MSC Developments in Aeroelasticity

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Abstract

The MacNeal-Schwendler Corporation has a long history of involvement with aeroelasticity. This paper briefly reviews past development efforts and the current capabilities in this area. Recent developments that have not been incorporated into standard documentation are given somewhat more emphasis. This paper concludes with a discussion of ongoing development activity.

1.0 Introduction

Aeroelasticity is a branch of aeromechanics that deals with the interaction among inertial, aerodynamic and structural stiffness effects in air vehicle design. It is an area that requires sophisticated engineering design, analysis and testing. MSC / NASTRAN has had the ability to perform aeroelastic analyses since the early 1970's and has had a design (optimization) capability since the release of Version 68 in 1994. This capability has been documented in a number of MSC publications, most notably the *MSC/NASTRAN Aeroelastic Analysis User's Guide* of Reference 1. This paper reports on the current state of aeroelasticity at MSC. As such, it can be considered an update of a similar paper that was presented in 1990 (Reference 2). The current paper emphasizes developments that have occurred since the publication of these documents and discusses a number of ongoing activities in the aeroelastic area.

2.0 Current Capability

2.1 Solution Sequences

A brief review of the aeroelastic capability currently residing in MSC / NASTRAN is given to provide a basis for the remainder of the paper. Table 1 identifies the four MSC / NASTRAN solution sequences used in aeroelastic analysis. SOL 144 addresses static aeroelasticity and, as such, is useful for making a preliminary assessment of the aircraft design loads and provides estimates for rigid and elastic stability and control derivatives. Reference 6 is a companion paper in this conference that presents work done to include a higher order panel method to compute the aerodynamic forces used in this solution sequence. The "Ongoing Development" section of this paper previews a number of enhancements that are underway in this area.

Table 1: Solution Sequences Related to Aeroelasticity.

SOLUTION	Description
144	Static Aeroelasticity
145	Aerodynamic Flutter
146	Dynamic Aeroelastic Response
200	Design Sensitivity and Optimization

The aerodynamic flutter of SOL 145 represents the most mature of the four solution sequences. The "Recent Enhancements" section of this paper discusses some changes that have been made in this area in Version 69 and V70 of MSC / NASTRAN.

The Dynamic Aeroelastic Response capability of SOL 146 provides the capability to analyze the transient or frequency structural response in the presence of either an aerodynamic (gust) or other dynamic (e.g., landing) loading. Reference 4 is a recent publication that goes into some detail as to how this solution sequence was applied extensively in the development of the B-2 Bomber.

The Static Aeroelastic and Flutter solution sequences were incorporated in MSC / NASTAN's design optimization capability of SOL 200 in Version 68. Material in the User's Guides of Reference 1 and Reference 5 is the best source for learning about the capability.

2.2 Support Activity

The aeroelastic capability is supported in a number of ways. The preceding subsection has identified key reference material. Numerous other publications are listed at the Internet Web Site for MSC's aerospace business: *www.macsch.com/aerospace*. First line technical support is provided by Technical Representatives distributed around the world, and a dedicated second level support staff is located in Los Angeles. The MSC / NASTRAN Development organization is available to answer detailed questions and to investigate potential code errors.

Seminars that explain the Aeroelastic capability are given periodically as part of MSC's training course offerings. In addition, the training materials that go with this course are an additional resource and include the briefing charts used in the seminar and a volume of reference material that contains publications relevant to the aeroelastic capability.

3.0 Recent Enhancements

The Reference 1 User's Guide is based on Version 68 of MSC / NASTRAN. Subsequent enhancements to the aeroelastic capability are not included in this manual. The majority of the aeroelastic development activity for these recent versions can be classified as maintenance, including error corrections. One notable "fix" in this regard is that Version 69 has restructured the aeroelastic calculations in order to significantly reduce the database requirements. With the correction, the V69 database for an aeroelastic task may be half the size of the V68 database. Four other enhancements are worthy of specific mention here: 1.) the PKNL flutter method, 2.) multiple boundary conditions in flutter analyses 3.) enhanced sorting of flutter roots and 4.) splining of aerodynamics to upstream superelements.

3.1 The PKNL Flutter Method

A new flutter method, designated PKNL (PK No Looping), was made available in Version 69 of MSC/NASTRAN. The new method, available as an option on the FLUTTER bulk data entry, is a variation on the PK method that does not loop on all combinations of user input density, Mach number and velocity.

