HAL
open science

New concepts for high energy absorbing structures protected against birdstrike

Bruno Derias, Pierre Spitéri, Philippe Marthon, Léon Ratsifandrihana

To cite this version:

Bruno Derias, Pierre Spitéri, Philippe Marthon, Léon Ratsifandrihana. New concepts for high energy absorbing structures protected against birdstrike. 13th International Conference on Computational Structures Technology (CST 2018), Sep 2018, Barcelone, Spain. pp.1-4. hal-03621623

HAL Id: hal-03621623

https://hal.science/hal-03621623v1

Submitted on 28 Mar 2022

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Open Archive Toulouse Archive Ouverte

OATAO is an open access repository that collects the work of Toulouse researchers and makes it freely available over the web where possible

This is an author's version published in:
http://oatao.univ-toulouse.fr/22709

To cite this version: Derias, Bruno and Spitéri, Pierre and Marthon, Philippe and Ratsifandrihana, Léon *New concepts for high energy absorbing structures protected against birdstrike.* (2018) In: 13th International Conference on Computational Strcutures Technology (CST 2018), 4 September 2018 - 6 September 2018 (Barcelone, Spain).

Any correspondence concerning this service should be sent to the repository administrator: tech-oatao@listes-diff.inp-toulouse.fr

New concepts for high energy absorbing structures protected against birdstrike

Bruno Derias[a,b], P. Spiteri[a], P. Marthon[a], L. Ratsifandrihana[b]

[a] IRIT, INP-ENSEEIHT, 2 rue Charles Camichel, 31000 Toulouse, France
[b] SEGULA Aerospace & Defence, 24 Déodat de Séverac, 31700 Colomiers, France

Abstract. The present study concern birdstrike on aeronautic structures. We consider both on one hand a mathematical approach followed by a numerical study and the other hand an experimental study allowing to validate the results obtain by the numerical way. From the theoretical point of view, we consider in the mathematical model of the structure large deformation, specific materials described by nonlinear law and the nonlinear behavior describing the contact between the structure and the projectile. The numerical simulation is performed by coupling the finite element method with the Smooth Particle Hydrodynamic method (SPH). Lastly in order to obtain short elapsed time of simulation the computational code is paralyzed and vectorized. The results of simulation are compared successfully with experimental study performed in laboratory.

Keywords: Aeronautics, composite, material, finite element, experimental, transient dynamic, nonlinear analysis, SPH, reinforced structure, avian impact.

1. Introduction

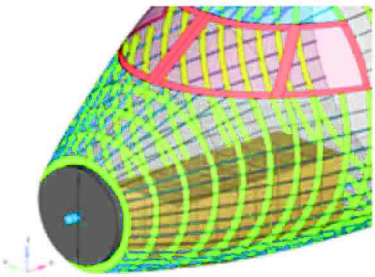
Statistics show the dangerousness, the recurrence and the increase of bird strikes [1-3]. More than 169,000 impacts were recorded between 1990 and 2015. Since 1988, more than 262 lives have been lost and 247 aircraft destroyed. Analysis shows that bird strikes could be responsible for up to 69,000 hours of flight downtime per year.

The airplane must be designed to ensure continued safe flight and landing after impact with a 4 lb bird (approximately 1.81 kg) when the velocity of the aeroplane (relative to the bird along the aeroplane's flight path) is equal to the cruising velocity (Vc) at sea level or 0.85 Vc at 2438 meters (8000 ft), whichever is the most critical [4-5]. Impacts can occur at airplane speeds exceeding 500 km/h. The duration of an impact can be less than 10 milliseconds.

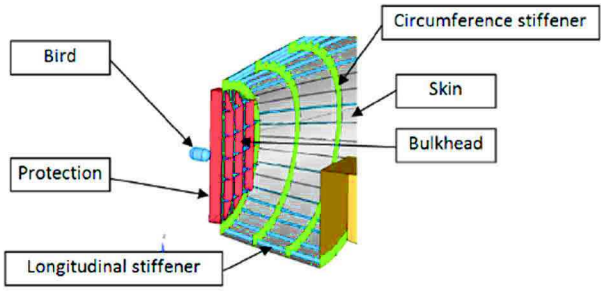
Several types of material can be used to protect against bird strikes. A commonly used solution adopted for energy absorption is an alloy honeycomb structure [6-7].

The objective of this study is to determine a new concept with at least the same performance as the honeycomb. Compared to the latter, the expected performance is to absorb 45% of the kinetic energy of the bird, with a mass of less than 20 kg and a thickness of less than 80 mm. Due to the transient and highly non-linear dynamic nature of avian impact, it is difficult to predict its effects on an aircraft. Experimental studies present a significant cost and do not allow the study of all positions and angles of impact. Verification of structural integrity is complex. The technology locks to be lifted for aircraft manufacturers concern the realization of virtual testing.

