

NASPRO 3.0 – SOFTWARE TOOL FOR TRANSFORMATION AND VIZUALIZATION OF AIRCRAFT STRUCTURE MODAL ANALYSIS RESULTS

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Summary: *The submitted paper presents a new software tool named NASPRO 3.0 aimed for transformation and visualization of the aircraft modal characteristics. The mode shapes are visualized in the specific graphic format, which demonstrates in an appropriate way modal deformations of different structural parts, controls and tabs of the aircraft, phase shift relations and node lines positions. It is useful for direct visual comparison of analytical and experimental mode shapes, assessment of the mode shapes changes in the parametric analytical studies and during preparation of the ground vibration test and flight flutter test of the aircraft structure.*

1. Introduction

Determination of the aircraft modal characteristics is an integral part of the aircraft certification process. Modal characteristics, it means natural frequencies, mode shapes, generalized masses and damping ratios of modes are important input data for evaluation of the aircraft aeroelastic (flutter) stability. Modal characteristics are investigated either experimentally or numerically. At the VZLU, the NASTRAN FE – based system is used for the numerical simulations. NASTRAN includes the aeroelastic module, which allows analyzing the aircraft aeroelasticity, in fact, with no limitation. For the experimental modal investigations, the PRODERA system is used. It allows harmonic or impulse excitation in 8 points and measuring of the structure response in 500 points.

2. Motivation

Standard commercial postprocessing tools integrated into FE systems offer tools like modal animations or axonometric visualization via deformed, fringe or vector plots for mode shapes visualization. However such visualization isn't sufficient for the aircraft structures. Even usage of the correlation criteria like MAC is problematic for identification of the specific modes in some cases. For purposes of visual presentation, comparison, assessment of differences and changes, the specific graphic format has been created (Latýn, 1984). This graphic standard demonstrates in an appropriate way modal deformations of the different structural parts, controls and tabs of the aircraft, phase shift relations and the node lines positions. It is a standard output of the ground vibration tests (GVT) performed by the VZLU modal test laboratory. Therefore it is possible to use it for the direct visual comparison of

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analytical and experimental mode shapes. Such kind of analytical shapes visualization is useful in preparation phase of the GVT. The knowledge in the mode shapes and locations of the node lines is important for the appropriate emplacement of the exciters and accelerometers

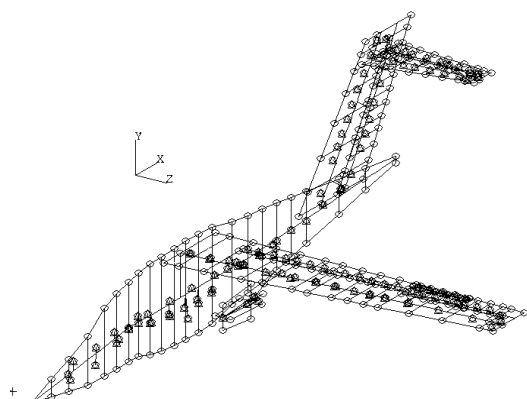


Fig. 1 – Beam FE model of the aircraft structure

during the GVT. The node lines position is also required for the calculations of control surface dynamic balancing with respect to the other main mode shapes. Besides, it is also important for preparation of the flight flutter tests (FFT) for appropriate emplacement of the impulse rocket exciters, since the design of exciters installation usually precedes the GVT. Finally the visualization format is useful for assessment of the mode shapes changes in the parametric analytical studies as well.

For the mentioned purpose, the SW tool named NASPRO 2.0 has been developed at the early nineties. The program, built by the Turbo Pascal operated on the MS.DOS operating system. However, this tool is unserviceable today. Moreover, the source code is not at disposal, therefore any improvement is impossible. The new SW tool NASPRO 3.0 replaces this obsolete tool.

