TEST AND NUMERICAL SIMULATION OF BIRD SYNTHETIC MODEL

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Abstract: Bird strike events are a potential dangerous problem faced by flight safety nowadays. These events are usually simulated through numerical approaches due mainly to the technical difficulties and high costs associated with experimental tests. 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.

The new synthetic model of bird with inner skeleton stiffness simulation was developed in the VZLU. The model was verified by means of gas gun tests on the smooth flat plate.

In this work, bird strike like phenomenon and correlated aspects such as contact, perforation and failure occurrence are addressed by using ABAQUS finite element explicit code.

An investigation on the accuracy, merits and limitations of a finite element approach to this kind of problem is presented as well as comparisons with gun tests.

Keywords: Aircraft, Impact, Bird Strike.

1. Introduction

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

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

Table 1. Technical specification of air gun.

The fig.1 shows test facilities with air gun installation.

Figure 1. Air pressure tank, quick-opening valve, action and barrel body.

2.1 Synthetic Bird

For development of the test philosophy and simulation was proposed new synthetic model of bird. The new synthetic bird respect real bird composition with inner skeleton stiffness and soft body. The fig.2 shows proposed model of synthetic bird.

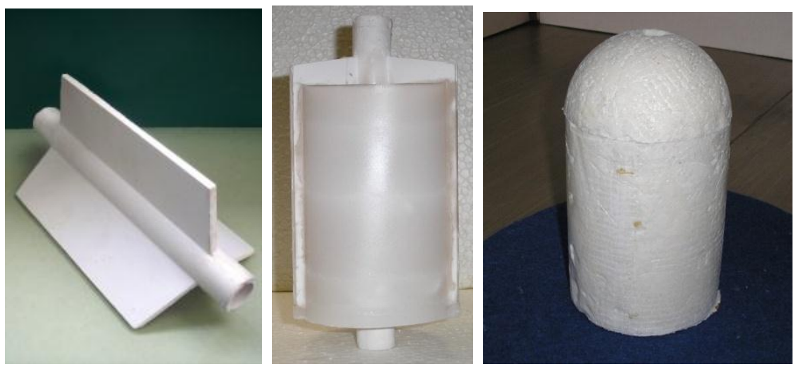

Figure 2. Proposed part and assembly of synthetic bird.

The table 2 shows summary of material used for synthetic bird manufacturing.

	Material	Density [kg/m3]	Young modulus [MPa]	tensile strengh [MPa]	Compression strength [MPa]	Poisson ratio
skeleton	gypsum	1020	1500	5	15	0,3
soft body	foam	0,3	150	5	8	0
	paraffin wax	0,8	55	0,15	0,658	0,4

Table 2. Mechanical property of material used for synthetic bird.

2.2 Arrangement for synthetic bird strike tests

For comparison between real and synthetic bird was arrangement built-up from frame with thick steel plate and safety barrel. In the plate were machined adjustable concentric circles for measurement deformation after impact. For measure of impact behavior was used thin plate from aluminum. The figure 3 shows arrangement for test.

Figure 3. Arrangement for comparison between real and synthetic bird strike test.

3. FE models

The ABAQUS/Explicit has been used for impact simulation. 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. 4.).
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 results from FE analyses are deformed and damage shapes.

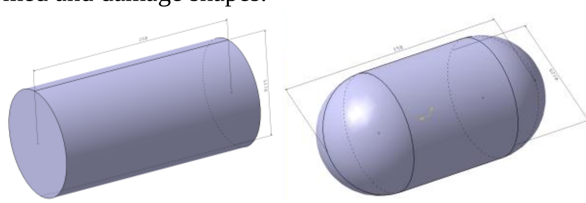

Figure 4. The geometry of bird dummy for FE simulation.

Two simulation approaches was used for the bird adopts:

- For synthetic bird - elastic-plastic model with shear and tensile failure. The bird is modelled within a Lagrangian approach as an above mentioned geometry (fig.4).
- For real bird - the linear Us-Up Equation of State (EOS) material model is chosen for the bird, as its behaviour can be idealized as hydrodynamic according [2]. The bulk modulus acts as a penalty parameter to enforce the incompressible constraint. Plasticity and ductile damage are also defined for the bird.

The figure 5 shows assembly of test simulation with model of synthetic and real bird.

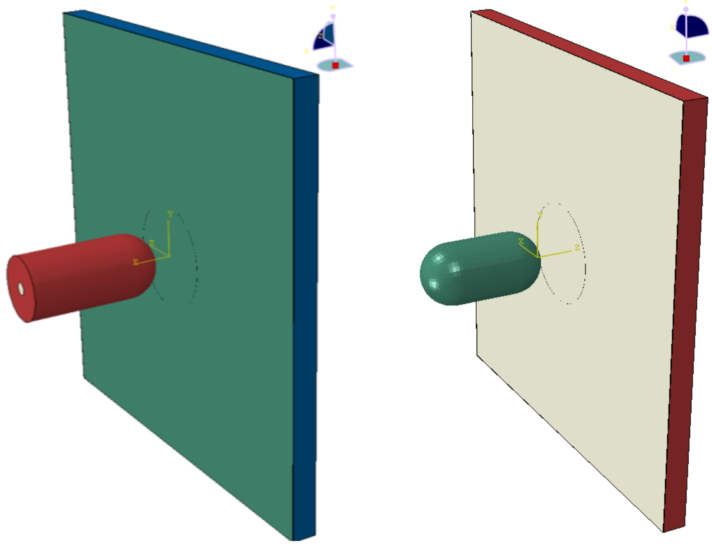

Figure 5. Assembly of test simulation with model of synthetic bird (left) and model of real bird (right).

