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INTERNATIONAL CONFERENCE of SCIENTIFIC PAPER
AFASES 2011
Brasov, 26-28 May 2011

CONCERNS REGARDING THE STUDY OF IMPACT BETWEEN AN AIRCRAFT AERODYNAMICAL SURFACE AND A FOREIGN OBJECT

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Abstract: The purpose of this study is to analyze a fast dynamic phenomena (the impact between objects) using "Finite Element Method" with direct applications for flight occurrences investigation.

The impact between a foreign object (a hard object which isn't or was not part of the aircraft) with an aerodynamical surface having a major roll in ensuring the aircraft aerodynamical stability during the flight is studied.

The point of interest in beginning the study was an aerodynamical surface generated by a flight occurrence, which keeps the marks of such impact. The practical interest of this study, although there are many variables, is to identify the impact circumstances that can cause a similar effect on the aerodynamical surface structure.

The interest reason, from a flight occurrence investigation point of view, is to issue theories regarding a possible loss of the aircraft aerodynamical stability, due to a collision at low altitude evolution. In such situation is difficult to identify the generating cause between the impact occurrence and a wrongful maneuver of the crew based only on the flight parameters (acceleration, velocity, trajectory, etc.) registered on aircraft Flight Data Recorder system.

Keywords: *impact study, aerodynamical surface, finite element method.*

1. INTRODUCTION

The aerodynamical surface chosen for the present study is an horizontal empennage from a Puma helicopter. As a result of a flight occurrence, the recovered empennage was damaged so that the aerodynamically features was serious affected. The empennage ripped shape indicates that the impact was from top to bottom (fig. no 1).

The empennage is fixed on the top left helicopter tail on the opposite side of the tail rotor. It is trapezoidal shaped and fixed on two points on the device. The setting angle value between empennage and helicopter tail is 2^0. This angle is adjusted in the factory and can not be changed.

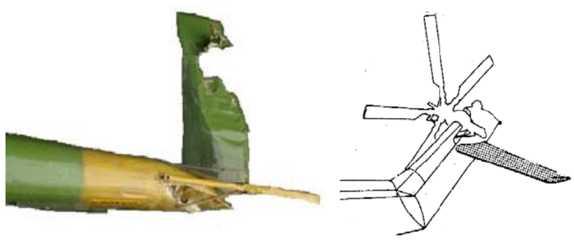

Fig. no 1 - The empennage ripped shape and the empennage normal shape

The interaction between the foreign object (named „projectile” in specific literature) and the aerodynamical surface (often named „target surface”) is one of the complex phenomena in mechanical structure, which is very difficult to be mathematical modeled due to the following causes:

- the stress is impulsive during a very short time (microseconds);
- the strength of impulsive force is very high, producing irreversible changes in the structure of the target surface and projectile;
- the behavior of the materials (for target surface and projectile) during the impulsive stress is very different from static stress behavior.

Taking into account those physics considerations that characterize the impact phenomena, it is necessary to use a mathematical model which can take account of the following particularities:

- because at the projectile – target impact the elastic limit of the projectile and target bodies material is exceeded, a physical nonlinearity will occur
- displacements in the target's body (aerodynamic surface) on the impact direction being bigger than the displacements in the perpendicular plans on the impact direction, results into a geometrical nonlinearity of the problem

the action of the projectile over the target being variable in time, it is necessary an analyze of the dynamic answer of the target structure following the impact with the projectile

2. RESEARCH WORK

2.1 Finite element modelation. For analyzing and solving, with “Finite Element Method”, an impact problem, generated by a real flight occurrence, between an aerodynamical surface and a foreign object is necessary to determine the stresses and the displacements in aerodynamical structure. Before that a few necessary assumptions must be done and also the studied bodies (aerodynamical surface and foreign object) must be modeled with finite elements, so that the repartition of stresses and displacements to present a comprehensive image of the structure behavior.

For creating the empennage model with finite elements there were used shell elements for its covering, wing spars, bracing ribs and beam elements for rib parts (fig.no 2). Taken into consideration the studied phenomena, the chosen material model is the elastic-plastic model.

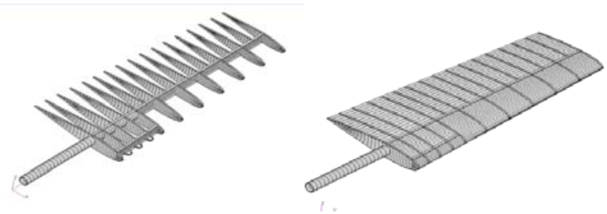

Fig. no 2- Empennage model with finite elements.

