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A numerical model for bird strike on sidewall structure of an aircraft nose

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Abstract In order to examine the potential of using the coupled smooth particles hydrodynamic (SPH) and finite element (FE) method to predict the dynamic responses of aircraft structures in bird strike events, bird-strike tests on the sidewall structure of an aircraft nose are carried out and numerically simulated. The bird is modeled with SPH and described by the Murnaghan equation of state, while the structure is modeled with finite elements. A coupled SPH–FE method is developed to simulate the bird-strike tests and a numerical model is established using a commercial software PAM-CRASH. The bird model shows no signs of instability and correctly modeled the break-up of the bird into particles. Finally the dynamic response such as strains in the skin is simulated and compared with test results, and the simulated deformation and fracture process of the sidewall structure is compared with images recorded by a high speed camera. Good agreement between the simulation results and test data indicates that the coupled SPH–FE method can provide a very powerful tool in predicting the dynamic responses of aircraft structures in events of bird strike.

1. Introduction

Bird strikes are a significant threat to flight safety and have caused a number of accidents with human casualties. According to the web site of the Bird Strike Committee USA,[1] over 250 people have been killed world-wide as a result of bird strikes since 1988 and the damage caused by bird and other wildlife strikes is estimated to cost USA civil aviation alone over $700 million per year. Also from the same web site, about 4800 bird strikes were reported by the US Air Force and about 10900 bird and other wildlife strikes were reported for USA civil aircraft in 2012. Collisions between birds and aircraft during flight can lead to serious damage to the aircraft structure. The point of impact is usually any forward-facing edge of the vehicle such as a wing leading edge, nose cone, jet engine cowling or engine inlet. Therefore, the international certification regulations require all forward facing components to prove a certain level of bird strike resistance before they can be employed in an aircraft.[2–5] Bird-strike tests provide a direct method to examine the bird strike resistance. However, to shorten the design cycle and reduce cost, numerical simulations are often used to examine and assess a structure's response to bird strike.

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There is a long history of research efforts, especially after the finite element (FE) method was adopted as a tool in the late 1970s, to develop numerical methods for bird strike simulation. An extensive list of references on this subject can be found in Refs. 2–7 Hedayati and Ziaei-Rad[8] introduced a bird model with a geometry similar to a real bird and compared their simulation results with experimental data as well as those using traditional bird models. They found that a bird could strike an aircraft component with its head, tail, bottom or wings and any of these orientations might produce a different effect on the response of the component. Four substitute bird models were introduced and the best substitute model was chosen to capture the pressure and force exerted by the real bird when impacting from different orientations. Smojver and Ivancevic[9] performed bird strike damage analysis of real aeronautical structures using ABAQUS/Explicit and the coupled Eulerian Lagrangian (CEL) approach. Goyal et al.[10–12] performed a bird striking on a flat plate based on the Lagrangian, smooth particles hydrodynamic (SPH), and arbitrary Lagrange Eulerian (ALE) approach respectively in LS-DYNA. Classical test data available in the literature and numerical models were used for basis of comparison. It can be concluded that that SPH simulations best represent the fluid-like response during an impact. A continuum damage mechanics approach was employed to simulate failure initiation and damage evolution in unidirectional composite laminates. The CEL formulation enabled the authors to overcome numerical instabilities caused by extreme material deformation. Wang and Yue[13] developed a finite element model of bird strike on a windshield structure including the windshield, framework, arc-frame, gasket and rivets, in which the adaptive contact relationship and boundary conditions were defined. A contact–impact coupling algorithm and the explicit finite element program LS-DYNA were employed to simulate the damage and failure process of the windshield structure at three bird-strike velocities. Meguid et al.[14,15] showed the mechanical property of a bird changed from the low velocity to the high velocity regimes. At low speeds it was neither uniform nor homogeneous but at progressively higher speeds the bird could be considered as a homogeneous jet of fluid impinging on a structure. Guida et al.[16] studied the bird strike against a composite tail leading edge, where the SPH grid free method was used to describe the bird splashing during the strike. However, none of the above numerical simulation approaches has been verified by real bird strike events since there is very little published information about bird strike experiments on aircraft structures.

In this study, experiments of a real bird striking on the side wall of an aircraft nose are conducted at a desired velocity of 150 m/s. The explicit finite element software PAM-CRASH is used to simulate the bird strike experiments. In order to improve the numerical stability and increase the accuracy of the deformation and damage prediction, a coupled SPH–FE method is adopted in which the bird is modeled using the SPH method with the Murnaghan equation of state and the structure is meshed with finite elements. With the use of SPH, numerical difficulties associated with extreme bird mesh distortion are eliminated. The material parameters are identified and the simulation results are compared with experimental data to verify the numerical model.

2. Test

2.1. Test apparatus

The test work described in the present paper was performed at Jiangsu Anchor Co. Ltd. The objective of the test is to obtain the dynamic response of an aircraft nose sidewall structure under bird strike. The test data will be used by the numerical model presented in Section 3.

Fig. 1 illustrates the arrangement of the test equipment. The gas gun system consists of a compressed air gun with a supporting compressor, instrumentation, and control system. The compressor pumps air into the air storage tank. A valve located between the driving air storage tank and the breech of the gun is designed to drive the high pressure air from the air storage tank into the gun. After the desired air pressure is reached in the pressure chamber, the pressure release valve will open and the gas will expand in the barrel to push the projectile forward. The bird includes the projectile and a sabot with a required mass which must be accelerated to a desired velocity. Before impacting on the specimen, the bird launcher

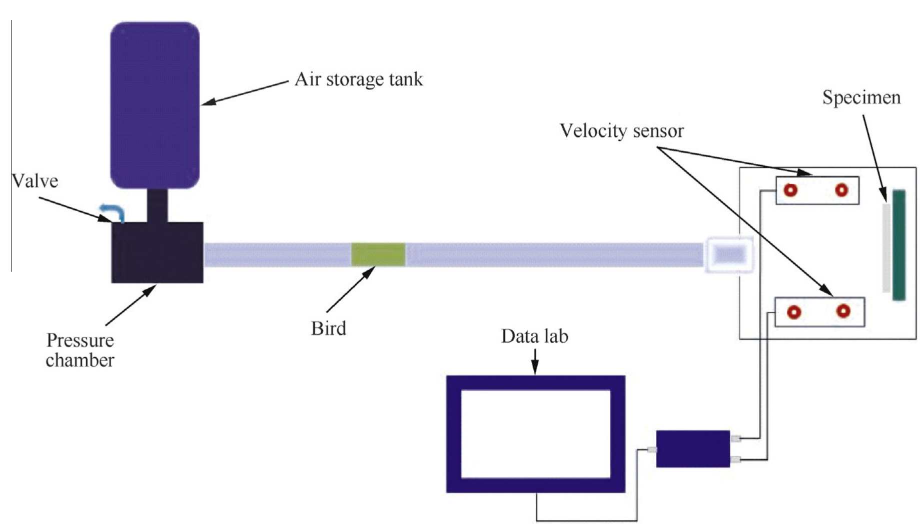

Fig. 1 Arrangement of test equipment.