4. Results

The figures 6 a figure 7 shows comparison between test and FE simulatiom.

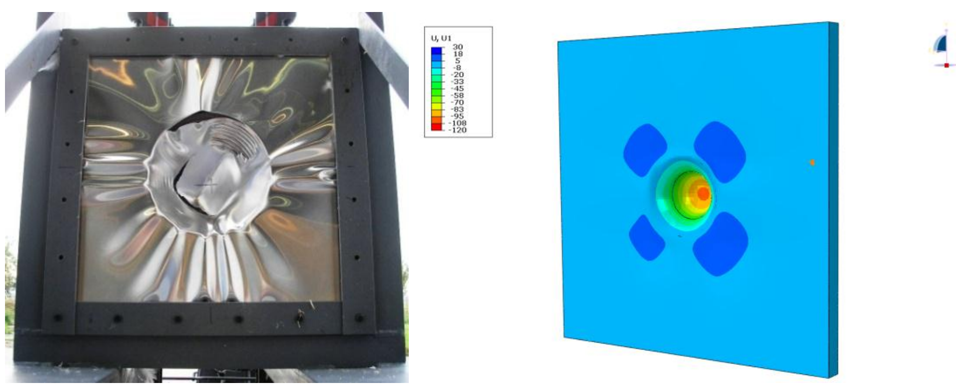

Figure6. Comparison between test (right) and FE simulation (right) for synthetic bird (weight of bird 1kg, impact speed 200km/h).

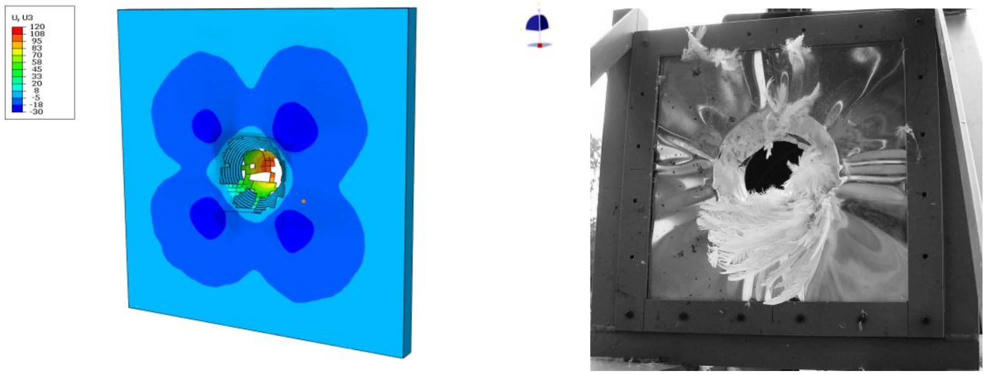

Figure7. Comparison between test (right) and FE simulation (right) for real bird (weight of bird 1kg, impact speed 300km/h).

4.1 Application to the real aircraft structure

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 comparison between test and simulation of windshield damage.

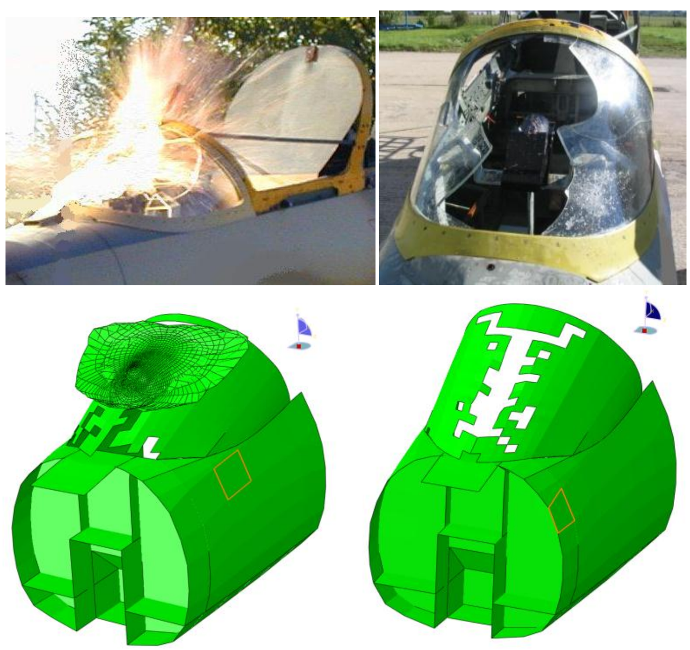

Figure7. Result of test [3] (above) and FE simulation (below)

5. Conclusion

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. References

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