

Folding and simulation of airbag deployment

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ABSTRACT

This paper deals with the simulation of airbag deployment in passenger cars during a crash. In an airbag system, the accelerometers trigger the ignition of a gas generator propellant very rapidly which inflates a nylon fabric bag. This bag reduces the deceleration experienced by the passenger in a crash situation. To simulate the performance of the airbag, it is important to obtain a realistic inflating process; therefore folded airbags must be used. The main problem is the transformation of the 3D shape to a 2D configuration, the so-called flattening of the 3D shape. The dynamic behavior of the airbag deployment process is simulated using Control Volume technique. In this work, the flattening of the 3D shape has been made and it is simulated using commercially available packages.

KEY WORDS: deployment, optimized folding, Control Volume.

1. INTRODUCTION

Airbag system consists of crash sensor (accelerometer) which is inbuilt of airbag control module, inflator, nozzle jet and airbag module. Front air bags are designed to deploy in frontal impacts. Before flattening the passenger airbag, the open box example model is created to fold.

Crash Sensor: Crash sensor is a MEMS accelerometer, which is a small integrated circuit chip with integrated micromechanical elements. The microscopic mechanical element moves in response to rapid deceleration, and this motion causes a change in capacitance, which is detected by the electronics on the chip, which then sends a signal to fire the airbag is shown in Fig (1).

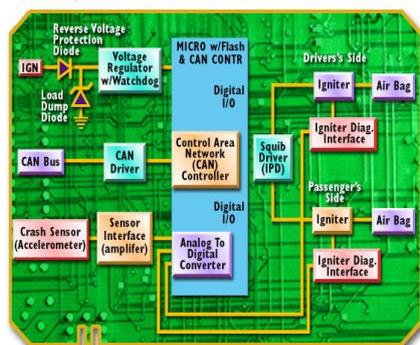


Figure.1. Airbag Control Module

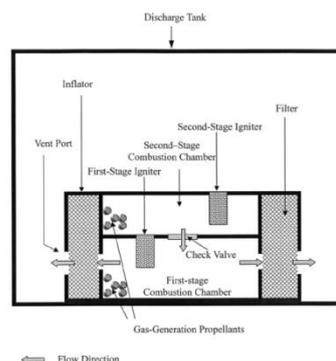


Figure.2. Dual Stage Inflator

Dual Stage Inflator: In principle, the inflator consists of two combustion chambers, each of which can be fired independently. The time between the firing of the two combustion chambers is termed "ignition delay time". (Wu, 2005) Depending on the position and weight of the occupant, the firing sequence and time delay of the two combustion chambers can be controlled. The ignition delay time of the second igniter is adjustable for controlling the gas output from the inflator.

At the beginning, the first stage igniter. After ignition, the high-pressure/high-temperature combustion products of the igniter enter the first-stage combustion chamber and introduce the preheating, ignition, and flame spreading process of the gas-generation propellants in the combustion chamber. The combustion product gases of the gas-generation propellants are mixed with those of the igniter and then filtered and cooled by the filter before entering the discharge tank. The second stage combustion chamber is then ignited with a certain delay time after the firing of the first-stage igniter. After the preheating, ignition, and flame spreading process of the second-stage gas-generation propellant, the combustion product gases enter the first-stage combustion chamber through the check valve and then enter the discharge tank.

Airbag Cover: The complete airbag module includes a folded airbag placed inside a plastic cover. Upon activation, the inflator is triggered to release gas into the bag. When the pressure inside the bag is high enough, the cover breaks open and then the bag unfolds to protect the occupant. A carrier made of ABS or PP is weakened along a predefined opening line by tiny holes (diameter around 0.1mm) generated by laser beam.

