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Numerical Simulation of Bird Strike Damage Prediction in Single Piece Windshield

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Abstract :ABAQUS/Explicit are used to do numerical analysis of bird impact damage. Computational method used for the analysis is coupled Eulerian Lagrangian method. The ojectetive of the work present in this paper is to evaluate Coupled Eulerian Lagrangian (CEL) approaches in ABAQUS Explicit suitable approach for bird strike analysis on single piece windshield and also , to analyse response of windshield due to impact 4 lb bird at speed as specified in airworthiness specification which for our case is 1350 km/hr (375 m/sec) .Bird material is used as Equation of states (EOS) and bird geometry used is cylinder with hemispherical end.

Index Terms— Windshield,bird strike,CEL,Abacus,cylinder with hemispherical end bird,EOS,bird impact

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1 INTRODUCTION

Collision between bird and aircraft is usually occurs as both occupy same air space. As per MIL-W-81572 and ASTM F330 The windshield and all supporting structure along with latching mechanism that are positioned ahead and protecting the pilot / crew shall be designed to withstand the impact of four pound bird when the velocity of the aircraft (relative to the bird along flight path) is equal to the maximum operational true airspeed achievable in level flight altitudes upto 5000ft. Structural damage which impairs operation of the aircraft not permissible. In the event of bird impact, design of the windshield system shall not permit more than 50 percent of the aircrew forward visibility to be lost. [1].

This paper deals with the numerical prediction of structural behavior and damage caused by bird strike in a single piece windshield. Use of finite Element Method in bird strike analysis reduce time required for analysis and provide economy also.[2]

At the time of impact bird behaves as a like fluid hence bird should be modeled exactly[2]. For impact analysis Eulerian approach and Lagrangian approach is widely used .In this paper for numerical simulation of bird in an impact event coupled Eulerian Lagrangian method is used.

1.1 Lagrangian method

In Lagrange an formulation ,mesh nodes are attach to the particles of materials. Hence each node represents one particle under examination.

Advantages

1) Easy tracking of time history properties of each particle of material.
2) Simpler imposing boundary condition on the material interface.
3) Low computational cost
4) Simpler modeling and low number of analysis parameter that have to be dealt by user.
5) Low CPU time.

Disadvantages

1) Severe element distortion can increase the number of required time step
2) Element distortion can cause element tangling.
3) Bird material cannot be split in to debris.

1.2 Eulerian Method

In the Eulerian formulation, mesh remains fixed in space and the material under study flows through the mesh

Advantages

No mesh distortion, constant time step
Numerically stable simulations
Complex bird splitting can be simulated
d)Good representation of splashing behaviour

Disadvantages

Model generation and results visualization more complex
No clear outer boundary
Numerical leakage total energy reduces with time
Fine Eulerian mesh necessary in impact zone- expensive
Relatively high computational time.

1.3 COUPLED EULERIAN LAGRANGIAN

In CEL approach the advantages of eulerian and lagrangian approach is combine together to improve accuracy in results.

In the work presented in this paper Lagrangian approach is used for bird modeling. The numerical practice simulating bird strikes has been applied on a model of single piece windshield. In this dimensions of the Eulerian part are 0.750 x 0.750 x 0.400m to ensure that the bird material doesn't protrude outside the Eulerian finite element grid consisting of 225000 elements.

2. NUMERICAL MODELLING OF BIRD

2.1 BIRD GEOMETRY

Bird geometry has been idealized by a cylinder with hemispherical ends and a length to diameter ratio equal to 2, due to the fact that this geometry of bird models showed the best correlation with real birds in experimental tests. As specified in various specifications we require to model 4lb bird[3].

2.2 MATERIAL MODEL FOR THE BIRD EQUATION OF STATE

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Bird material has been replaced by an equal mass of water, and the density has been reduced to 938kg/m3 as to take into account 10% porosity due to trapped air in the lungs and bones of real bird.

To define the EOS material in Abaqus, only four material properties need to be specified – ρ_0, C0, s and Γ0. Based on extensive literature survey EOS properties for the bird has been selected as defined in [2], which are CO = 1480m/s, s = 0 and Γ0 = 0.

Total length of the bird is 228mm with cylindrical length 114mm and spherical radius of 57mm as shown in figure below.

