Bird Strike Analysis on Single Piece Windshield

Mr.N.P.Dhake[1] Prof. Dr. M. S. Kadam[2]
[1,2]Department of Mechanical Engineering
[1,2]Jawaharlal Nehru Engineering College, Aurangabad, India

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 ap-proach for bird strike analysis on single piece windshield and also, to analyse response of windshield due to impact 1.81kg (4lb) birdat 150m/sec (540km/hr) (as specified in airworthiness standards). Bird material is used as Equation of states (EOS) and bird geometry used is cylinder with hemispherical end.

Key words: Bird strike analysis, windshield, CEL Hydrodyanamic theory

I. INTRODUCTION

Collision between bird and aircraft is usually occur as both occupy same air space Basic of hydrodynamic theory [2] of a soft body impacting a flat target are briefly indicated below -

The impact behaviour consists of four main phases -

a) Initial shock at contact,
b) Impact shock decay,
c) Steady flow and
d) Pressure decay (Fig. 3.1.1)

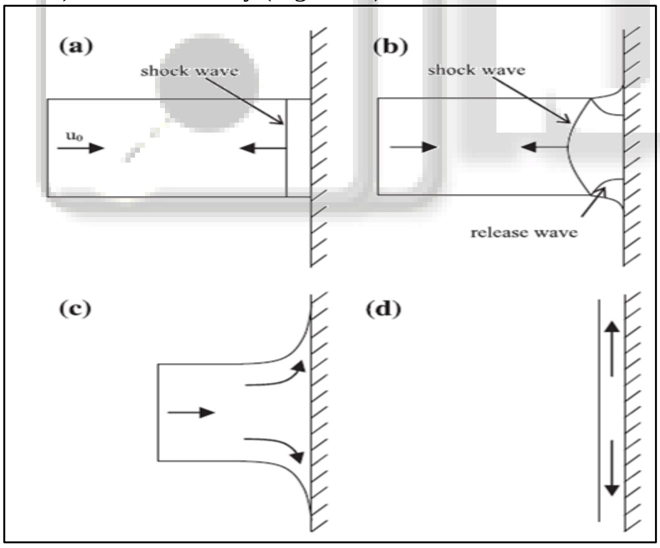


Fig. 1: Illustration of shock and release wave in soft body impactor

Suppose the impactor with an initial velocity U_0 hits a surface, the material at the contact point is instantaneously brought to rest and a shock wave with the velocity U_S is generated. This shock wave is parallel to the impacting surface and it propagates in the normal direction to the impacting surface. This gives rise to a significant pressure gradient at the impactor outer surface because of the shock-load on the one side and the free surface on the other side. This leads to an outward acceleration of the material particles and a release wave is formed, which propagates inwards towards the centre of impact, interacting with the shock wave. It should be noted that the velocities of the shock and release waves are much greater than the initial velocity of the impactor.

This release wave causes a significant decrease in the pressure at the impact point. Therefore, the high initial pressure peak at the centre of impact lasts less than a microsecond. After several reflections of the release waves, the material flows steadily, with a constant pressure and velocity in the impactor. The existence of steady flow depends on the length / diameter ratio of the impactor. During the phase of steady flow, the shock wave trace is constantly weakened by the release waves until the bird and its trace are reduced to zero through the release process. A typical pressure curve for such a soft body impact on a rigid target plate is depicted in Fig. 1.2. The initial pressure peak in the contact point in a perpendicular impact is typically referred to as the Hugoniot pressure PH

$$P_H = \rho_0 \, U_S \, U_0$$

with ρ_0 as the initial density of the impactor.

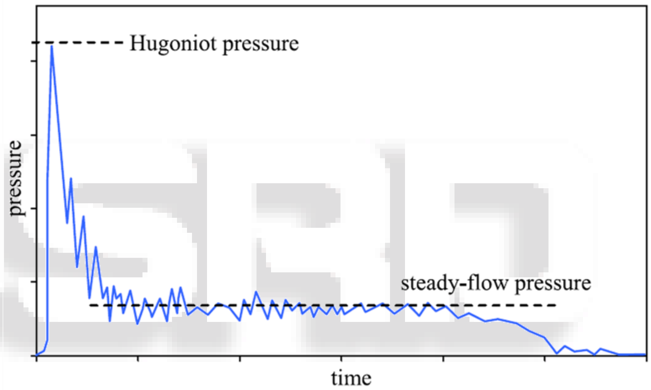


Fig. 2: Typical pressure curve for normal soft body impact on a rigid plate

The steady-flow pressure P_S can be estimated by the Bernoulli relationship

$$P_S = \frac{1}{2} \rho_0 \, U_0^2$$

The total duration t_d of the impact can be approximated by the time needed for the impactor to flow through its own length L

$$t_d = \frac{L}{U_0}$$

Coupled Eulerian Lagrangian method is the grouping of eulerian and lagrangian formulation.In Coupled Eulerian Lagrangian approach advantages of eulerian and lagrangian methods are used .Usually in case of fluid structure problem Lagrangian mesh is used for discretize the structure. Eulerian mesh is used for discretize the Fluid. The interface between fluid and structure can be represented using boundry of lagrangian domain. At same time, Eulerian mesh is used to represent fluid that may experience large deformation. Eulerian mesh has no problem regarding mesh and element distortion.The only drawback of coupled eulerian Lagarngian method is it need long computational time