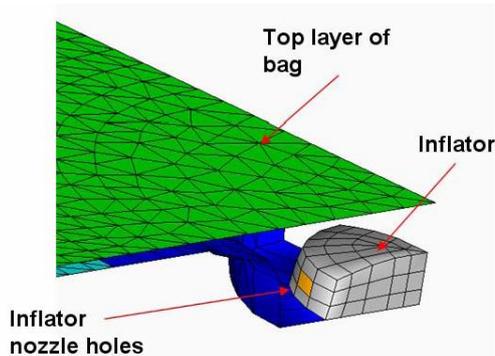


Figure 3. Nozzle with Inflator

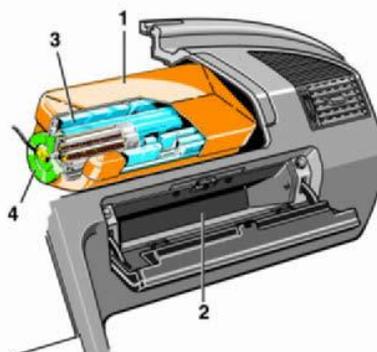


Figure 4. Front Passenger Airbag

Front Passenger Airbag: The front passenger airbag unit (1) is installed either above the glove box (2) or in place of it, depending on the vehicle model series. The air bag (3) has approximately twice the capacity of the driver airbag. It deploys within approximately 30 milliseconds. The effect of the front passenger airbag, its operating times, triggering sequence and inflation and deflation processes are comparable with those of the driver airbag. Depending on the vehicle model, either one-stage or two-stage gas generators (4) are used in the front passenger airbag units. This gas generator contains 200 grams sodium azide. (Mercedes, 2005) Since they are an integral part of the vehicle design, it is not possible to retrofit airbags to a vehicle that does not have them.

Folding Of Passenger Airbag

Steps Involved: 1. Assuming the airbag is ellipsoid.

$$\frac{x^2}{l^2} + \frac{y^2}{b^2} + \frac{z^2}{h^2} = 1$$

The inflated passenger airbag dimensions are taken from The MacNeal-Schwendler Company

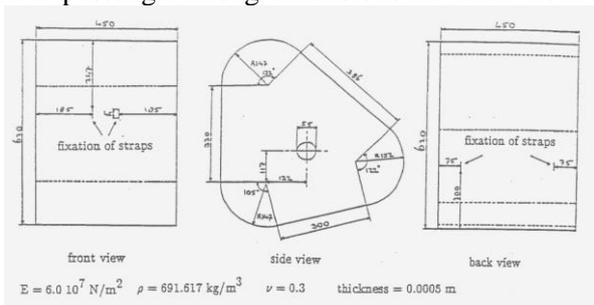


Figure 5. Inflated Airbag Dimensions

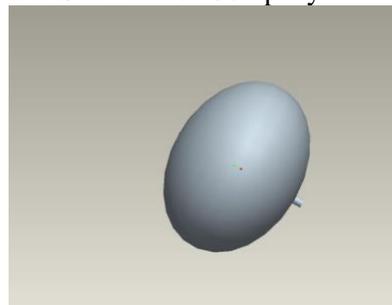


Figure 6. CAD Model

From these dimensions, Approximate CAD model is created from the actual model.

2. Initially two dimensional geometry of airbag is taken. In case of two dimensional folding, only the length (l) and breadth (b) are considered. As the airbag is symmetric about both the axes, only the quarter portion of the airbag is modeled and folded. The inputs for this folding are the length, height (h) and number of folds (n_f). In this, the folding direction (z) is along the height. The folding points (P) are calculated as shown in fig 3.3 in 2-Dimensional elliptical curve.

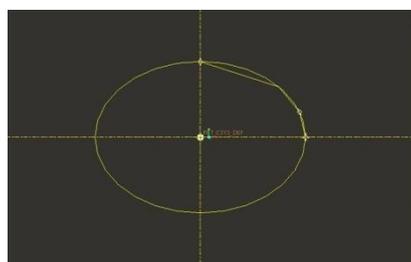


Figure 7. Folding Points Calibration

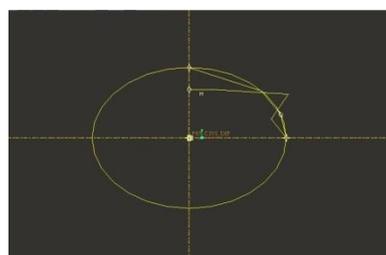


Figure 8. First Fold in 2-D

$$z_i = \frac{h}{n_{f_i}} \quad \text{for } i = 1, 2, \dots, n_f$$

$$x_i = l \sqrt{1 - \left(\frac{z_i}{h}\right)^2}$$

$$p = \left[(0, 0), (l, 0), (x_i, z_i) \right]$$

3. After calculating the folding points, the next step is to find the angle between the vertices.

$$\theta_j = \cos^{-1} \left(\frac{(p_j - p_{j-1}) \cdot (p_j - p_{j+1})}{\|p_j - p_{j-1}\| \|p_j - p_{j+1}\|} \right) \text{ for } j=1, 2, \dots, n_f - 1$$