With the PK method, all combinations of these parameters are used so that the input of two densities, two Mach numbers and eight velocities results in 32 flutter analyses. The new method requires input of the complete specification of density, Mach number and velocity for each point that is to be analyzed and is designed to address the requirement of performing only match point flutter analyses. It is suggested that this method be applied by moving through the atmosphere at a constant Mach number in order to avoid the expensive generation of aerodynamic matrices at a large number of Mach numbers.

Through an oversight, the PKNL method was not made available for design in Version 69. This was corrected in Version 70 so that flutter constraints can be specified in SOL 200 based on a PKNL method of flutter analysis.

3.2 Multiple Flutter Boundary Conditions

The flutter analysis capability was enhanced in Version 69 to allow for the simultaneous consideration of multiple boundary conditions. This is most useful in Solution 200 in that these conditions can now be treated in a design task. It should be emphasized that there is an MSC/NASTRAN restriction in aeroelastic analysis that only one aerodynamic symmetry is allowed per run so that symmetric and antisymmetric aerodynamics cannot be run simultaneously.

3.3 Enhanced Sorting of Flutter Roots

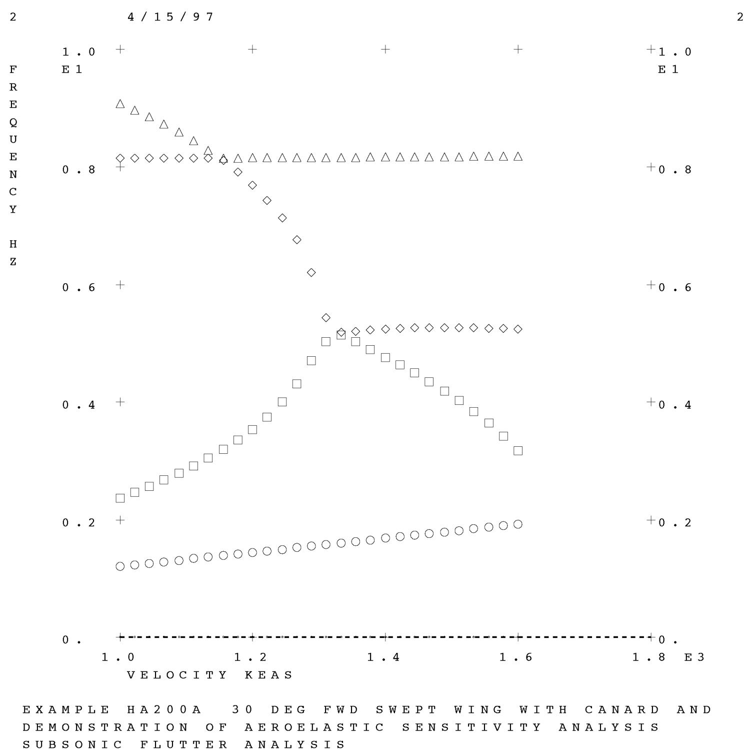
A minor enhancement for flutter analysis in Version 70 has been an improved sorting of flutter roots extracted using the PK or PKNL flutter methods. Previously the roots were sorted on the frequency of the complex modes so that frequency crossings, which are often present in a flutter analysis, were not properly displayed. Figure 1 shows a “before and after” display of a flutter analysis and it is seen that the roots are correctly sorted and tracked in Version 70.

3.4 Splining to Upstream Superelements

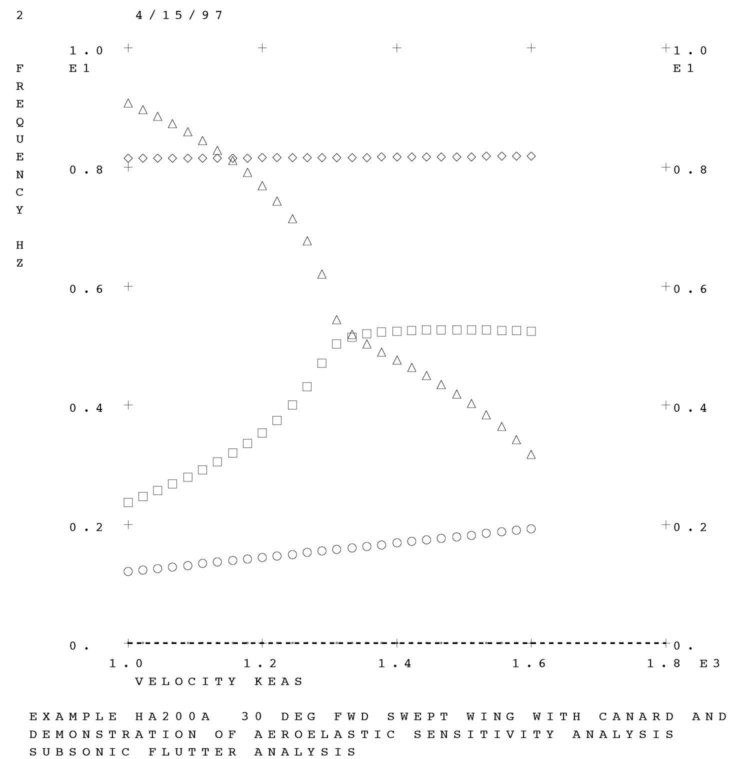
The standard aeroelastic capability requires that the user connect the aerodynamic model to the structural model at points that are in the residual superelement. For structural models that have been developed using superelements, this may require extensive remodeling in order to move the appropriate grids from the upstream superelements to the residual. A DMAP alter has been developed that allows direct splining of aerodynamics to the upstream superelements. Information on the alter, including examples, can be found in the SSALTER library. It should be cautioned that the method is most suitable in SOLutions 145 and 146 and is not appropriate for SOLution 144.

