Paper Number

Modeling of folding of passenger side airbag mesh

Anoop Chawla, Prashant V. Bhosale and Sudipto Mukherjee
Department of Mechanical Engineering, IIT Delhi, New Delhi (India)

ABSTRACT

Airbag as a safety device fitted in automobiles is fast gaining public acceptance. Improvements in design of automobile components, often achieved by computer modeling and simulations, are becoming standards for automobile testing and design. Due to airbags acceptability for four wheeled vehicles, the concept of airbag in motorcycles is now being tested by many [references]. Currently passenger side airbags, which have a larger volume than the driver side airbag, are considered for airbags to be mounted on motorcycles. Modeling of folding of passenger side airbag is a complex and time consuming process. In this work the modeling of folding of passenger side airbag of 160 liter is considered. This airbag mesh is to be used for exploratory simulations of crashes of an Indian motorcycle mounted with an airbag. Commercial software tools used for modeling of airbag folds do not give a realistic inflation process due to large distortion of airbag mesh elements. In this work we use simulations for getting the mesh of a folded passenger side airbag. Unreformed mesh containing six layers of cloth is first generated in Finite Element software IDEAS^{TM}. This mesh is then exported to PAMCRASH^{TM}. The fold sequence is then modeled using simulations so as to duplicate the manual folding process. Folds are thus generated in the airbag mesh using simulations in PAMCRASH^{TM}. For each simulation of folding, the mesh is held between rigid planes and these planes are given velocities corresponding to the folding process. This method of fold simulation is time consuming. But it gives folded airbag mesh of complex shapes. Inflation process of folded airbag mesh is in better agreement with unfolded airbag mesh inflation process.

INTRODUCTION

Motorcycle riders come under the category of vulnerable road users. Deaths of motorcycle riders in road crashes were 23% in Delhi, India [23% of what?]. Death proportion of motorcycle rider in the road crash was the second largest after 43% pedestrian deaths in Delhi, India [1].

A typical scenario of a motorcycle crash is a frontal impact of a motorcycle with an opposing vehicle where the rider hits the opposing vehicle and falls on the road resulting in severe injuries to the upper parts of the body. Airbags in the motorcycle are now being considered so as to absorb the kinetic energy of the rider, thereby reducing the likelihood of severe injuries for the motor cycle riders. The energy of the motorcycle rider is absorbed by the cushioning effect provided by the airbag, and by the deflation of the inflated airbag, which occurs due to the holes provided in the airbag fabric. In the case of the motor cycle airbag, the position of the rider varies much more than in the case of four wheeled vehicles where the occupants are confined with seat belts. The rider position also varies with the style of the motor cycle and the rider. This causes the rider to be often out-of-position i.e. he comes in the trajectory zone of the inflating airbag. This is a dangerous situation as the airbag inflates within 40 ms and the speed of the airbag material coming out of the airbag module is around 200 mph (321 km/hr). Keeping all these issues in mind, the feasibility of airbags in motorcycles is under study. There are many variables for this research. Some of the variables are size of the rider, motorcycle size, posture of the rider, triggering reliability, location, size and shape of the airbag, environmental conditions etc [2].

Improvements in design of automobile components are often achieved by computer modeling and simulations. ISO 13232 is a standard for testing the effectiveness of motorcycle mounted safety devices. To study feasibility and benefits of the safety device installed in the motorcycle requires 200 computer simulations according to ISO13232. These simulations are for different configurations of the motorcycle and the opposing vehicle with and without safety device installed in the motorcycle. Results are then compared for injuries occurring to rider with and without the safety device installed in the motorcycle. This comparison of results reveals whether the proposed device is beneficial or harmful for rider [3]. For motorcycle mounted airbag, inflation process can induce injuries to the rider because the rider can often be in an out-of-position posture. For this type of situation folding of airbag is important to assess the interaction between the rider and the inflating airbag. Thus in the simulation of motorcycle crash it is important to model folded airbag in a realistic way.

Computer modeling of airbag folding is a time consuming and a tedious job. Currently passenger side airbags (which have a larger volume compared to the driver side airbag) are considered for studying airbags on motorcycles. There are four types of methods for modeling of folding. 1. Mesh 2D surfaces and fold the mesh, 2. Mesh 3D surfaces, flatten and then fold, 3. Flattening and meshing, 4. Simulate flatten and folding.

In the first method 2D surface is meshed with definite folding lines. This 2D surface is then folded by geometric transformations about the folding lines. With this method all types of folds are done like thin (sharp) fold, thick (smooth) fold, roll fold, tuck fold and double tuck fold. During the process small changes in element length take place due to the geometric transformations. In the second method, the 3D mesh is flattened to a minimum thickness of airbag fabric by appropriate scaling and the nodes at the edges are moved outwards to avoid large distortions in elements. Then the folding is done about the folding lines using geometric transformation as in the first method. In this case, the flat surface is obtained from 3D surface of airbag after simplification which leads to an incorrect volume, surface area and shape in simulation.

