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Detailed FE Model of the Airfoil Utilization to the Aeroelastic Analysis

Využití podrobných MKP modelů v aeroelastické analýze

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ABSTRACT

The structural philosophies built on the DAMAGE – TOLERANCE base has been applied more and more last time. Safety demands of them also impact to the sphere of the aircraft structure aeroelastic safety. The requirements to determine the aeroelastic stability for a number of defect cases appear as one of the most important.

The mostly used simple beam dynamic FE models, which describe the high aspect ratio airfoil dynamic properties with the sufficient accuracy, are capable to be used only for some of them. Further series of defect cases has to be investigated by means of the detailed FE models. The adaptation and completing of the models appointed for static calculations is expected as the best method.

The paper deals with the detailed FE model adaptation and completing possibilities, which makes the model suitable for the dynamic analyses. The modal and flutter analyses are presented on the selected examples. Results of the analyses carried out on the detailed FE models are compared with the same ones performed on the simple beam dynamic FE models. The results differences are acceptable, therefore the detailed FE models are prepared to the defects introducing and for the defect cases calculations.

Keywords: Aeroelasticity, modal analysis, flutter, FEA, FE model

INTRODUCTION

The aeroelastic safety certificate is required for each type of the aircraft. The dynamic beam FE models are mostly used for the aeroelastic calculations. The dynamic beam models describes the high aspect ratio airfoils dynamic characteristics with a suitable accuracy and also have a number of advantages, in particular short computing times or good possibilities to update the models to the experimental results (stiffness tests – static tuning, ground vibration tests – dynamic tuning) etc. The main advantage is the fact, that the beam models describe only the global dynamic characteristics of the aircraft with no unwelcome local mode shapes.

The aircraft structures developed according to the DAMAGE – TOLERANCE philosophy are required from the airworthiness requirements side to prove the aeroelastic stability for a number of defect cases. Some of them (rod, rudder, tab or engine bar brakes etc.) can be solved by means of the beam FE models; the other ones (the more complicated cases like operating tear or fatigue and combat damages) must be solved by means of the detailed FE models in spite of disadvantages of them. One of the most important disadvantages is the fact, that the detailed models hold the number of the local unwelcome mode shapes (skin or bulkheads vibrations etc.). The local mode shape types are absolutely useless for the aeroelastic analysis and make the serious problems of the global mode shapes identification.

THE DETAILED FE MODEL ADAPTATION

The preparation of the special detailed model for the dynamic analysis seems to be complicated and ineffective. The most effective method to get the detailed model appears in the usage of the detailed model originally build for the static strength analyses. The static models certainly don’t be complete in mass

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properties, since the static model consists of the parts of the structure which are important for the strength analysis (roughly 2/3 of the total mass). The remaining mass properties are in need of to be added.

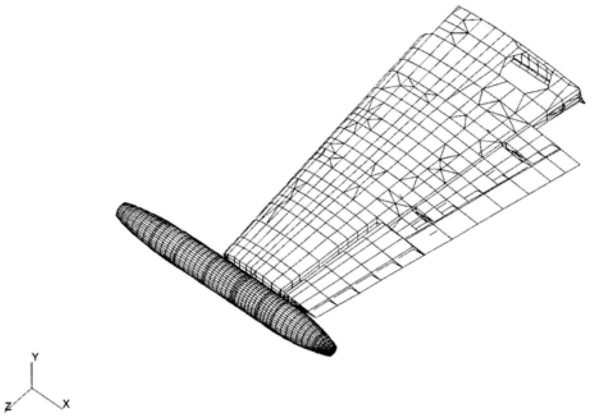

Fig.1 – Light combat aircraft isolated wing detailed FE model (initial state)

The mass properties adding process is described in the following text on the light combat aircraft isolated wing example. The initial FE model is shown in the figure 1.

Besides the initial FE model the total mass properties table was at disposal. The mass of the initial FE model was 308,5 kg, the required total mass from the table was 550,8 kg. The required mass properties table divided the structure into the structure parts (wing, aileron, flap, wing tip fuel tank, undercarriage) and the structural parts was divided into segments (strips of the structure). The initial FE model had to be divided into the same segments, therefore the initial model updating was necessary. The example of the FE model segment is shown in the figure 2.

