

A procedure of applying aerodynamic loads on a MEF aeronautical structure

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Abstract: *The purpose of this paper is to present a practical way to introduce aerodynamic loads from a pressure field to perform a FEM analysis using PATRAN/NASTRAN programs. Commercial codes offer integrated solutions for this problem, but we developed here a procedure adapted to a specific way to compute the aerodynamic loads as pressure fields on a grid on the mean surface of a bearing surface (wing or tail assemblies).*

Key Words: *aircraft design, aerodynamic loads, and finite element simulations, stress loads, stress analysis of aeronautical structure*

1. INTRODUCTION

An accurate determination of flight loads represents a challenging process of aircraft design. It is a complex process, and it requires skilled and experienced engineers who must integrate results from different departments, wind tunnel tests, computer simulations, historical data, and empirical formulations into several load cases that provide a realistic assessment of the flight vehicle's environment.

Under these conditions, the vehicle must satisfy requirements imposed by different regulatory agencies as part of the vehicle certification process. The main goal of this paper is to present a procedure to introduce aerodynamic loads in a stress analysis of an MEF aeronautical structure when the aerodynamic loads are computed as pressure fields on a grid on the mean surface of a bearing structure.

In a previous paper, [5] we developed a method to introduce aerodynamic loads as concentrate forces in the MEF nodes of the structure. The tools and techniques (grouped in a system) used in the process of designing new aircraft are intended to make the design and analysis activities of the aeronautical structures more efficient.

These tools and techniques actually support all kinds of activities that are taking place during the lifecycle of a specific structure (redesign, harness, maintenance, investigation after specific events, etc.).

The main goal of these attempts to introduce accurate aerodynamic loads is a good approximation of the response of the structure [1, 2, 3, 4].

Considering, for example, an airplane wing designed with CAD tools, the database will include it as an entity with many other information attached (such as: geometric data, info about the materials used, proposed analysis method, results of a previous analysis, notes). This entity is associated with other information that may be interesting in different stages of its lifecycle. Although the collaborative environment, through the created infrastructure, ensures communication between partners of a project and, in some cases, various tools for technical information access or transfer, the right use of them is sometimes difficult.

The difficulties appear mainly because the procedures, technologies and software systems are usually implemented in different forms from partner to partner.

In such cases to ensure a full understanding of the information between partners, converters or other applications that may help, or notes and even re-making of some activities are used.

2. PROBLEM FORMULATION

Problem formulation implies three aspects: a) the specific aerodynamic data and the way this data are transmitted, b) the finite element model data, and c) to clarify the way to transmit the aerodynamic data to the finite model data.

a) Aerodynamic data

The aerodynamic department elaborated a rectangular grid on the mean surface of the bearing surfaces (wing, tail assemblies) as presented in Figure 1.

On these surfaces, the total pressures are computed considering that on a rectangle of the grid the pressure is constant.

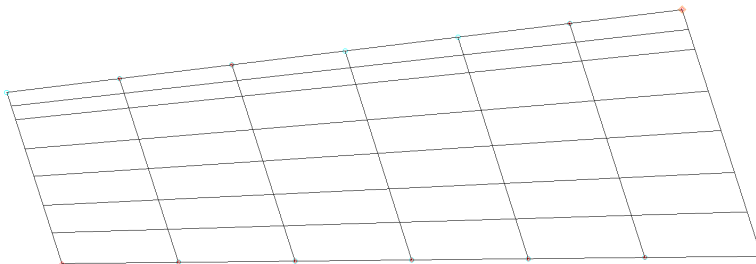


Fig. 1 Aerodynamic grid

The coordinates of the aerodynamic pressure are provided in a text file called “mesh-cruise.nod”. The mesh of surfaces is divided into segments and numbered on subassemblies. The aerodynamic pressures are given on these rectangles defined on these segments in a text file *.aer.

b) Finite element model data (MEF)

A finite element model is the reproduction of a piece or an assembly using plate and/ or beam elements (figure 2).

