4% X-strain compression in channel adjacent to knee cut out
Future work

• Generate the experimental data for a mature product and process the data for comparison with real test data.
• Evaluate and use the knowledge built up by technology right at the concept phase of the design for an inherently better product.
• Use the data processed to improve the current design and perform the validation of the improvement.

Survitec benefits

• Change management
• Obsolescence management
• Reduced Design Iteration
• Push Design Boundaries

Customer benefits

• Optimized Design Solution
• Reduced Time Frame
• Eliminate Redundancy
• Better informed Equipment level Statement of Requirement

Reduced time to market
Summary

- 3D DIC is a viable method for obtaining full-field strain data from pressurised anti-g garments
- Garment geometry, reinforcement features and safety harness location affect the strain field at local areas
- The strain generated is in sync with the observed data (failures) in the garment
- Future work can be undertaken using this method to observe other failure regions on the garments
- The processed data generated to be checked against the real test data (Sanity Check)
- Repeatability and consistency of the experiment to be verified
- Perform simulation using the data to create fabric/textile behaviour when integrated into a system