The mass analysis by the NASTRAN FEA system was performed on the each segment. The results were compared with the required values from the table and the remaining mass properties (mass, center of gravity, moments of inertia) were determined. The remaining mass properties were added into the model via concentrated masses, which were connected with the surrounding significant structural points by the splines to minimize the unwelcome influences to the mode shapes generalized masses. The method of the concentrated masses connection is described in the figure 3. The FE model final state (after the mass properties adding) is illustrated in the figure 4. The agreement between the final FE model and the required values is on the good level except two parameters of the flap (z_T, I_z). The differences are probably caused by the big mass changes among the flap segments (due to flap mechanization).

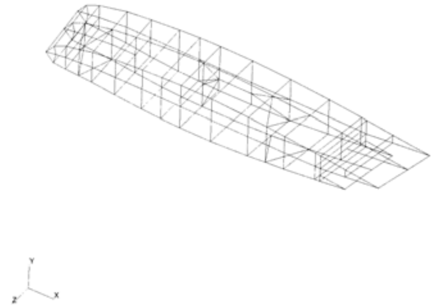

Fig.2 – FE model segment

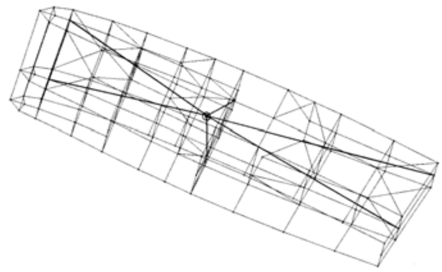

Fig.3 – Concentrated mass connection

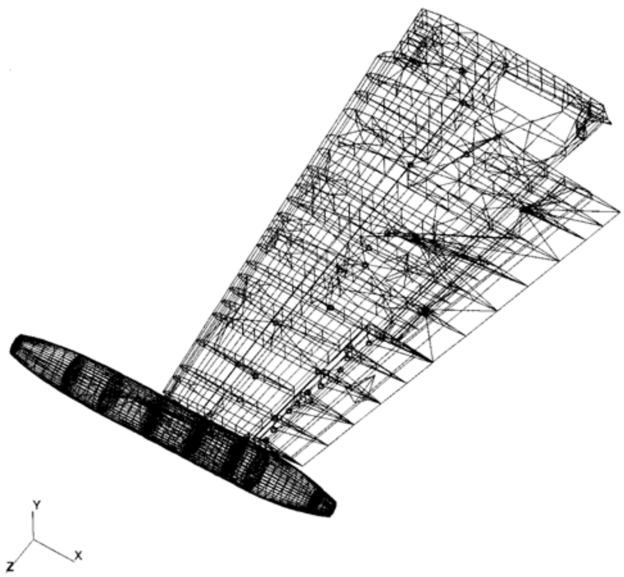

Fig.4 – Light combat aircraft isolated wing detailed FE model (final state)

MODAL ANALYSIS

The modal characteristics of the final detailed model (fig.4) were compared with the modal characteristics of the dynamic beam model (fig.5), which had been tuned to the experimental results. The modal characteristics calculations were performed by means of the NASTRAN system for the frequency range up to 100 Hz. There were founded 6 mode shapes on the beam model and 81 mode shapes on the detailed model. The global mode shapes were identified on the detailed model and compared with the modal characteristics of the beam model (example - fig.6).

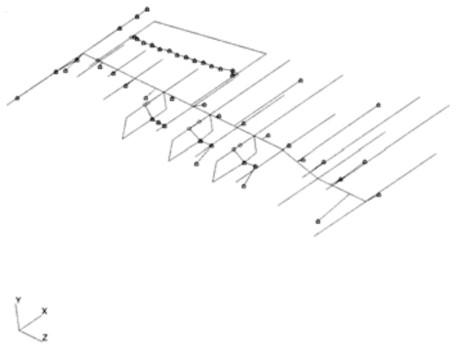

Fig.6 – Light combat aircraft wing dynamic beam model

The modal characteristics accordance is on the good level, for example difference of the first bending frequency is roughly 0,5%, the difference of the first torsion is around 4,5%.