The transformation angle is calculated from the previous angle θ_j and number of folds.

$$\alpha = \theta_j / k \text{ for } k = n_f, \dots, 2, 1$$

Using this transformation angle, a new set of points is calculated. The rotational transformation about a point is given by

$$\begin{pmatrix} x_j' \\ z_j' \\ 1 \end{pmatrix} = \begin{pmatrix} \cos \alpha & -\sin \alpha & x_{j-1} \cdot (1 - \cos \alpha) + z_{j-1} \cdot \sin \alpha \\ \sin \alpha & \cos \alpha & z_{j-1} \cdot (1 - \cos \alpha) + x_{j-1} \cdot \sin \alpha \\ 0 & 0 & 1 \end{pmatrix} \cdot \begin{pmatrix} x_j \\ z_j \\ 1 \end{pmatrix}$$

where x_j' , z_j' are transformed co-ordinates. These co-ordinates replace the existing corresponding co-ordinates.

$$p(x_j, y_j) = p(x_j', y_j')$$

4. Then the same is extended to 3-Dimensional. The third dimension is the y co-ordinate, which is equal to the x co-ordinate.

$$p_m = \left[\pm x_j \pm x_j \pm z_j \right] \text{ for } m=1, 2, \dots, 8$$

The third and fourth steps are repeated until the last folding is done. During the last folding the transformation angle is set in such a way the total thickness of the airbag is to be maintained according to the number of folds. For the above passenger airbag, $l = 310$ mm, $h = 225$ mm and $n_f = 3$.

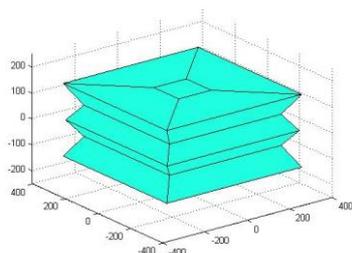


Figure.9. First Fold

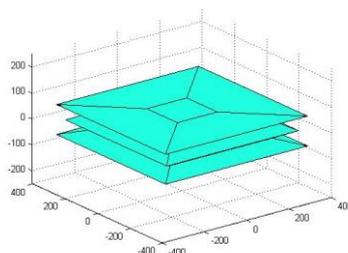


Figure.10. Second Fold

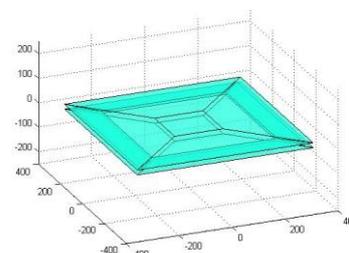


Figure.11. Third Fold

The code is developed to find the folding points in MATLAB.

Finite Element Modeling: The finite element modeling process involved various steps as follows

- Co-ordinate points are obtained from last fold of airbag (Modeling). During modeling, this airbag is fixed with the rigid plate.
- Sharp corners will not be flexible during simulation. To avoid this problem, the corners are triangulated. The entire airbag model should be closed for the control volume simulation technique.
- Where to avoid self penetration within the airbag, the upper part of the airbag (airbag top) and lower part of the airbag (airbag bottom) is meshed with single surface contact. The contact between airbag and plate is node to surface contact. It is indicated by pyramids along the surface of the airbag bottom.