4.0 Ongoing Development

This section discusses current development efforts at MSC in the aeroelastic area, both to publicize these efforts and to solicit feedback. The majority of this work is preceding under the aegis of the Flight Loads System discussed in some detail in Reference 3, presented at this conference. This paper gives an overview of this project and emphasize some components not discussed in Reference 3.



a. Prior to Version 70



b. Version 70

Figure 1. Enhanced Sorting of Flutter Roots.

4.1 Flight Loads System

4.1.1 Generic Control Law

This aspect of the Flight Loads System acknowledges the increasing importance and complexity of control systems in the prediction of flight loads. It is recognized that the control system complexity makes it unlikely that the full sophistication of control/structures interactions could be easily captured in MSC/NASTRAN. Instead, this development effort is intended to address some of the key features of the control system and hopefully aid in the preliminary design of an air vehicle. Among the concepts being addressed are:

1. Control surface hinge moments
2. Position and hinge moment limits on the control surface travel. (The position limits can be a function of dynamic pressure).
3. Gain scheduling of the control surface as a function of Mach number and angle of attack.
4. Ability to consider redundant control surfaces when performing a trim analysis.

One example of this last concept is a vehicle that has multiple surfaces (e.g., inboard and outboard wing flaps and an elevator) to control pitching. A synthesis technique based on the work documented in Reference 7 is used to address this case.

4.1.2 Enhanced Aerodynamics

A number of aerodynamic methods are available in MSC/NASTRAN: the Doublet Lattice Method is the workhorse for subsonic aerodynamics, and ZONA51 fills a comparable role for supersonic flow. These ‘‘flat plate’’ methods are ideal for flutter analysis, but it is felt that a higher fidelity code is required for the calculation of loads. MSC has initiated the installation of the A502 code (Reference 8) as an additional aerodynamic method that allows complete modeling of the three dimensional surface of the vehicle.

4.1.3 3D Splines

The addition of 3-D aerodynamics necessitates enhancement of the techniques used to couple the aerodynamic and structural models. A number of techniques are under investigation for this task. As an interim goal, the next release of MSC/NASTRAN is scheduled to enhance the existing methods with a thin plate spline and to allow the separate splining of forces and displacements.

4.1.4 Aerodynamic and Aeroelastic Databases and Data Import

The Flight Loads System will be required to function within an existing production environment that is likely to have customized processes that will either drive the Flight Loads Systems (e.g., external aerodynamics might be imported) or postprocess results (e.g., deformed shapes) from the system. This is being planned for by the development of a special purpose database that will allow the specification of multiple aerodynamic models, aerodynamic results and aeroelastic results. The user will be able to use MSC provided tools to insert external data into the database. External data must conform to the published descriptions of the data formats.

4.2 Graphical User Interface

Work is underway on the development of a user interface for the aeroelastic capability. This welcome activity is to be built around MSC/PATRAN and will support not only the Flight Loads System that is under development, but the current aeroelastic capability as well. Model generation and display, as well as postprocessing of aeroelastic results, is to be supported.

5.0 Concluding Remarks

Aeroelasticity is an integral part of MSC/NASTRAN and has been continuously developed and maintained for over 25 years. The capability is in line with MSC's vision of providing CAE solutions to major manufacturers.

It should be recognized that the presentation of this paper and the entire Aerospace User's Conference is an outgrowth of the establishment of MSC's Aerospace Business Unit. This reorganization has brought a reemphasis on the aerospace segment of MSC client base in general and on the aeroelasticity area in particular. Significant staff and resources are being put into aeroelastic development. User interest and involvement in these developments is welcome.

6.0 References

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