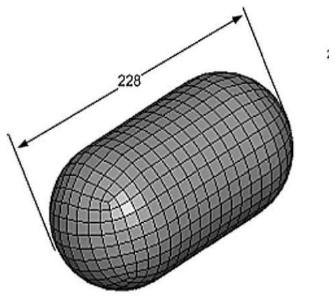
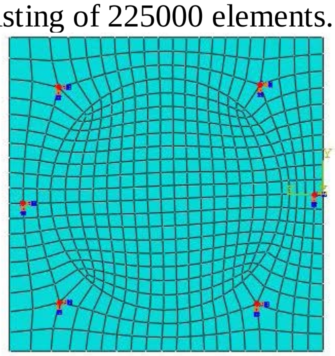


Fig 2.1EOS Bird

2.3VALIDATION OF BIRD MODEL

Welsh experiment has been modelled in abaqus using coupled Eulerian Lagrangian approaches. For this aluminium plate (550 X 550 X 6.35mm) is discretised by 521 and 1510 S4R shell elements, as shown in Figure. The steel support frame has been replaced by boundary conditions as the nodes outside the 0.4064m diameter opening had restrained displacements in the thickness direction. Additionally six nodes had all six degrees of freedom restricted so as to take into account the effect of the bolts. The Bird has been modelled using EOS material. In case coupled Eulerian Lagrangian approach, dimensions of the Eulerian part are 0.750 x 0.750 x 0.400m to ensure that the bird material doesn't protrude outside the Eulerian finite element grid consisting of 225000 elements.



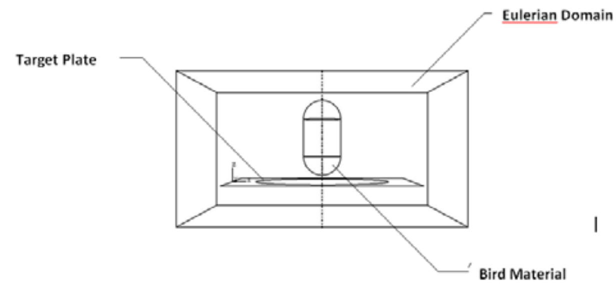


Fig.2.2Numerical model to simulate welsh experiment

3 MODELLING OF WINDSHIELD BIRD STRIKE ANALYSIS -

Our proposed Single Piece Windshield is part of cylinder (of radius 345mm) made from stretched acrylic sheet (12mm thick) in line with other front line aircraft suchas MiG-21 BIS UPG, Su-30 MKI etc. The edges of proposed transparency are attached to the aircraft structure using 6mm diameter steel bolts. The proposed windshield is modeled in abaqus using cylindrical shell of radius 345mm with 1936 S4R shell elements. In order to simulate the bolted joint, portion (highlighted) of the shell is considered fixed. Dimensions of the Eulerian part are 1.1 x 1.1 x 1.0m to ensure that the any material doesn't protrude outside the Eulerian finite element grid, consisting of 357000 elements (ref Fig. 3.1).

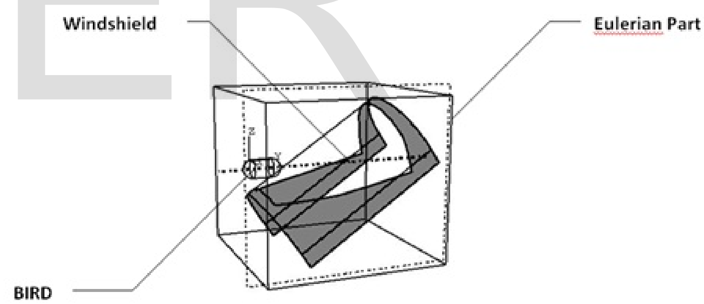


Fig. 3.1Numerical model to simulate bird impact on aircraft windshield

3.1 VALIDATION OF BIRD MODEL
EOS BIRD

i) Validation of the EOS bird material model has been done by comparing Hugoniot and stagnation pressures developed due to impact of bird on a rigid target at the velocity of 116 m/s normal to the plate.

According to [2] the value of Hugoniot pressure at the impact velocity of 116m/s is 93.6MPa. Theoretical values of stagnation pressures are calculated using equation, which is 6.3MPa for impact velocity of 116m/s and duration of impact, is 0.00196sec.

From the graph in [6] the shock pressure developed due to impact of bird on a rigid plate at 116m/sec is

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approx 95MPa.