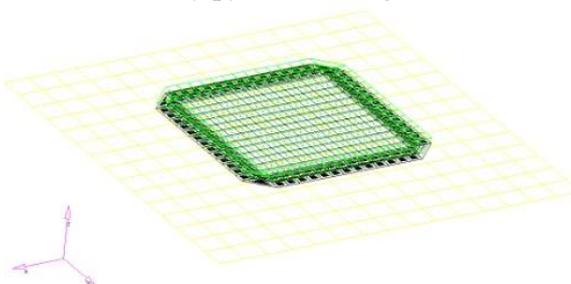


Figure.12. Airbag with Rigid Plate

Results and discussion of numerical simulation: For most in-position situations where the interaction between the airbag and the occupant does not occur until the airbag is fully deployed, the regular Finite Element (FE) airbag model, inflated via a control volume (CV) method, gives satisfactory results.

In these CV FE airbag models, there are two fundamental assumptions: the gas inside the airbag is modeled as an ideal gas and the pressure and temperature are assumed to be uniform everywhere inside the airbag. These assumptions are close to reality only when the airbag is fully deployed (John Vince, 2005).

In any time step the volume of the airbag is being calculated by applying the Gaussian integral theorem. Assuming an ideal gas law and an adiabatic process, pressure can be determined as a function of density ρ as:

$$p = (k - 1)\rho e$$

where k is the isentropic coefficient $k = \frac{c_p}{c_v}$ and e the specific internal energy ($e = \frac{E}{\rho_o}$). For two neighboring states

denoted with subscripts 1 and 2 there is:

$$\frac{e_2}{e_1} = \left(\frac{V_1}{V_2}\right)^{k-1} = \left(\frac{\rho_2}{\rho_1}\right)^{k-1}$$

With this equation from a known volume V_2 at a time step $t = t_2$, the volume at the previous time step V_1 and the appropriate internal energy e_1 the actual internal energy e_2 can be determined. From the internal energy the pressure can be calculated and applied as pressure load normal to the entire internal airbag fabric. The inflating gas is given

by a time dependent mass flux $\dot{E} = c_p \dot{m}_{tot}$.

The performance of the airbag at different time intervals

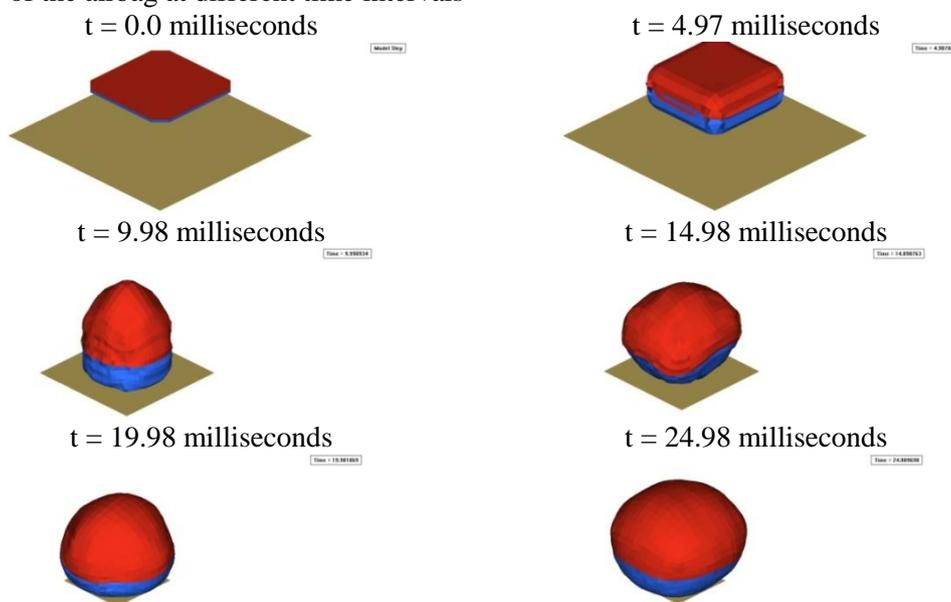


Figure.13. Passenger Airbag Kinematics

2. CONCLUSION

An effort is taken to simulate the passenger air bag with the optimized folding method. To simulate this phenomenon with the folding as it is an algorithm is developed. The folding points are calculated using the transformation matrices in MATLAB. Suitable boundary conditions are applied to the meshed model in HyperMesh. The dynamic behavior of the airbag deployment process is simulated using Control Volume technique in LS-DYNA. As a result it is found that the passenger airbag inflates within 25 milliseconds.

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