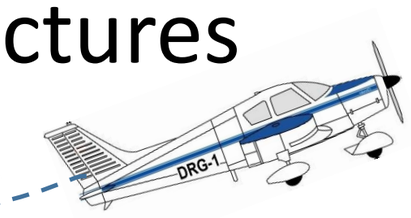
How identical is identical?

Experimental studies of nominally similar structures using laser vibrometry

S. Walker



Why do we care?

A major challenge to the application of Structural Health Monitoring (SHM) to populations of structures, such as wind farms, is the variation between normal (i.e. undamaged) cases within a population.

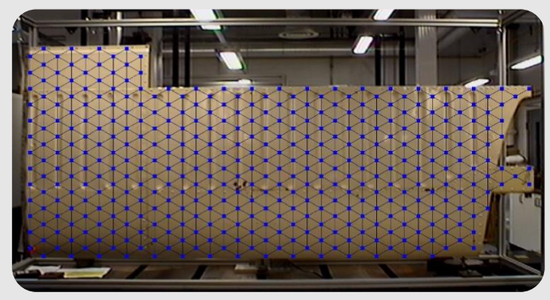
It is unfeasible to measure the normal case for each structure, so population-based SHM aims to infer any given structure's normal case from that of a nominally similar structure.

This ongoing work aims to understand the variation in normal cases between two nominally similar structures. Two sides of an aircraft tailplane were used.

Experimental Arrangement

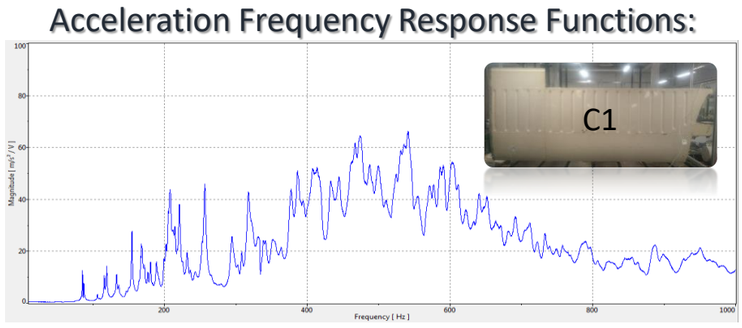
- Structures were freely suspended on soft springs
- Excitation was by an electrodynamic shaker at 0-1000Hz (White noise)
- Response was measured using a Scanning Laser Doppler Vibrometer (SLDV) recording at 156.5mHz resolution (6400 spectral lines)

- Data was recorded at 447 measurement points on each structure, averaged over 5 tests
- Mean coherence was ~92%
- Shaker location and drive rod length were studied before testing and found to have minimal effect on results