Graph indicating Hugoniot pressure developed due to impact of numerically modelled EOS bird on a rigid plate at 116m/sec is shown below as Fig 3.1. The Hugoniot pressure and stagnation pressure in numerical model using abaqus is 90MPa and 9MPa respectively. Also, the pressure time history resembles with results published in [2]. This shows that the results obtained due to impact of bird using EOS on a rigid plate showed good agreement with experimental results published in [2]

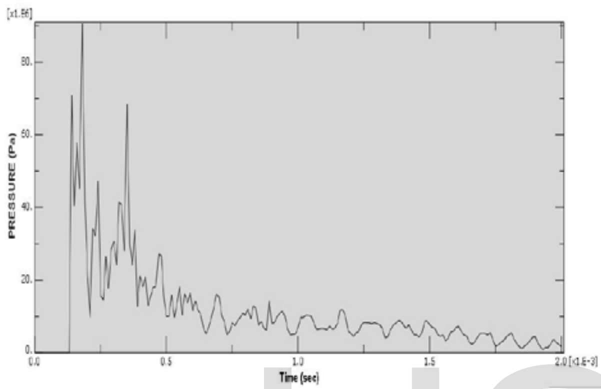


Fig. 3 .2 Graph showing development of Hugoniot pressure due to impact of EOS bird on a rigid plate at 116m/sec

Also, fluid like behaviour of the bird can be simulated. This can be illustrated from the following.

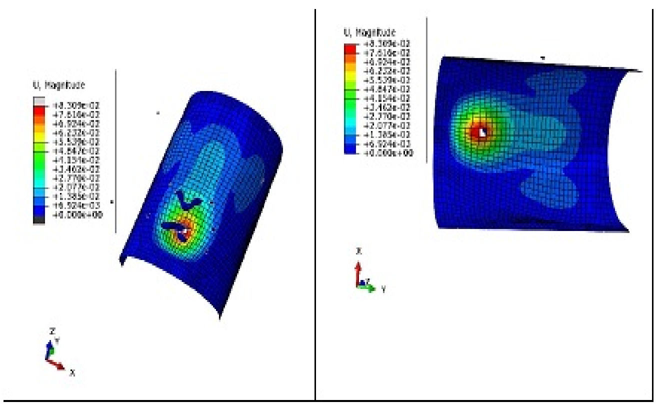


Fig.3.3 Condition of windshield after impact of 1.81 kg bird on 37mm acrylic windshield at 375m/sec (at location 1 with angle 90°)

From the figure it is evident that due to impact of 1.81 kg bird on 37mm thick windshield, elements in the small area were removed indicating complete degradation of load carrying capacity resulting in damaged / broken region. Hence 37mm windshield is not able to sustain impact of 1.81kg bird at 375m/sec.

Windshield thickness has been further increased to 38mm, as 37mm thickness of windshield cannot sustain impact of 1.81kg bird at 375m/sec (ref Fig. 3.3). The deformed shape of windshield due to impact of bird on 38mm thickness at loaction1 with 90°, is shown in figure Fig. 3.4

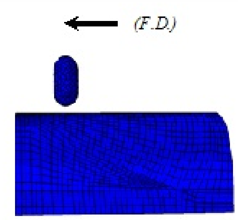
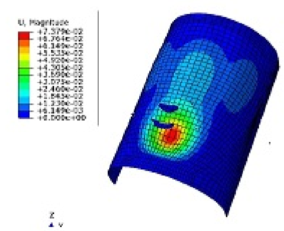
Angle	Bird and windshield (before bird strike)	Deformed windshield (after Bird strike)
90°		

Fig.3.4Bird strike on 38mm acrylic windshield (at location 1with 90°)

.From the Fig. 3.4.1it is evident that due to impact of 1.81kg bird at 375m/sec on windshield. However, absence of broken area / region in the windshield implies equivalent plastic displacement as per damage evolution law has not reached, and elements did not lost their load carrying capacity.

CONCLUSION

From the above, it is evident that to ensure bird impact resistant windshield as per Mil required thickness of windshield should be increased to38 mm then windshield become capable of sustaining the impact of a 4 lb bird at maximum cruise velocity, with no serious penetration. The windshield is able to sustain impact of 1.81kg bird at 375m/sec speed. The maximum deformation produced in thickness direction is 73mm at location with 90Deg (Fig.3.4).

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