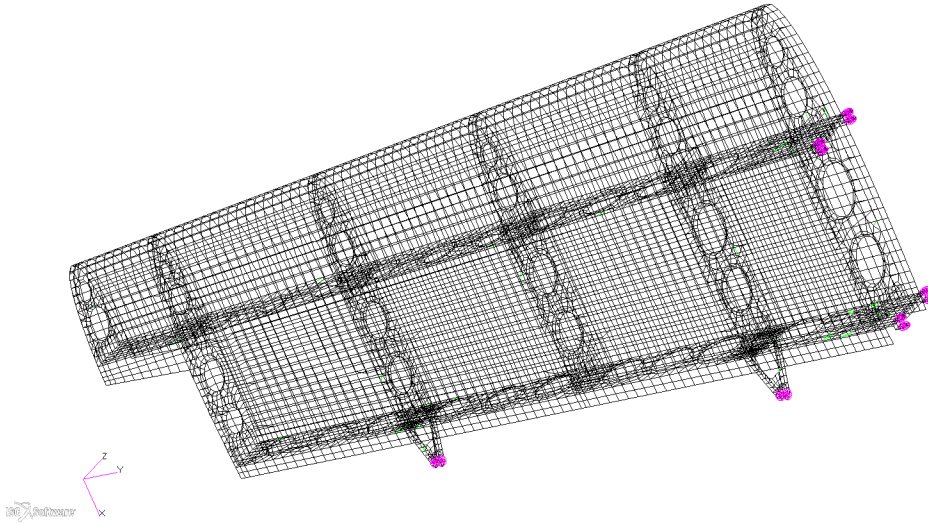


Fig. 2 Example of a MEF model

These elements are built on the contour of the assembly and its components.

c) Problem to be solved

In an MEF analysis, pressure distribution must be given on the exterior surfaces of the model. The problem is to transfer the aerodynamic grid defined on the mean surface to the skin surface and to apply the constant distributed pressure on the skin elements.

Note: To have a balanced application of the pressure loads, one considers applying half of them on each side of the wing.

3. MAIN STEPS OF THE PROCEDURE

3.1 Transferring the aerodynamic grid on the surface of the wing

To transfer the aerodynamic grid to the FEM model the following operations are performed:

- In a PATRAN file (ex: Geom.db) the “Master Geometry” file of a part of the analyzed structure is imported from a CATIA file.
- We consider from the file of the aerodynamic mesh “mesh-cruise.nod” the coordinates of the nodes of the considered structural part and create a NASTRAN file with a numbering of the nodes and their coordinates as in the following example:

GRID,1,,8167.8,-1704.,180.

GRID,2,,8205.6,-1704.,180.

GRID,3,,8262.3,-1704.,180.

To obtain that we follow the steps presented below.

The coordinates of the aero grid belonging to the analyzed part are transferred to an EXCEL file. They are introduced in a table.

- The dimensions are changed from meters to millimeters (if necessary);
- A column with the text GRID is added;

- A column numbering the nodes is added;
- The NASTRAN command is built.

“GRID,1,,8167.8,-1704.,180.”

Using function CONCATENATE (see Tab. 1 below).

Table 1. The EXCEL line for creating the NASTRAN command

		Node number		X [mm]		Y [mm]		Z [mm]		NASTRAN command
GRID	,	1	„	8167.8	,	-1704	„	180	.	GRID,1,,8167.8,-1704.,180.

Note:

Changing the meters in millimeters one can obtain integer values coordinates. To avoid this the NASTRAN command must include the decimal point. This file is imported in/into the PATRAN file in the same group as the geometry of the considered part, choosing to import only the nodes.

The aerodynamic grid is built in the PATRAN file, joining the nodes using lines. This mesh is translated on the skins of the MEF model as presented in Figure 3.