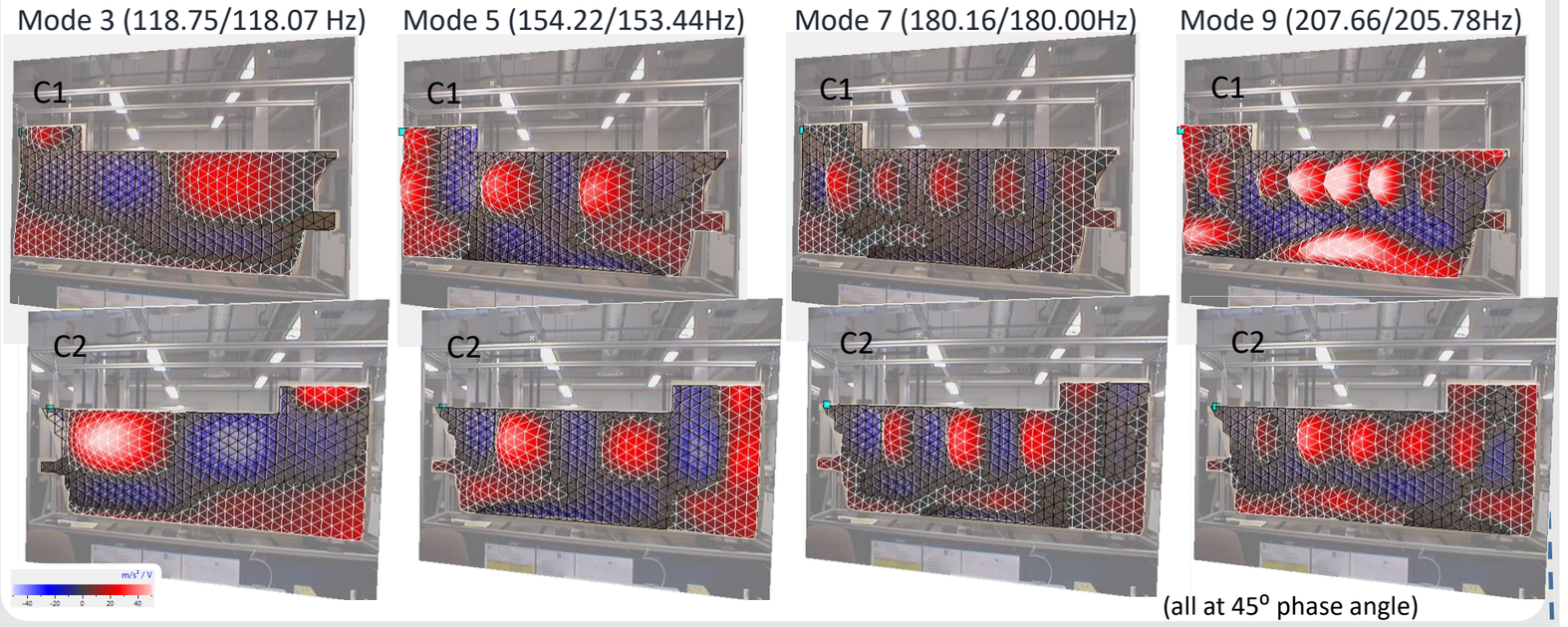


Results

Acceleration Frequency Response Functions:

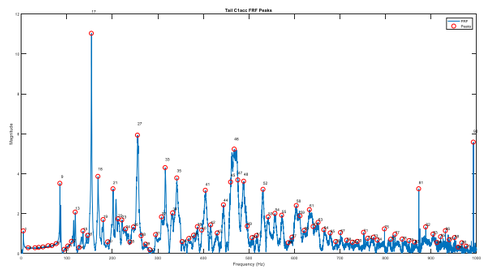


Operating deflection shapes:

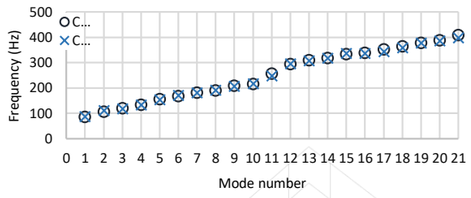


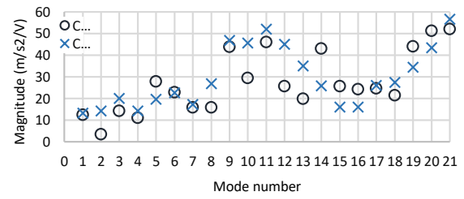
(all at 45° phase angle)

Modal Analysis:

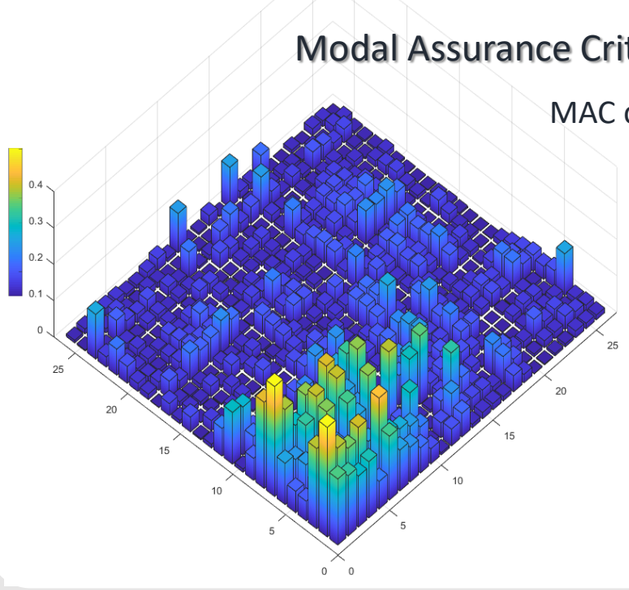


- Modes identified in MATLAB
- 21 modes found in 0-500Hz range
- Small variation in modal frequencies between C1 and C2 (↙)
- Larger variation in response magnitude between C1 and C2 (↓)





Modal Assurance Criterion



MAC compares two sets of modes:
0 = no similarities
1 = identical

C1 vs C2 MAC shows that responses are very different beyond the first ~10 modes

Conclusions & next steps

Nominally similar structures were found to exhibit different responses to excitation. Modal analysis and MAC suggest major differences between structures, particularly at higher modes. Further work will expand the study:

More structures:

Ongoing work will test further nominally similar structures. Four further tailplane structures will be tested in undamaged states.

Damage:

Tests with added mass (additional 1.5%) pseudo-damage showed little variation between original structure response and added mass structure response. Additional mass appears to be a poor representation of real damage, so real damage tests will be carried out by cutting the structures.

Results will inform the development of population-based SHM methods

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