3. Program Description

The name of the program (NASPRO) is assembled from the words NASTran and PROdera. The program is assigned for the postprocessing of the modal analysis of the aircraft structure beam FE model (see fig.1) performed by means of the NASTRAN program system, solution 103 (normal modes). The program input is a NASTRAN text output file (*.f06 file) and the *.dxf

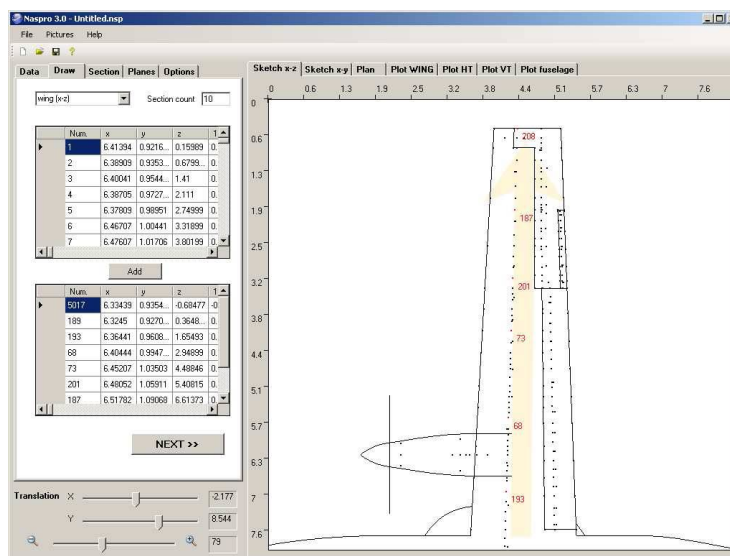


Fig. 2 – Program window – selection of nodes

graphic files with the aircraft geometry (plan view, side view). The program is divided into several parts. The part “draw” is assigned for selection of the FE model nodes, which are used for the transformation of the modal deformations (see fig.2). The part “section” is assigned for definition of sections, which the deformations will be pictured in. The part “planes” is assigned for the definition of the structural parts, controls and tabs and their reference axes. The part “options” consists of the tools for adjusting and handling with the picture. The program output consists of the basic aircraft visualization (plan view, side view) with relative deformations in the defined sections, node lines or node points (out of the plan view outline)

and the supplementary visualization describing the phase relations among the structural parts (part “plan”). Besides, program provides the graphs of the translational and rotational deformation amplitudes in the reference axes of the structural parts (part “plot”) and finally the table of summary information (modes, frequencies, generalized masses).

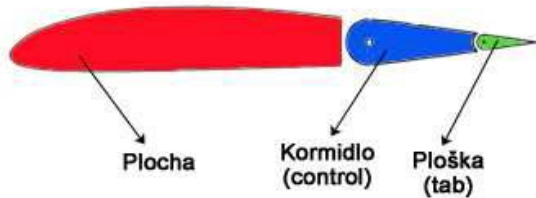


Fig. 3 – Types of structural parts (surface – control – tab)

an x-axis in the longitudinal direction, the y-axis is in the vertical direction, and the z-axis is in lateral direction. As the next step, the user defines the structural parts, controls and tabs. The structural parts are sorted by the type (surface / body, control, tab – see the fig.3) and by the direction of the reference axis (wing, fin, fuselage). Also, the sections to draw the deformations in are selected. The modal deformations are transformed from the specified FE nodes to the reference axes of surfaces / bodies or to the pivot axes of controls and tabs by means of the cubic spline. The leading and trailing edges are defined as well (see fig.4). Finally the specific mode shape is selected and the visualization is drawn.

