Development of a Virtual Testing Methodology for Structural Fatigue Testing Setups

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Introduction

• The National Aerospace Laboratory (NLR)
• Structural Test Setups

• Thesis Assignment
• Virtual Testing Methodology

• Modelling
• Measurements and Verification

• Conclusions and Recommendations
The National Aerospace Laboratory (NLR)

Departments:

• Aerospace Systems and Applications
• Air Transport
• Wind Tunnels
• Aerospace Vehicles

The National Aerospace Laboratory (NLR)

Facilities

Test Aeroplanes

Structural Testing

Simulators

Aerodynamic Testing
Structural Test Setups

- People standing on wings (1910)
- Sandbags (1920)
- Cable Systems (1970)
- Virtual Testing (2010) ?

Structural Testing

- Certification of Aerospace structures
- Proof of structural integrity
  - Static testing (Ultimate load testing)
  - Fatigue testing (Durability testing by cyclic loading)
Structural Testing

Fatigue Test

Reference Load

Load [N]

Time [sec]

Fatigue Testing Setup

Applied Load

Time [sec]

Start

Cruise

Landing

Reference load = Applied Load

Structural Test Setup

Fatigue Test
Structural Testing

Multi-scale activity

Virtual Testing

“Simulation of the behaviour of test articles in their test environment, reducing the overall costs and risks of actual tests”
Thesis Assignment

*Development of a Virtual Testing Methodology* for *Structural Fatigue Testing setups*
Structural Testing Methodology

Advantages:
• Pragmatic approach provides quick results

Disadvantages:
• Separate design processes
• No prediction of integrated system performance
• No dynamic analysis
• Controller tuning based on operator experience
• Performance Test setup is only known once test setup has been built
Proposed Testing Methodology

Advantages:
• Prediction of system behaviour
• Ability for design iterations, robust design
• Providing a first set of controller parameters
• Increase of system performance
• Reducing Risks and Costs, by using numerical simulation

Disadvantages:
• Time consuming to verify simulation models
• Specific components are different for each test setup, new models need to be developed

Modelling

• Develop numerical models that predict test setup behaviour
• Include non-linear behaviour
• Include controller architecture
• Reference signal tracking
Modelling

- Reference Signal, time dependent signal
- Maximum frequency content of 5 Hz is assumed
- Reference Signal tracking up to 0 - 5 Hz
Modelling

Demonstration Test Setup

Modelling Hydraulic Actuator

- Operation
  - Flow regulated
  - Internal pressure built up by external force
  - Eigenfrequency is dependent on piston position
  - Friction disturbs ideal dynamic behaviour

![Modelling Diagram](image-url)
Modelling Hydraulic Actuator

- **Bode Response Diagram**
  - Piston position centred
  - Magnitude: \( B \) and \( A \)
  - Phase: \( \angle (B, A) \)

Measurements and Verification

Numerical Model = Demonstration test setup
Measurements and Verification

• Open Loop Frequency Response

• Closed Loop System Force Feedback
Conclusions

• Developed a virtual testing methodology for structural fatigue testing setups

• Developed numerical models
  • Integrates; mechanical, hydraulic and control system
  • Predict controller parameters
  • Included non-linear behaviour

• Verified closed loop and open loop frequency responses
  • Verification up to 40 [Hz] compared to linear simulation models

Recommendations

• General
  • Extend and verify the modelling for a full scale test setup

• Mechanical system
  • Include backup structures in the modelling

• Hydraulic system
  • Include multiple actuators and investigate their interaction

• Control system
  • Investigate automatic tuning methods, using control theory
Thank you for your attention...

Have a nice flight during summer holiday’s!!