BIRD STRIKE ANALYSES ON THE PARTS OF AIRCRAFT STRUCTURE

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Abstract

The submitted paper describes using air gun with smooth borehole for proof of bird strike resistance of aircraft parts. The finite element code ABAQUS Explicit was mainly employed in the study of sensitivity on the simulations to material properties, mesh characteristics, and impactor models.

1 Introduction

Bird impact is often the dimensioning load condition for several aircraft parts, such as windshields, leading edges (fig.1), engines, radomes, pitot probe, antennas etc.

Fig.1. Bird strike damage of leading edge

Whilst almost all bird strike clearance is performed via testing using real birds on representative structure, some alternatives methods are now possible. Definition of structures within appropriate non-linear finite element (FE) codes is now well known and developed, however, bird models vary considerably between workers. Differences in density, shape and aspect ratio are easy to see. Differences in mechanical properties are not as transparent. Unless data to define analytical birds can be justified against viable sources, it is unlikely that certification of structures by analysis alone will be successful. Similar thoughts apply when considering substituting real birds for synthetic birds in testing.

2 Test Method and Facility

Required velocity is achieved by properly pressurized of gun pressure vessel. The exact point of impact is set by setting of specimen towards muzzle of gun.

Test method is based on gained experience from previous tests carried out in VZLU. Bird is accelerated in smooth bored barrel on rated speed using compressed air energy. Required speed is reached by changing pressure in pressure tank of the air gun. By positioning of the test specimen with respect to the gun axis accurate strike place is reached. Speed measurement system used during the test is based on the time measurement needed for defined distance the bird fly before the strike. Distance is given by two grids of wire position the flying bird subsequently breaks and by that disconnects related electric circuits. Speed of the bird is determined by measured time and known distance. Overall speed measurement accuracy is ±2%. Air tank is pressurized on the same value, but fired bird speed alters due to barrel cleanness and bird body shape. Impact speed tolerance of the bird can be kept within ±25km/h. Application of described procedure allows to make a structure corrections or changes, if necessary. Also it reduces the analysis time since it replaces the parametric study to evaluate influence of stiffness changes. It increases the efficiency of the certification process.

2.1 Air Gun

The tab.1 shows technical specification of air gun using in VZLU.

Diametr of muzzle [mm]	length of muzzle [m]	weight of bird	velocity of bird [km/h]
125	25	2lb (0,91kg)	650
125	25	4lb (1,81kg)	450

Tab.1. Technical specification of air gun

The fig.2 shows test facilities with air gun installation.

Fig.2. Air pressure tank, quick-opening valve, action and barrel body

3 FE simulation

The ABAQUS/Explicit has been used for impact simulation onto the part of aircraft structure. The first study of bird simulation shows different behavior between simulation of impact into the oblique part of aircraft structure (e.g. leading edge, windshields etc.) and sharp geometry part (e.g. pitot probe, antenna etc.). From this point of view the bird for sharp parts such as pitot probe was modeled as a cylinder with refine mesh on the contact surface for point of view some numerical singularities elimination. For oblique parts has been used standard bird model (cylinder with spherical ends) (fig. 3.).
The bird nodes are charged with an initial velocity. The combination of tensile failure and shear failure criterion was used.
The test specimen and model of bird was modeled by CATIA v5 CAD system. The CAD model was transferred to the pre-processor FEMAP for meshing. The results from FE analyses are deformed and damage shapes.

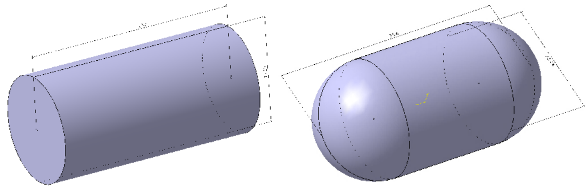

Fig.3. The geometry of bird dummy for FE simulation

3.1 FE model of Bird

In the simulation, the bird adopts an elastic-plastic model with shear and tensile failure, verified in this paper an instance in the other literature. The bird is modelled within a Lagrangian approach as an above mentioned geometry (fig.3).
The shear failure model is based on the value of the equivalent plastic strain at element integration points. The failure is assumed to occur when the damage parameter exceeds one [4]. The damage parameter, ω, is defined as

$$\omega = \left(\bar{\varepsilon}_0^{pl} + \sum \Delta\bar{\varepsilon}^{pl}\right) / \bar{\varepsilon}_f^{pl} \qquad (1)$$

,in which $\bar{\varepsilon}_0^{pl}$ is an initial value of the equivalent plastic strain, $\Delta\bar{\varepsilon}^{pl}$ is an increment of the equivalent plastic $\bar{\varepsilon}_f^{pl}$ is the failure strain. The summation is performed over all increments in the analysis. When the shear failure criterion is satisfied, all the stress components will be set to zero and the elements fails.

