Data Sheet

MSC Nastran Aeroelasticity

Aeroelastic analysis: Static trim, flutter, and dynamic aeroelastic response

Overview

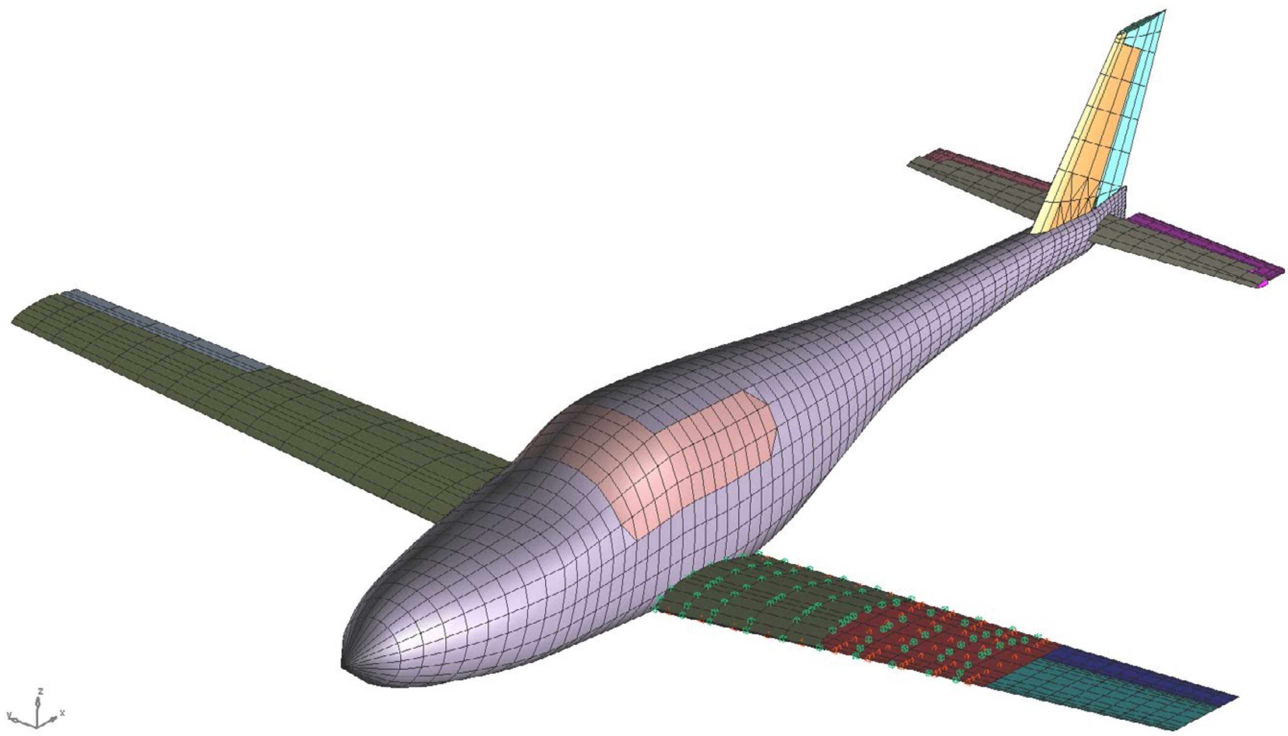
The effects of aeroelastic loads due to subsonic and supersonic environmental conditions can greatly impact the stability, response, and performance of structures. Structural design and control system analysis can involve understanding the performance characteristics due to static aeroelastic stress, loads, aerodynamics, and flutter. Combining the effects of aeroelastic analysis with structural analysis can be challenging. MSC Nastran provides capabilities to perform static aeroelastic, dynamic aeroelastic, and flutter analysis of structures at subsonic and supersonic speeds.

Aeroelasticity

Static Analysis

Static (or quasi-steady) aeroelastic problems deal with the interaction of aerodynamic and structural forces on a flexible vehicle that results in a redistribution of the aerodynamic loading as a function of airspeed. The aerodynamic load redistribution and consequent internal structural load and stress redistributions are of concern to the structural analyst. The possibility of a static aeroelastic instability, divergence, is also of concern to the structural analyst. The aerodynamic load redistribution and consequent modifications to aerodynamic stability and control derivatives are of interest to the aerodynamicist and the control systems analyst.

The static aeroelastic capability in MSC Nastran addresses these needs by enabling the computation of aircraft trim conditions, with subsequent recovery of structural responses, aeroelastic stability derivatives, and static aeroelastic divergence dynamic pressures.



Flutter Analysis

Flutter is a dynamic instability of an elastic structure subjected to aerodynamic forces. Structures are carefully designed to avoid this phenomenon.

MSC Nastran allows you to perform modal flutter analysis for subsonic and supersonic unsteady aeroelastic scenarios. Methods for predicting flutter in damped, linear structures include: the K, PK, KE, PKS, PKNL, and PKNLS-method. After analysis, the flutter frequencies and damping are obtained as functions of velocity and the relative modal amplitudes found, and important critical flutter speeds and divergence speeds may be determined via V-g and V-f plots. The resulting data can directly be used in the certification of flight vehicles under the FAA and JAA requirements.

Dynamic Analysis

The purpose of dynamic aeroelastic response analysis is to study the reactions of an aeroelastic system to prescribed loads and displacements, and to atmospheric gust fields. Examples of response problems in which aerodynamic effects should usually not be neglected include high speed landing loads, in-flight store ejection loads, and loads and accelerations in a gust field.