The mode shape visualization consists of the basic aircraft visualization (plan view, side view – see fig.5 and 7) with relative deformations in the defined sections. In-plane deformations are visualized by means of the arrows placed in front of the leading edge. Node lines are visualized inside the outline of the plan view and side view respectively. Outside of the outline are visualized node points in the selected sections. The deformations of the engines are drawn by a specific way. Main visualization also includes the supplementary visualization describing the phase relations among the structural parts. Besides that, program provides the graphs of the translational and rotational deformation amplitudes in the reference axes of the structural parts (see fig.6) and finally the table of summary information (modes, frequencies,

The NASTRAN output file (*.f06 file) is opened (short data format is required) and the nodes coordinates and modal deformations are imported. The sketch of the aircraft (plan view, side view) is imported from the dxf files. The data format dxf is easy to create, edit or re-import. Apart from the AutoCAD, the dxf data format is supported by the various graphic tools like Corel Draw or Adobe Illustrator. The global coordinate system has

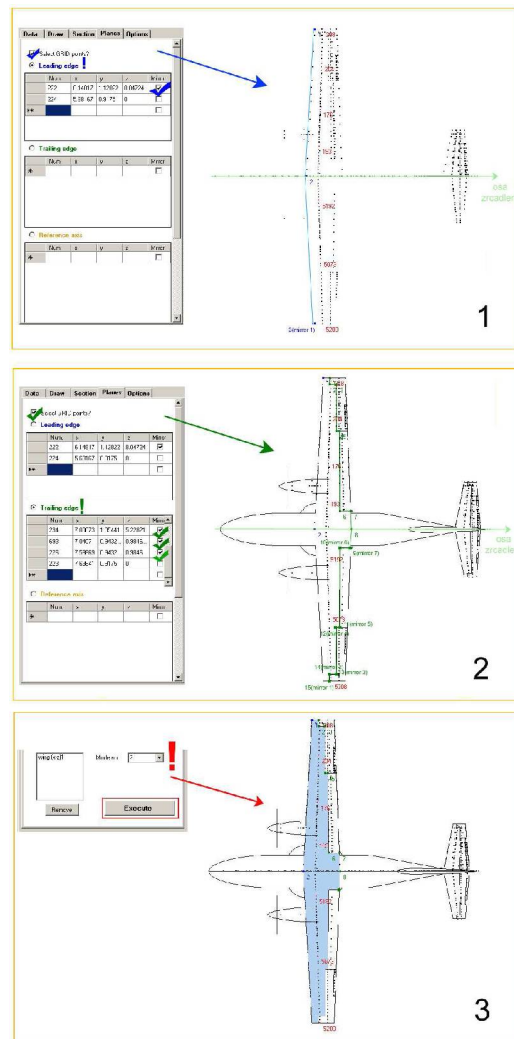


Fig. 4 – Leading / trailing edges definition

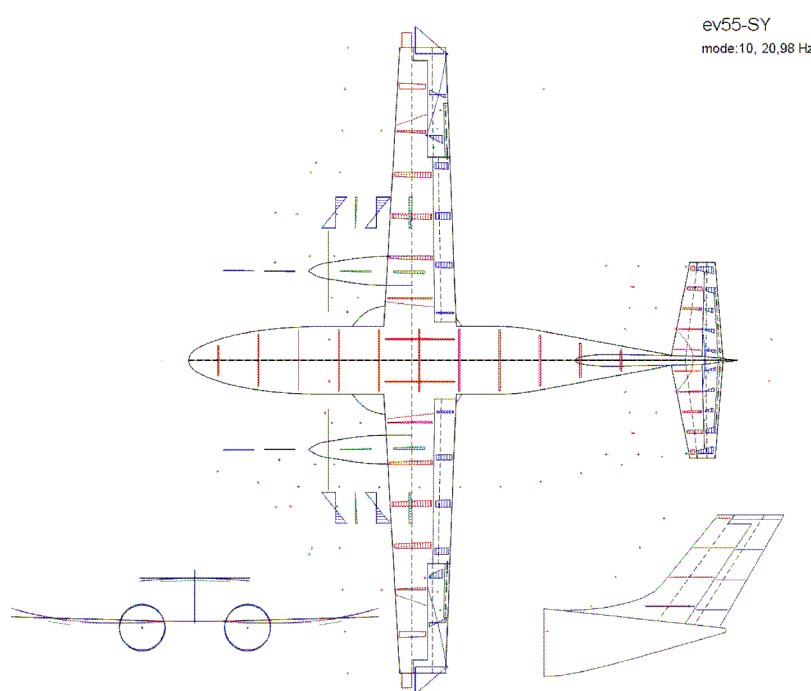


Fig. 5 – Program NASPRO - mode shape visualization (twin turboprop)

generalized masses).