The aim is to combine experimental and numerical studies in order to reduce development costs.



(a) Front-nose-airplane



(b) bird shock protection

Figure 1: Airplane nose with bird shock protection

2. Methods

The methodology developed is divided into 4 phases:

2.1 Study of a reference case

This section focuses on the analysis of the dynamic behaviour during a bird strike of a conventional solution which is a honeycomb absorber on a reference aircraft. This study makes it possible to understand the different physical phenomena that occur during impact.

2.2 Concept study

This section focuses on the study of different concepts at the coupon level. It makes it possible to prioritize them in terms of absorption capacity, mass and thickness by integrating assembly and manufacturing parameters. At the end of this step, a new concept is expected to be defined. This constitutes a technological breakthrough in the research work presented. The aim is to determine a concept that will absorb as much as a honeycomb and that has equal or less mass and thickness.

2.3 Experimental study

A test programme is conducted to characterize the behavior of the new concept. It presents data for designing a numerical model representative of the test results.

2.4 Modeling - virtual testing

Compared to the scale of the bulkhead, a comparative study is carried out of the previously selected concept in substitution of the classical solution with a honeycomb. The energy absorbed in the structure, the absorber and bird is analyzed, as well as the areas of plasticization and failure. This is a basis of interest for the different solutions.
A numerical model of the new bulkhead is then constructed. This model is used to develop a methodology for the simulation of bird impact. This model will make it possible to check the strength of the structure and optimize its mass. The representativeness of the impact makes it possible to pre-validate the bulkhead and to constitute an experimental plan for validation.
The bird's flesh consists mainly of water. A hydrodynamic model is the most suitable. The Smoothed Particle Hydrodynamics (SPH) method was chosen. This method makes it possible to model finely the large deformations, as well as the fragmentation of the bird, by adapting the number of particles and the shape of the particle network. The penalty method is used to simulate the shock between the SPH particles and the Lagrangian structure. It is very efficient. The explicit centered finite difference temporal integration scheme was chosen. On the one hand, it does not require assembly or inversion of the stiffness matrix. On the other hand, its stability condition imposes a time step limit that can be easily assured, because it is a problem with high loading speed. Another interest of an explicit code is also the possible parallelization of the calculation.

3. Results

The analysis of the dynamic behavior of the reference bulkhead with a honeycomb enabled to distinguish clearly the chronology of impact, the absorption zones and the structural damage.
45 % of the bird's kinetic energy is absorbed by a conventional honeycomb absorber, which is 80 mm thick and weighs approximately 20 kg.

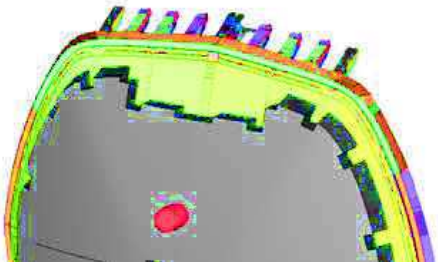


Figure 2: Reference bulkhead

A state of art, matrix of choice, analytical and numerical analyses have directed the choice towards a concept. The stiffness of the new concept was determined from the absorbed energy considering an objective in terms of force and absorption stroke. A test plan was defined to characterize the behavioral laws of this concept. The type of test, the means of testing and the dimensions of the coupon were chosen. Coupon-scale compression, tension and shear tests were carried out. The behavior at quasi-static and dynamic speeds has been tested.

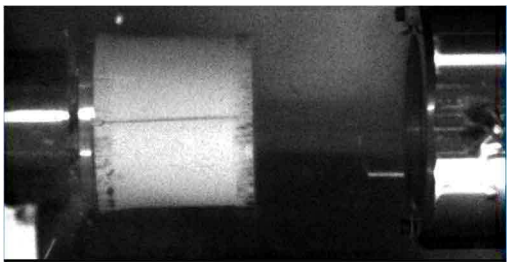


Figure 3: Dynamic test at the scale of the coupon

The numerical model at the coupon scale of the test made it possible to correctly represent the phenomenon of energy absorption.

Figure 4: Numerical model of the dynamic test at the scale of the coupon

The comparison between the honeycomb and the new concept, at the scale of the bulkhead, shows that the proposed solution is promising. The behavior of the bulkhead is similar to that of the honeycomb solution. The new concept has a mass greater than 5 % and a thickness of 36 % less.

The numerical model, at the bulkhead scale, allowed to simulate the avian impact, verify the strength of the structure, optimize its mass and find the most critical angle and impact position. The parallelization on several cores of the computation decrease calculation time. Based on this model, a test plan was drawn up. The characteristics and the location of gauges, accelerometers and cameras were determined.