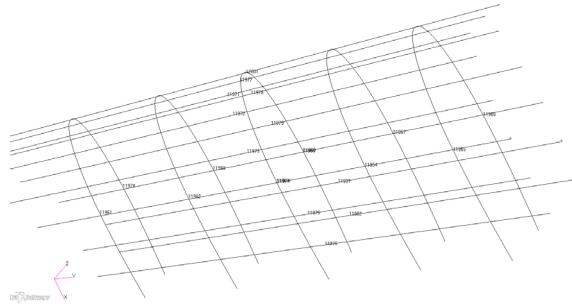


Fig. 3 Aerodynamic grid translated on the skin of a bearing surface

3.2 Overlapping the aerodynamic grid on the MEF model

The file Geom.db is imported into a group of MEF file. In the groups of the skins of the MEF file a part of the corresponding aerodynamic grid. For a part of the skin results an image is presented in Figure 4.

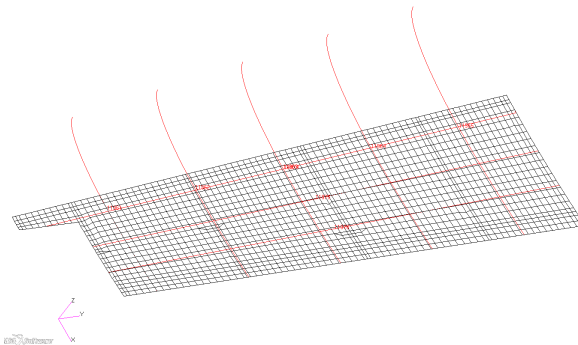


Fig. 4 Overlapping the grids

3.3 Applying the pressure loads

For the first loading case, constant pressure loads are applied on each rectangle of the aerodynamic grid as presented in Figure 5.

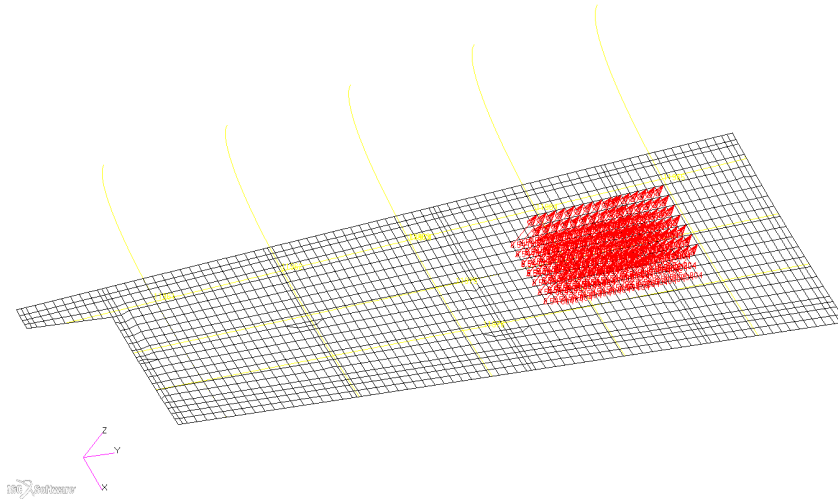


Fig. 5 Applied pressure on a rectangle of the aero grid

These loads are identified considering the load case taken into account, with two numbers defining the position of the rectangle in the aerodynamic grid and adding a S for the upper skin. Ex: P1BVC11 means P=pressure; 1BVC=load case; 11=number of the rectangle on the lower skin.

Note:

When the pressure loads are applied manually in PATRAN the plus sign is considered outwards to the surface on which they are applied.

To apply the second load case, the following steps are considered.

- First of all, a NASTRAN file with the FEM model and the pressure loads manually introduced in PATRAN is created.
- The part which contains the applied pressure is transferred in an EXCEL file.
- A table is created, taking care to have only one line commands.
- In each set of applied pressure on a number of elements we replace the value of the pressure with a new one corresponding to the new load case.
- The NASTRAN commands for applying the pressure are restored using the function CONCATENATE.
- In the denominating commands, the name of the load case is replaced as follows:

SUBCASE 1

\$ Subcase name: **3GUC+-PRES**

SUBTITLE=**3GUC+-PRES**

- The name of the case is replaced with the name of the new case (the names are bolded and underlined).