MSC Nastran allows one to perform modal dynamic aeroelastic response analyses, e.g. frequency response, transient response, and random response analysis. The excitation may consist of applied mechanical forces using any aerodynamic theory or gusts with the Doublet-Lattice and ZONA51 theories only. The response parameters can include loads, stresses, and displacements as functions of time or frequency.

Aeroelasticity II

The Aeroelasticity II module provides a supersonic counterpart (ZONA51) for unsteady aerodynamics, which is compatible with the subsonic doublet lattice method available in Aeroelasticity I. This aerodynamic method is licensed from ZONA Technology, Inc. and packaged with MSC Nastran for convenient access by engineers requiring supersonic aeroelastic analysis of structures that experience unsteady supersonic lifting surface aerodynamics such as high-speed transports, launch and re-entry vehicles, air combat vehicles and missiles.

Monitor Points

Monitor Points are used to represent summations of forces, displacements, stress and other quantities over certain regions of the finite element (FE) mesh about a selected point. These monitor points can then be combined to represent the integrated trimmed loads appropriate for critical loads survey.

Example applications include:

Extract the applied loading for a specified set of structural nodes and aerodynamic elements. This enables batch calculation of VMT (shear, moment and torque) data as well as aerodynamic coefficient data for specified regions and locations.

Determine the summation of internal loads, useful in calculating resultant forces at a cut in a structure.

Splines

Spline Types

The interpolation from the structural to aerodynamic degrees of freedom is based upon the theory of splines. Splines available in MSC Nastran include:

- Surface spline
- Linear spline
- Curved surface spline
- 1D finite beam spline
- 3D finite surface spline (6DOF surface)
- 3D finite beam spline (6DOF beam)
- Rigid body spline
- Externally evaluated spline via an external spline server

Spline matrices may be exported to. op2 or .pch file types. Splines may be verified with MSC FlightLoads.

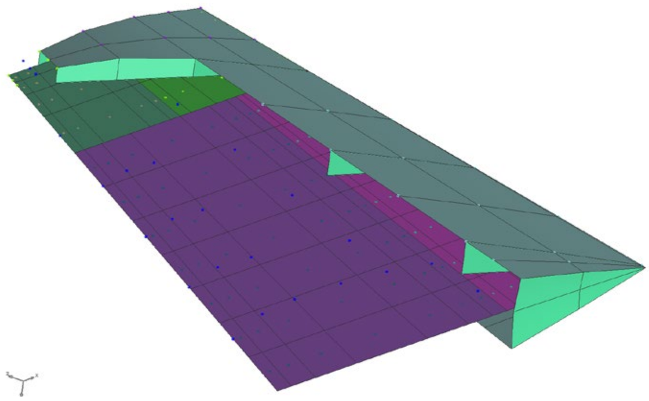
Spline Blending

With the increasing use of CFD aerodynamics and the dense meshes and smooth displacements CFD requires, a need has arisen to overlap the splines and use blending techniques to average the displacements of the adjacent splines.

MSC Nastran simplifies the process by only requiring the user to select the splines that participate in the blends and define the depths for the overlap region. MSC Nastran automatically determines the aerodynamic and structural grids that are within your defined depth and adds them to the relevant splines.

Optimization

Aeroelastic design sensitivity and optimization are available in the MSC Nastran Optimization module, available separately. Flight vehicles can be designed optimally for aeroelastic loads, flying qualities, and



Splining of aerodynamic panel and structural mesh

flutter as well as for strength, vibration frequencies, and buckling characteristics.

Defining an aeroelastic optimization task is dependent on monitoring response quantities. MSC Nastran permits the specification of a number of responses for static analysis including displacements, stresses, strains, and forces, and these capabilities are available in static aeroelasticity. The response quantities for aeroelastic design include:

- Trim variables in a static aeroelastic response. These allow the user to design for limits imposed on, for example, the trim angle of attack or control surface travel.
- Stability derivatives. These allow the user to specify limits on, for example, the rolling effectiveness of an aileron.
- Flutter damping level. This assures flutter stability without a requirement to determine the actual flutter speed.

Once a quantity is identified as a response, it can be used as a constraint condition; design objective; or in combination with other responses and/or design variables in the objective function. This capability of combining responses and design variables is a unique innovation in MSC Nastran.

Capabilities

- Static Analysis
- Aircraft trim conditions
- Aerodynamic loads
- Structural responses
- Aeroelastic stability derivatives
- Static aeroelastic divergence dynamic pressures
- Rigid/Flexible mesh concept
- Flutter Analysis
- Flutter and divergence speeds
- V-g, V-f plots
- Flutter Analysis Methods: K, PK, PKNL, PKS, PKNLS, KE
- Interpolation Methods for Flutter Analysis
- Linear interpolation on k-only
- Surface interpolation on Mach number and k
- Termwise cubic interpolation
- Dynamic Analysis
- Perform frequency response, transient response, random response analysis
- Review response parameters such as loads, stresses, and displacements as functions of time or frequency
- Aeroservoelastic analysis
- Integrate CFD data in trim analysis via the HSA toolkit
- Subsonic and supersonic aerodynamics
- Internal Aerodynamic Theories
- Doublet-Lattice subsonic lifting surface theory (DLM)
- ZONA51 supersonic lifting surface theory
- Constant Pressure Method for supersonic lifting surface theory
- Subsonic wing-body interference theory (DLM with slender bodies)
- Mach Box method
- Strip Theory
- Piston Theory
- Discrete and harmonic gust analysis
- Hinge moment calculation
- Output trim results and stability derivatives to CSV (Comma Separated Values) files

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