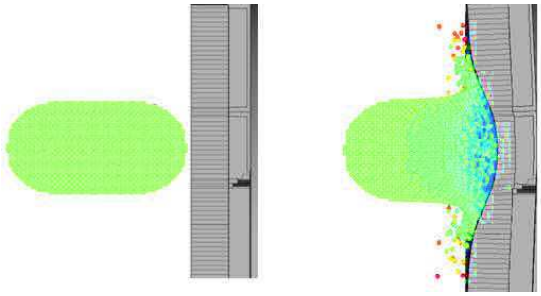


Figure 5: Numerical model with SPH bird at the scale of the bulkhead

The final real test validates the concept against bird-strike. The main physical phenomena are correctly represented by the numerical model. Local fracture phenomena of rivets and stiffeners were not detected. Analyses were conducted to understand the origin of the difference and propose modifications. The numerical model has been updated and its representativeness improved.

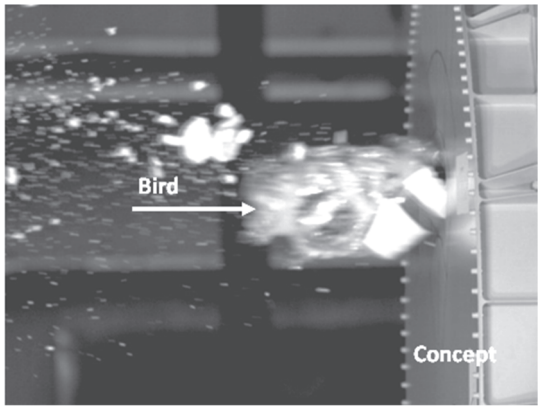


Figure 6: Bird strike test at the scale of the bulkhead

4. Conclusions and contributions

The originality of the study lies in the global approach conducted and which integrate a state of the art of manufacturing technologies, materials and behavioral characteristics. But also, analyses of avian shocks on different aeronautical airplanes. To define predictive

numerical models, the impact phenomenon was studied, analyzing different formalisms for the bird. But also methods to simulate the highly non-linear transient dynamic phenomena on the structure. The experimental aspect was analyzed in detail. The means of testing necessary to characterize materials at the coupon scale, but also to validate the bulkhead were studied. Lessons have been learned and methodologies have been developed to provide a comprehensive methodology for defining a bulkhead concept for industrials program.

Thus, the originality of the study lies in the methodology deployed and the new predictive concept of bulkhead which is based on a numerical simulation model. This approach has made it possible to define a new concept with a thickness lower than that obtained in the case of a honeycomb, for a substantially equivalent weight. The study was validated in one test. In addition, the use of the SPH method makes it possible to take into account large deformations of the structure.

This type of study is feasible for other industrial applications, the method and concept can be used in other sectors such as Defense and Space. The absorption capacity of the concept makes it an interesting shielding solution.

The main advantage of this approach lies in the fact that tests at the scale of the coupon are no longer necessary and that numerical simulation would make it possible to design structures, which would decrease time and cost of development for manufacturers. This study identified methods for describing behavioral laws. It is therefore now possible to get rid of tests and define these laws directly from basic data.

References

1. Dolbeer, R.A.: Birds and aircraft – fighting for airspace in even more crowded skies. In: Human – Wildlife Interaction Human – Wildlife Damage Management, Internet Center for Human–Wildlife Conflicts3 (2), Fall 2009, pp. 165–166. University of Nebraska, Lincoln (2009)
2. Dolbeer, R.A., Wright, S.E., Weller, J., Bergier, M.J.: Wildlife strikes to civil aircraft in the united states 1990–2008. In: FAA National Wildlife Strike Database, Serial Report Number 15 (2009)
3. Dolbeer, R.A., Anderson, A.L., Weller, J., Bergier, M.J.: Wildlife strikes to civil aircraft in the united states 1990–2015. In: FAA National Wildlife Strike Database, Serial Report Number 22 (2016)
4. European Aviation Safety Agency.: Certification Specifications and Acceptable Means of Compliance for Large Aeroplanes. In: CS-25 BOOK 1, Amendment 18, 22 June 2016 13.
5. European Aviation Safety Agency.: Certification Specifications for Engines CS-E, Amendment 3, 23 December 2010
6. Aktay, L., Johnson, A.F., Kröplin, B.H.: Numerical modelling of honeycomb core crush behavior. Eng. Fract. Mech. 75, 2616–2630 (2008)
7. Ivañez, I., Fernandez-Cañadas, L.M., Sanchez-Saez, S.: Compressive deformation and energy-absorption capability of aluminium honeycomb core. Compos. Struct. 174, 123–133 (2017)