- A new NASTRAN file is created from the old one changing only the region of the applying loads, the name of the load case and the name of the file.
- This file is imported in the MEF model of the structure.

Note:

We recommend using an exponential form for writing the pressure values and to verifying the sign of the manually applied pressure. After following these steps, a new MEF load case is obtained. For another load case, the EXCEL sheet is copied, and the procedure is repeated.

4. CONCLUSIONS AND RECOMMENDATIONS

Using this procedure was necessary because applying concentrated forces leads to an unrealistic distribution of stress and displacement (see figure 6.1). Instead, using the procedure described above leads to more accurate results in accordance with basic manuals of design and analysis of flight vehicles [1, 2, 3, 4] (see figure 6.2).

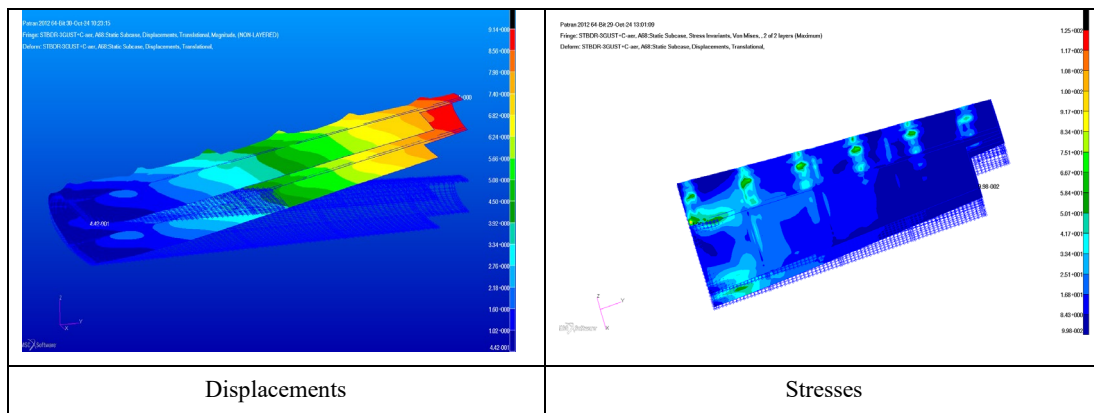


Fig. 6.1 Displacements and stresses with concentrated forces

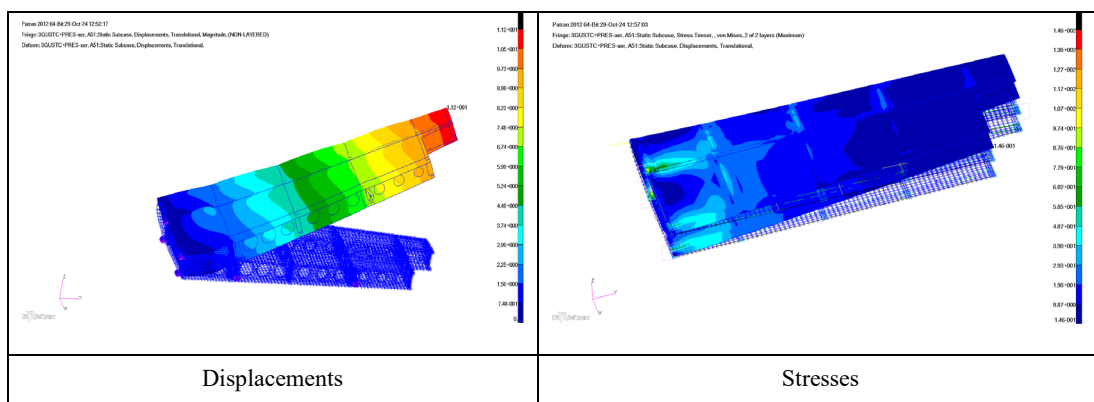


Fig. 6.2 Displacements and stresses with pressures

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