Practical Applications of Aeroelastic Analysis for Aircraft Design and Certification

2012 Aerospace Users Symposium

Presented By: Robert Lind
Engineering Manager
TLG Aerospace, LLC
Robert.Lind@TLGAerospace.com

September 18, 2012
Outline

• Introduction
• Loads and Dynamics Analysis
• Requirements for Design and Certification
• Aircraft Design Cycle
• Analysis Cycles for Civil Certification Programs
• Typical Modelling Fidelity for Product Design and Analysis Cycles
• Important MSC Nastran Capabilities for Loads and Flutter Calculations
• Summary
TLG Aerospace LLC
- Aerospace engineering services company founded by experienced DER engineers in 2008
- Specializes in dynamic and static loads, flutter, aerodynamic design, CFD, aeroelastics, ground and flight test, FAA certification, and aircraft performance and handling qualities
- In-house FAA DERs – Loads and Dynamics Part 25, and Flight Analyst
- In-house staff has experience with over 100 aircraft models from more than 40 different manufacturers
Introduction

- Robert Lind
- Engineering Manager, TLG Aerospace
- FAA Flight Analyst DER
- University of Washington Aeronautics
- 20 years experience in
  - Aircraft certification
  - Aircraft dynamic and static aeroelastic response analysis including flutter
  - Aircraft performance and handling qualities
  - Aerodynamic design and analysis
  - Flight and wind tunnel test planning, execution, data reduction, and documentation
Aircraft loads are the forces and moments applied to the airplane structural components to establish the required strength level of the complete airplane.

Include air pressure loads, inertia force loads, thrust loads, ground reaction loads:
  - External Loads –
    • Static, Dynamic, Ground, Flight
  - Internal Loads
  - Flutter
  - Fatigue
  - Damage Tolerance

Rational conditions and criteria cases specified by certification authority (FAA, EASA, etc). These are minimum requirements. Additional requirements are often specified by manufacturers.
Overview of Loads and Dynamics Analysis
Requirements for Design and Certification

- Loads and dynamics calculations require a full aircraft analysis of the air pressure and inertia forces.
- Analysis must cover all possible flight and ground conditions. Typical variables are speed, altitude, flap angle, airplane gross weight, airplane center of gravity, passenger and payload distribution, fuel quantities, engine thrust, airbrake positions, automatic control system settings.
- Failure conditions must also be examined.
Loads and Dynamics Analysis Input Data

- Airplane geometry
- Aerodynamic data, global and distributed
- Weight (inertial) data, global and distributed
- Stiffness data for load-carrying structure
- Design speed envelope
- Systems and Operational data
- Regulations and requirements
Aircraft Design Cycle

Multiple Iterations

Initial assumptions required – ‘You have to start somewhere’

Design data are continually updated

Analysis begins at initial design and continues through final certification and in-service support

Revision and data source control are essential
Typical programs have four major releases

- **Product Development**
  - Minimal Input Data
  - Trade Studies
  - Initial Sizing

- **Preliminary Design**
  - CFD + FEM Data
  - Identify Critical Conditions
  - Structural Refinement

- **Design-to-Loads**
  - Increased Fidelity Data
  - Wind tunnel testing
  - Structure built to these loads

- **Certification Data**
  - GVT Data
  - Flight test clearance
  - Flight Test Validation
Minimal Input Data

Doublet lattice aerodynamic model. No scaling.

Idealized beam structure.

Small subset of total loads cases. Selection based on past experience and simple predictions.

Focus on rapid turnaround and trade studies for feasibility checks and initial sizing.
Typical Modeling for Preliminary Design

**Bound the Envelope**

**Doublet lattice** aerodynamic model. Scaling to CFD and/or initial wind tunnel data. May use direct pressure inputs.

**Idealized beam** structure updated from FEM results. Some structure may be FEM.

**Sensitivities and** sweeps to identify trends and select critical conditions.
Typical Modeling for Design-to Loads

**Provide Critical Cases**

**Aerodynamic Model Doublet lattice** DL, CFD mesh, or hybrid. Scaling to CFD and wind tunnel data. Significant use of direct force/pressure inputs.

**Structural Model** uses beam and FEM models to provide critical results.

**Large Matrix** of cases to establish critical loads.

**Structure will** be built to these loads.
Typical Modeling for Certification Loads

Certification Data

**Flight test** safety clearance provided by certification loads.

**Aerodynamic Model** validated by flight loads survey (pressures, strains).

**Structural Model** validated by GVT and static test.

**Loads must** be shown to be accurate or conservative.
**Important MSC Nastran Features for Loads**

- **Aerodynamic data can be input directly on aerodynamic or structural meshes.**
  - Input directly as pressures on panels or forces on structural grid points.
  - Allows arbitrary inputs such as spoiler, thrust, flap effects.
  - Non-linear inputs and trim.

- **User-defined input variables**
  - Arbitrary combinations of user-defined inputs can be used as part of the balanced airplane calculations.
  - Allows control surface gearing, symmetry enforcement, arbitrary cases.

- **Separate rigid and flexible mesh**
  - Allows separation of aerodynamics and correction factors for rigid and flexible response.
Important MSC Nastran Features for Loads

• **Monitor points**
  – Arbitrary summation of forces at user-specified locations.
  – Required for FEM-based calculations.

• **Aerodynamic database reuse**
  – Expensive calculation performed only once.
  – Known data can be vetted and files reused to avoid errors.

• **Restart capability**
  – Significant time savings for tuned discrete gust calculations.
Summary

- MSC Nastran is a core element of the TLG loads and dynamics process
  - ‘Whole airframe’ analysis
  - Multidisciplinary
  - From simple, quick, and empirical to detailed and validated
  - High validation requirements for safety