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BIRD STRIKE SIMULATION BY ADAPTIVE SHELL MATERIAL POINT METHOD

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ABSTRACT

To develop an effective and efficient numerical approach for bird strike simulation, an adaptive shell material point method (ASMPM) is proposed, which takes full advantage of both the finite element method (FEM) and material point method (MPM). The MPM is employed to model the bird and the Belytschko-Lin-Tsay shell element is used to model the aircraft structure. The interaction between the bird and the structure is handled by a particle-to-surface contact algorithm. The distorted or failed shell elements are converted to MPM particles adaptively.

Keywords: bird strike simulation, material point method, shell element.

INTRODUCTION

Bird strike becomes a serious threat to the safety of the aircraft, and takes an important place in the aircraft certification process. Bird strike is a strongly nonlinear process, in which the bird undergoes extreme deformation while the aircraft structures may be destroyed. The Finite Element Method (FEM), Arbitrary Lagrange Eulerian (ALE) and Smooth Particle Hydrodynamics (SPH) methods are three most established numerical approaches to study this problem. However, the FEM encounters fatal problems of mesh distortion and entanglement, while the ALE is rather complex in capturing boundary and convection calculating, and the SPH is somewhat time consuming due to neighbor searching. There is no generally accepted uniform approach to bird strike simulation (Heimbs, 2011). The Material Point Method (MPM) (Sulsky, 1994) avoids the abovementioned shortcomings of both the FEM and ALE methods, and shows advantages of computational efficiency and stability over the SPH method. It has been widely applied to the problems involving extreme material deformation (Lian, 2013). Thus, the MPM is employed to model the bird in this talk.

An aircraft is mainly composed of thin-walled structures, so that the shell finite element is efficient and accurate to model these structures in small deformation. Hence, a shell element is incorporated in our MPM3D code, and coupled with MPM particles based on a particle-to-surface contact algorithm (Chen, 2015). To fully take advantages of both the FEM and MPM, the adaptive finite element material point method (Lian, 2012) is extended to bird strike simulation, in which the distorted and failed shell elements are converted to MPM particles adaptively. The proposed approach is first validated by several numerical tests, and then used to simulate a bird strike on an aircraft wing leading edge structure.

RESULTS AND CONCLUSIONS

The wing leading edge is one of the most likely place to be striked by a bird. As shown in Fig.1, the leading edge structure is composed of four ribs, one skin and one spar, which has a

length of 1200mm, a left height of 280mm and a right height of 240mm. The bird has a diameter of 93mm and a length of 186mm. The whole computational model include the bird and wing are shown in Fig.2. The bird and the wing is discretized by particles and shell elements, respectively.

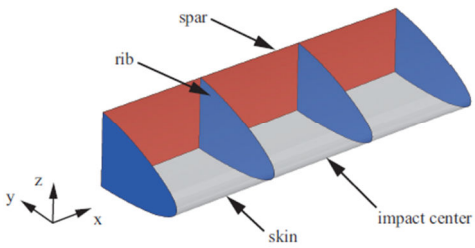

Fig. 1 - The wing leading edge

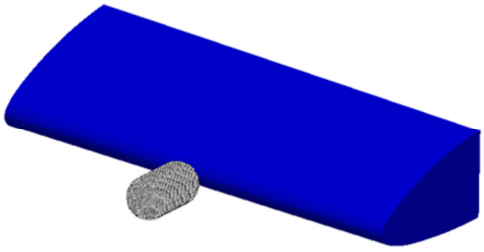

Fig. 2 - The whole computational model

Fig. 3 shows the cut shape of the structure in the end. All the results obtained by MPM3D are in good agreement with those of LS-DYNA, which gives strong evidences to the validation and practicality of our approach. Furthermore, MPM3D results are much more smooth than the DYNA results.

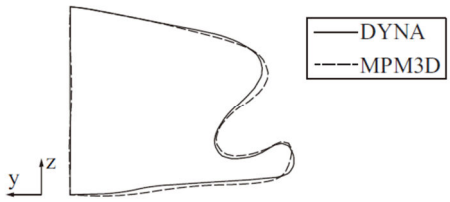

Fig. 3 - Cut shape of the structure at the final moment

This study shows that the adaptive shell material point method (ASMPM) is suitable to model bird strike simulation.

ACKNOWLEDGMENTS

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