Program includes various checking tools to avoid the user-made faults. Program is serviceable for any kind of the aircraft design configuration in terms of the number and configuration of the lifting surfaces, tail, engines, pods etc. or any part of the aircraft respectively. Program was created by means of the C# programming environment. It is operable on the common versions of the MS/Windows system. Program is equipped by the graphic user interface; it fulfills standard requirements

regarding the user comfort or standard operations (export, saving, printing, etc.).

Program debugging was performed on the example of twin wing-mounted-engine utility 11-seat turboprop aircraft (EV-55) and a single-seat glider (G-304S).

4. Conclusion

Submitted paper presents a new software tool for transformation and visualization of the aircraft structure modal characteristics. It replaces the 18-years old obsolete tool, which is unserviceable today. The new tool will be used during development of the new aircraft and the research projects at the VZLU as well. According to the experiences from the practice, the further improvements and modifications will follow.

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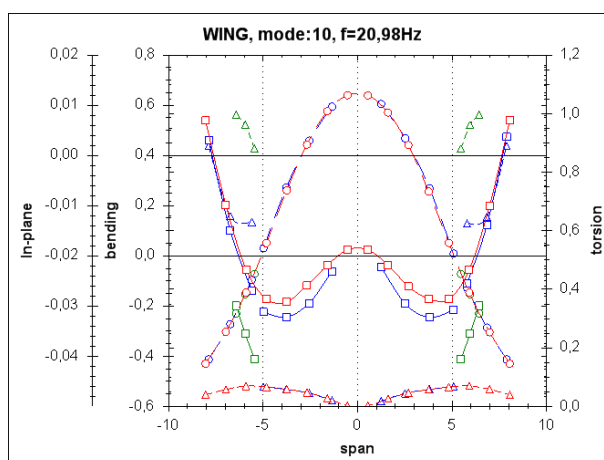


Fig. 6 - Program NASPRO – deformation curves

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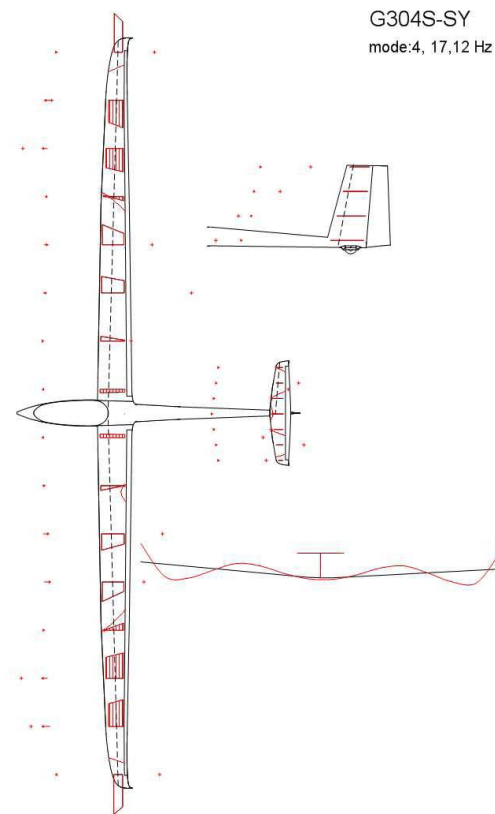


Fig. 7 – Program NASPRO - mode shape visualization (glider)