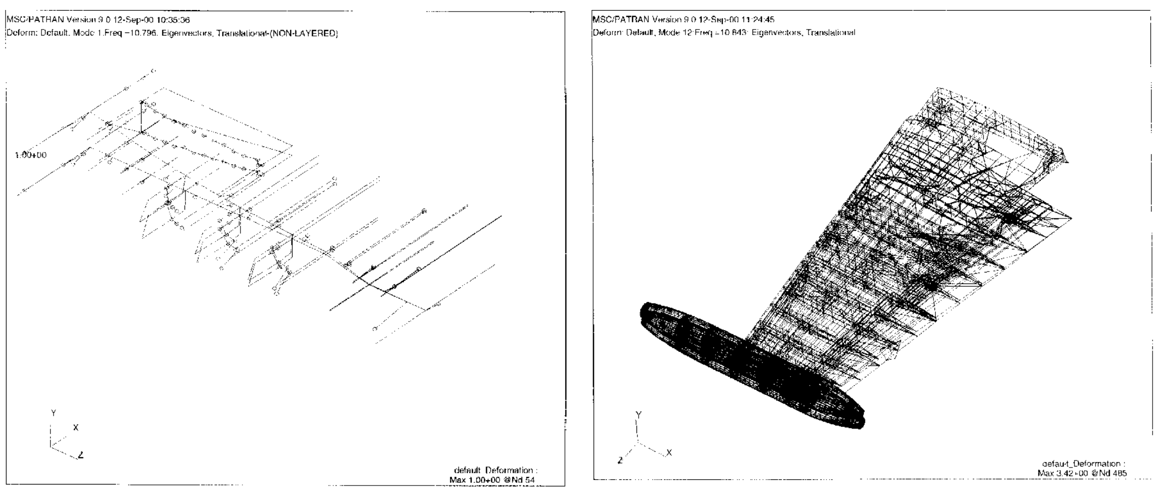

Fig.6 – Mode shape (1st bending) – beam and detailed FE models

FLUTTER ANALYSIS

The detailed model flutter analyses were performed by the NASTRAN system using the three aerodynamic theories (Doublett-Lattice, Strip, Wing-Body Interference) and the two methods for the flutter equation solution (PK, KE). The 2 DOFs bending – torsion flutter (1st bending – f = 10,84 Hz, 1st torsion – f = 22,14 Hz) was investigated. The checking analysis was performed by means of the beam model using the Doublett-Latice aerodynamics and the PK method. The level of the results accordance is illustrated in the figure 7. The figure 7 represents the v-g-f diagram (velocity – damping – frequency) for all the calculations. It is obvious from the fig.7, that the detailed and beam models flutter characteristic accordance are on the good level.

CONCLUSION

The paper presents the possible process of the static detailed model adaptation to make it usable as the dynamic model.

The testing analyses shows the good accordance with the dynamic beam model, therefore the detailed FE model are prepared to the modal and aeroelastic analyses, mainly for the more complicated defects introducing and calculations of the defect cases.

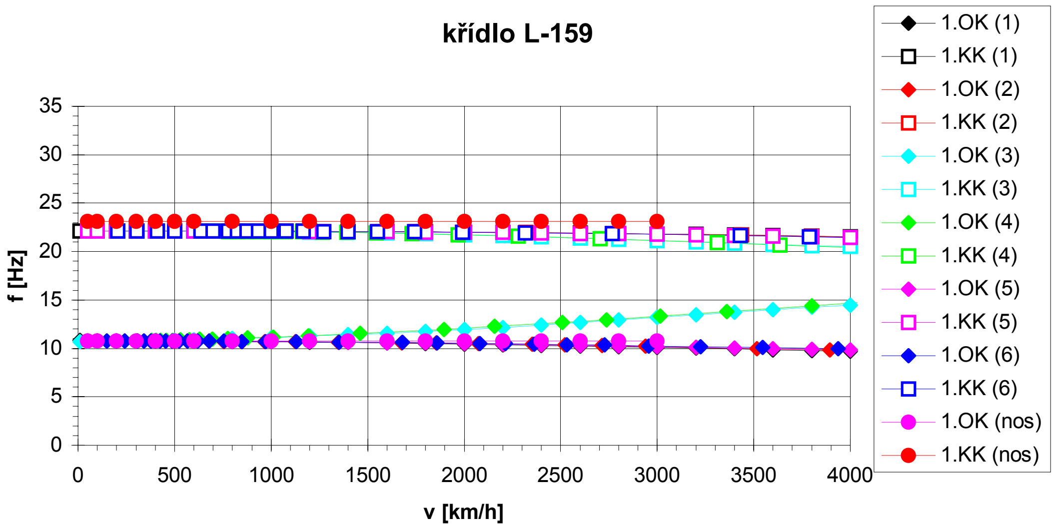

Fig.7 – Flutter characteristics comparison (v-g-f diagram) - (1)-(6) = detailed model, (nos) = beam model

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