For simulate the phenomena, the necessary material properties are: the minimum breaking stress (σ_b), the minimum creep stress (σ_c), the breaking elongation (ε_b), the density (ρ), the coefficient of longitudinal elasticity (E), the Poisson coefficient of transversal contraction (μ).

The approximation for Hooke's material characteristical curve is presented in the fig. no 3.

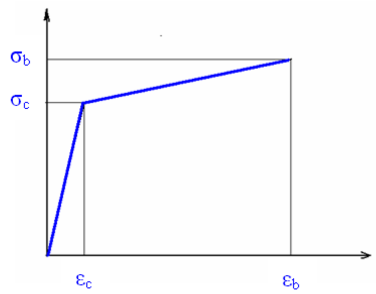

Fig. no 3 – The Hooke's material characteristical curve

The specific creep elongation (ε_c) is calculated with the following formula:

$$\varepsilon_c = \frac{\sigma_c}{E} \qquad (1)$$

The downgrade tangency (E_{tan}) for plastic area is calculated with the following formula:

$$E_{\tan} = \frac{\sigma_b - \sigma_c}{\varepsilon_b - \varepsilon_c} \qquad (2)$$

The interest situation for beginning this analyze is that a hard object hits the aircraft horizontal empennage when its velocity is 70 m/s. It is considered that the direction impact is from the upper to lower side, perpendicular on the horizontal plan. The object is considered hard because this represents the most detrimental case for the aircraft aerodynamical structure. The hard (foreign) body velocity is variable in all studied cases from 20 m/s to 80 m/s, having a section area of 120x120 mm.

A nonlinear, dynamic analyze was concluded. The equations are solved explicitly. For each impact case the computing time is chosen so that the impact effect over the empennage to be determinate. The time increment is automatically calculated depending on the minimum distance between two nodes of the modeled structure, density and rigidity.

2.2 Results case no 1. The impact between empennage and 1 kilo hard body with 20 m/s velocity.

The effect over the structure is insignificant. A plastic deformation occurs (contact mark) on the wing extrados. The kinetic energy that is transferred to the empennage disperses itself under elastic waves form (fig. no 4).

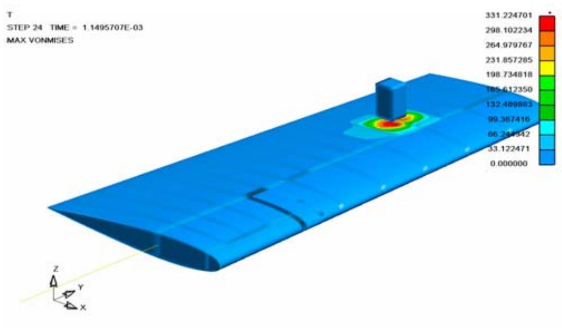

Fig. no 4 - Results case no 1

2.3 Results case no 2. The impact between empennage and 1 kilo hard body with 40 m/s velocity.

The covering of the extrados wing is ripped on an approximately 40x40 mm area (fig. no 5).

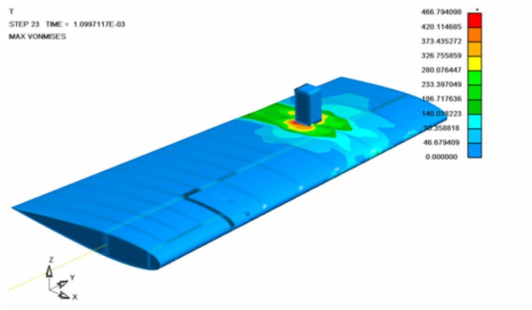

Fig. no 5 - Results case no 2

2.4 Results case no 3. The impact between empennage and 1 kilo hard body with 60 m/s velocity.

The covering of the extrados wing and the 13th bracing rib is ripped on an approximately 220x80 mm area (fig. no 6).

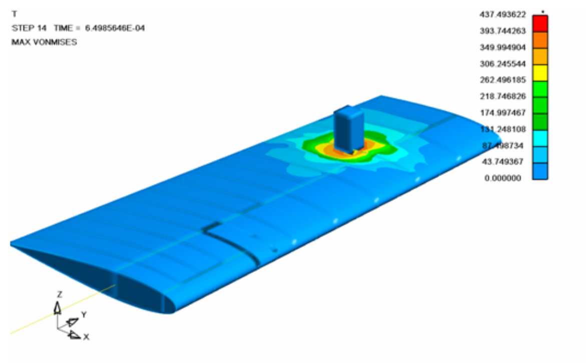

Fig. no 6 - Results case no 3

2.5 Results case no 4. The impact between empennage and 1 kilo hard body with 80 m/s velocity.

The empennage is perforated during the impact. The covering of the extrados wing, the bracing rib and the covering of the intrados wing are ripped. The effect is greater on the extrados. The ripped area width is approximately equal to the body width.