II. NUMERICAL MODELLING OF BIRD

A. *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.

B. *Material Model for The Bird Equation of State*

Bird material has been replaced by an equal mass of water, and the density has been reduced to 938kg/m^3 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, C_0, s and Γ_0. Based on extensive literature survey EOS properties for the bird has been selected as defined in [8], which are C_O = 1480m/s, s = 0 and Γ_0 = 0.

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

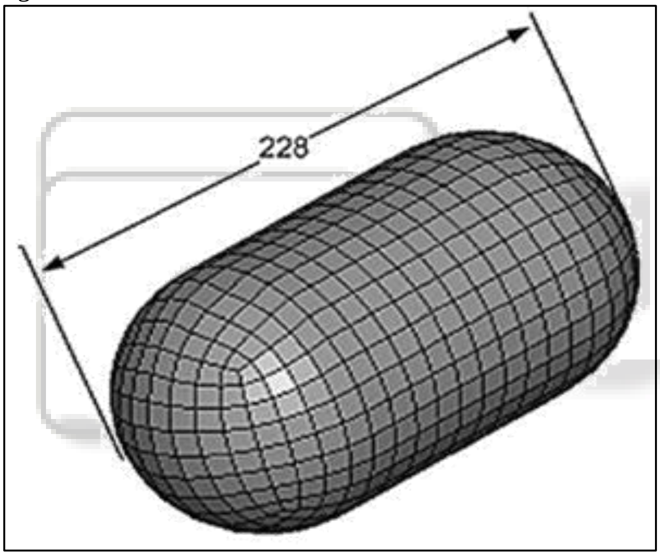


Fig. 3: EOS Bird

III. DAMAGE AND FAILURE

Material failure refers to the complete loss of load-carrying capacity which results from progressive degradation of the material stiffness.

Let us consider the typical response of a material specimen during a simple tensile test. The stress-strain response will show distinct phases as shown in 3.2.

Initially, the material response is linear elastic (a – b), followed by plastic yielding with strain hardening (b – c). Beyond point c there is a marked reduction of load-carrying capacity until rupture (c – d). The deformation during this last phase is localized in a neck region of the specimen. Point c identifies the material state at the onset of damage, which is referred as the damage initiation criterion. Beyond this point, the stress-strain response (c – d) is governed by the evolution of the degradation of the stiffness in the region of strain localization. The curve c - d can be viewed as the degraded response of the curve c – d' that the material would have followed in the absence of damage.

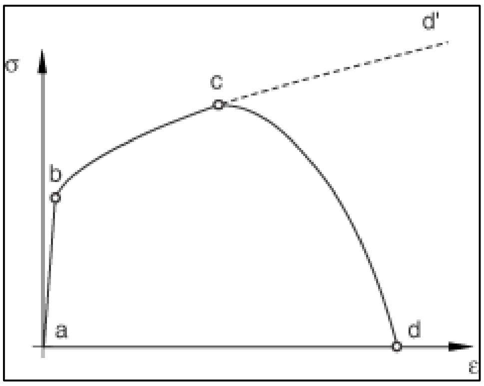


Fig. 4: Typical uniaxial stress-strain response of a metal specimen

Thus, the specification of a failure mechanism consists of four distinct parts:

- the definition of the effective (or undamaged) material response (a - b - c - d'),
- a damage initiation criterion (c),
- a damage evolution law (c - d), and
- a choice of element deletion whereby elements can be removed from the calculations once the material stiffness is fully degraded (d)

IV. EOS BIRD

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 116m/s normal to the plate.

According to [8] the value of Hugoniot pressure at the impact velocity of 116m/s is 93.6 MPa. Theoretical values of stagnation pressures are calculated using equation, which is 6.3MPa for impact velocity of 116 m/s and duration of impact, is 0.00196sec.

From the graph in [4] the shock pressure developed due to impact of bird on a rigid plate at 116m/sec is 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 4.1. 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 [8]. 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 [8].