4 Comparison between test and simulation

The above mentioned technique for measurement and simulation was used for verification on the real part of aircraft structures.

4.1 Pitot probe

For bird strike simulations onto test specimen was used a 2lb (0,91kg) bird. The test specimen was pitot probe from aluminium alloy [1]. The test specimen and model of bird was modelled by CATIA v5 CAD system. The CAD model was transferred to the pre-processor FEMAP for meshing. The fig.4 shows assembly of test specimen with model of bird and FE mesh on the both bodies.

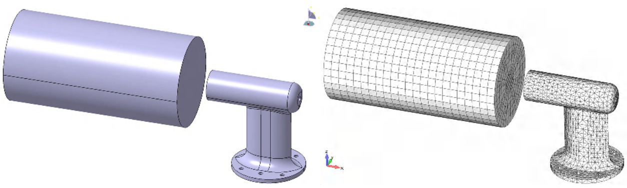

Fig.4. Assembly of test specimen with model of bird

The results are contour map of displacement and stresses on the test specimen. The fig.5 shows generation of equivalent plastic strain during impact simulation on the lengthwise of cross section of bodies and comparison with test.

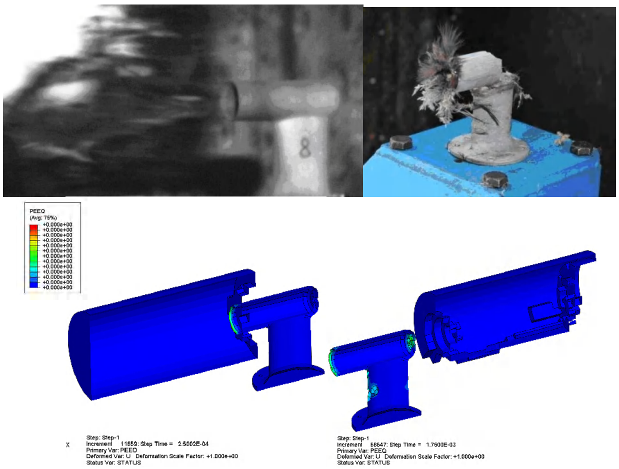

Fig.5. Result of test [1] (above) and FE simulation (plastic strain) (below)

4.2 Windshield glass of civil aircraft

In the experiment [2], bird impact tests are carried out on windshields, which are 14,18 and 20mm thick laminated glass. The bird mass was 1,81kg and impact velocity was between 300km/h and 450km/h. The FE model of the windshield takes into account the glass in usual to simplify the modeling process. The supporting structures are simplified by corresponding boundary condition of glass. The fig. 6 shows test results.

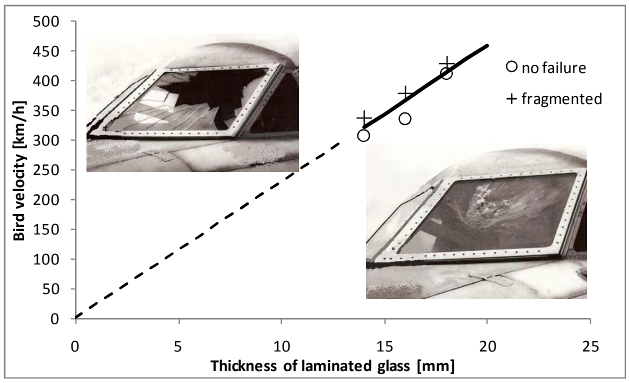

Fig.6. Test results of bird strike resistance on the civil aircraft windshield [2]

The simplified FE model shows good agreement with test results. The fig.7 shows input FE model (above) and result (below) after bird impact up to velocity from fig.6.