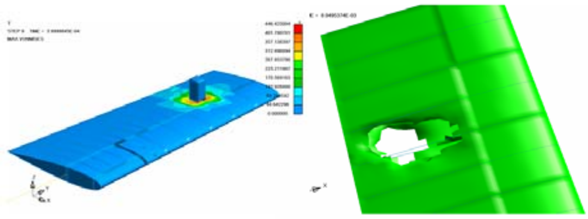

Fig. no 7 - Results case no 4

2.6 Results case no 5. The impact between empennage and 1 kilo hard body with 80m/s velocity. To obtain a ripped area, the body is shifted on OX axis towards empennage trailing edge with 100 mm.

The empennage is perforated during the impact and the empennage trailing edge is ripped. The covering of the extrados wing, the bracing rib and the covering of the intrados wing are ripped.

Fig. no 8 - Results case no 5

2.7 Results case no 6. The impact between empennage and 1 kilo hard body with 80m/s velocity. For studying the rupture area changes, the body is shifted backward with 100 mm and rotated with 90^0, having a contact section area of 240x120 mm.

The empennage is perforated during the impact, but the empennage trailing edge is not ripped, because the energy is better dissipated in the empennage structure. The covering of the extrados wing, the bracing rib and the the covering of the intrados wing are ripped. The rupture gets bigger, the ripped area width is approximately equal to the body width.

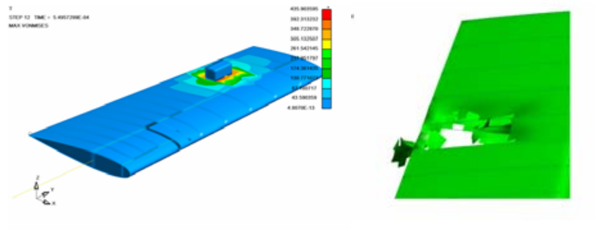

Fig. no 9 - Results case no 6

2.8 Results case no 7. The impact with a viscous-elastic-plastic body (biological tissue consistency) with a 5 kilo wight (maximum weight for biological body considered in this paper), and 40m/s impact velocity. This velocity is considered to be the maximum of a nose diving bird.

The effect over the structure is insignificant. Only a plastic deformation of the structure occurs. Due to the impact conditions and material properties, the body transfers towards the structure only a small amount of energy. This energy is taken and dissipated in the elastic waves form.

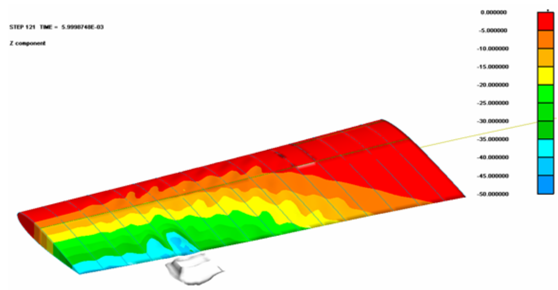

Fig. no 10- Results case no 7

3. CONCLUSIONS & ACKNOWLEDGMENT

Simulations prove that, during the impact with a biological tissue consistency body, the only occurrence is a small plastic deformation of the structure. Due to the impact conditions and material properties, the body transfers towards the structure only a small amount of energy, which is taken and dissipated in the elastic waves form. The impact with a hard body is the most detrimental case. These conclusions, for serious ruptures, lead to impact simulations only with hard bodies.

Along with the increase of the impact velocity, the destructive effects over the empennage structure increase. The frontal area and the shape of the body significantly influence the rupture area and the energy dissipated in the structure. In the impact case when the body is oriented with the small section on the impact direction, the kinetic energy transfer area is small and the rupture produces on a width comparable area with the width of the body.

By shifting the body backward and rotating it by 90^0, so that the contact is on the maximum section, the rupture increases in wing span, but decreases on the chord of wing (at the same body weight).

A conclusion of the numerical simulation performed is the fact that fast dynamic phenomena, or even the ultra fast ones, become accessible and can be sequential handled through numerical simulation, thus being able to view the development process. Once the structure model is valid, sequential representation of the simulation, at different time steps, somehow eliminates the usage of other expensive viewing methods, such as high speed cinema and shooting in X-ray spectrum.

The purpose of numerical simulation methods is not to eliminate the experimental study of the phenomena. The cohabitation of both methods in studying the fast dynamic phenomena is the right solution, the experimental data transferred to simulation are practically returned under the form of useful optimizations in experimental field.

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