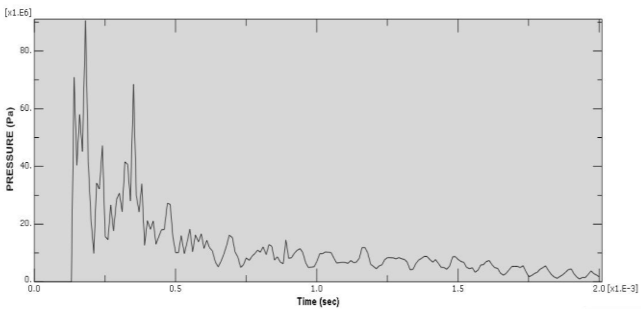


Fig. 5: Graph showing development of Hugoniot pressure due to impact of EOS bird on a rigid plate at 116m/sec

Condition of windshield after impact of 1.81kg (4 lb) bird at 150m/sec (540km/hr) and 155m/sec (558km/hr) on 12 mm thick windshield is shown in figure Fig4.2. From the figure it is clear that due to the impact of bird at 155m/sec element removal was taken place as these elements have reached the damage initiation criteria and completely lost their load carrying capacity as per damage evolution law. However, due to bird strike at 150m/sec windshield is deformed by 73 mm and equivalent plastic strain (PEEQ) was observed below 0.30. All the elements were active (output variable STATUS = 1) and have some load carrying capacity. From this we can say 12mm windshield cannot sustain bird strike at 155m/sec. However windshield is able to sustain bird impact at 150 m/sec.

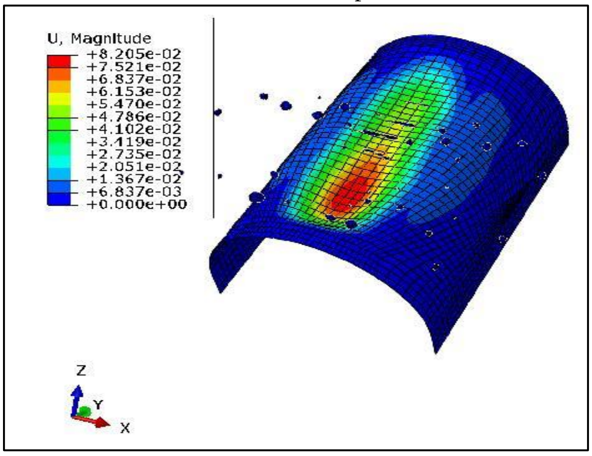
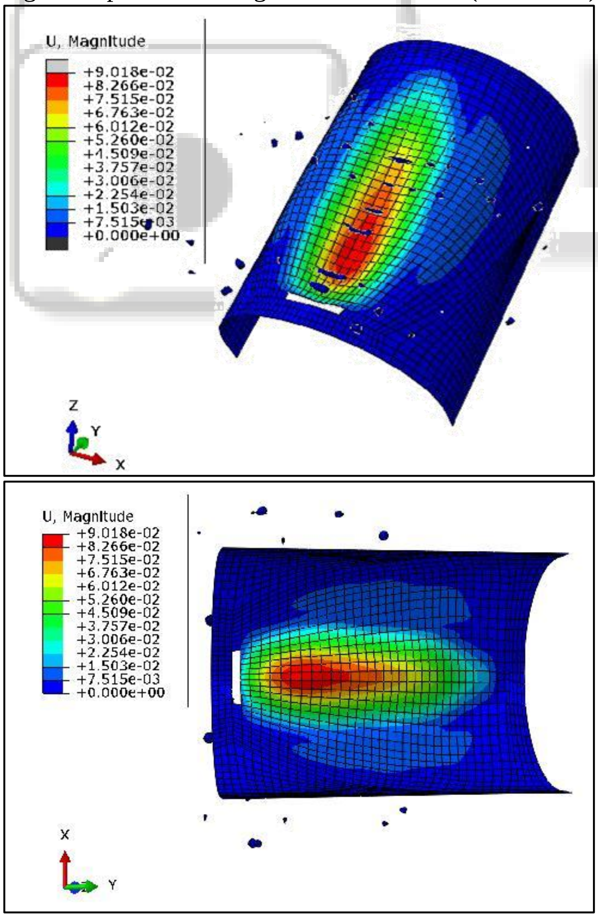


Fig. 6: Impact of 1.81 kg Bird at 150 m/sec (540 km/hr)



Impact of 1.81 kg Bird at 155 m/sec (558 km/hr)

Fig. 7: Condition of 12 mm thick acrylic windshield after bird strike at 150 m/sec and 155 m/sec

V. CONCLUSION

From the above, it is evident that 12mm thick windshield can sustain impact of 1.81kg (4lb) birdat 150m/sec (540km/hr) (as specified in airworthiness standards)

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