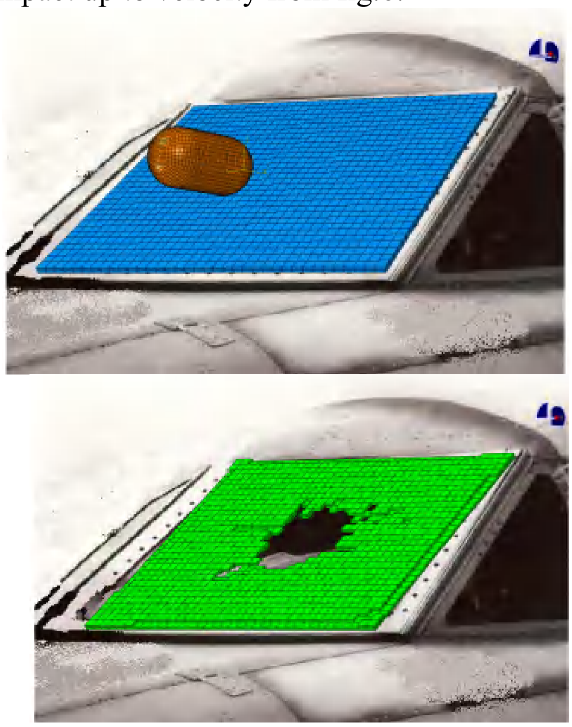

Fig.7. FE simulation of bird strike resistance on the civil aircraft windshield

4.2 Windshield glass of military aircraft

In the experiment [3], bird impact tests are carried out on windshields, which is a 16mm polycarbonate shell. The bird mass was 1,81kg and impact velocity was between 300km/h and 450km/h. The FE model was generated from general model from point of real simulation of boundary conditions. The fig.8 shows test and simulation of windshield damage.

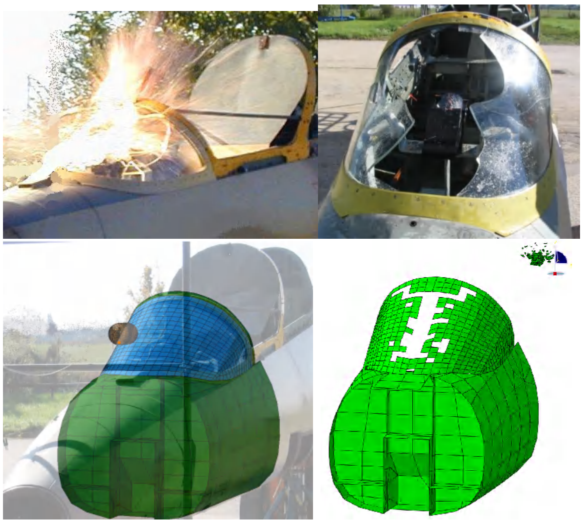

Fig.8. Result of test [3] (above) and FE simulation (below)

5 Future works

For further development of the test philosophy and simulation it is necessary the new synthetic model of bird with inner skeleton stiffness simulation. The fig.9 shows proposed model of synthetic bird and meshed parts for FE simulation. The simulations will be increased about CEL (Coupled Eulerian –Lagrangian) technique which is implemented in ABAQUS code.

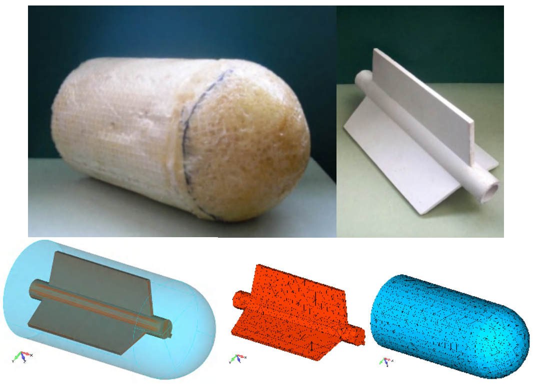

Fig.9. Result of test (above) and FE simulation (below)

5 Conclusions

The results of numerical simulation show robust capabilities of new generation of explicit FE codes for simulation of high velocity impact. For improvement of simulation are important inputs of material properties especially from point of view damage and damage evolution. The differences between experiment and FE simulation result from above mentioned unknown material properties and mass distribution on the real bird.

6 Acknowledgement

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