In the third method, the 3D shape of the inflated airbag is divided into a set of 2D surfaces. This division of surfaces is made according to the folding sequence / pattern. Folded surfaces are made by some simplifications in the geometry. Mesh is then generated on the flattened surfaces. In this case the shape of the inflated airbag with folded surfaces differs from real inflated airbag shape. This difference is minimized by scaling the mesh (THIS IS NOT CLEAR). In the fourth method folding of airbag mesh is done by simulations. The flat airbag surface is first meshed. This mesh is then sandwiched between appropriate rigid planes and the folding process is then simulated by giving appropriate initial velocities to the rigid planes. Though the method is time consuming it gives a realistic mesh of the folded airbag and helps model the inflation process of the airbag in a realistic way. We have followed this method of simulation for modeling the folded passenger side airbag mesh [4].

Chawla et al [5] describe another algorithm for folding airbag mesh. This algorithm handles only roll type of folds. In it, geometric transformations according to the fold parameters are first applied to the 3D mesh of the fabric, Elements on the folding line are split and the coordinates of the nodes are optimized so as to minimize the loss in area of the fabric. Since this algorithm currently handles only roll folds, it is not possible to use it for meshing the passenger side airbag

Airbag mesh folding tool used in PAMCRASH™ [6] also gives problems while folding the passenger side airbag mesh as it gives many penetrations and element distortion are high. It is very difficult rather impossible to model folding on 3D passenger side airbag mesh having complex folding sequences as in real life using PAMCRASH™ and other similar commercial tools for folding the airbag mesh.

METHODOLOGY

Realistic behavior of folded airbag mesh is achieved by series of simulations. We have used the rigid planes for folding the airbag mesh. The sequence of folding duplicated like the manual folding of the airbag. Instead of hands we have used rigid planes for modeling of folding on passenger side airbag mesh.

MESH GENERATION

Airbag mesh is generated in IDEAS™ Finite Element Software. Airbag mesh consists of six layers. Top cover for these layers is having two elements in width wise direction. There are 4495 elements and 4543 nodes in the airbag mesh. Quadrilateral and triangular elements are used for airbag mesh. In front view 'V' shape is seen for the airbag mesh. Distance between farthest layers is 17mm. Maximum distance at width side is 900mm and height of the airbag is 500 mm.

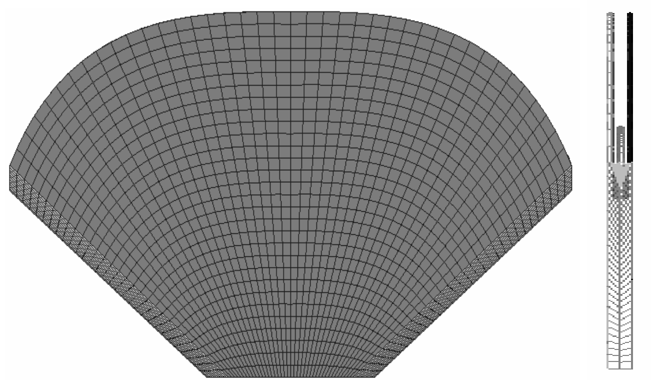


Figure.1 Front View and Right Hand Side view of initial airbag mesh in IDEAS™.

SIMULATIONS STRATEGY

The airbag mesh is exported to PAMCRASH™ software. All the simulations of the folding airbag mesh are done in this software. Each animated simulation results are seen by opening *.DSY file in PAMVIEW™. The appropriate state of *.DSY file is opened in GENERIS™. This file is exported as Mesh file and saved as *.unv. This *.unv file is again opened in GENERIS™. In GENERIS™ appropriate definitions for airbag and rigid planes are given. The initial and boundary conditions are defined. This file of GENERIS™ with all definitions is saved as *.pc and supplied to solver as input file. This sequence of simulations is repeated for each fold. Randomly in between the fold simulations inflation simulations are run to check the mesh behavior during inflation process of airbag.

PARAMETERS TAKEN FOR SIMULATIONS

MATERIAL PROPERTIES OF AIRBAG FABRIC - Typical material properties for airbag fabrics are taken as given below. These properties are used to simulate inflation process of airbag.

Density of fabric = 1024 Kg/m^3

Young's modulus = 1e8 N/m^2

Shear modulus = 5e6N/m^2

Thickness of one fabric layer = 0.26mm

The material of airbag fabric is made soft for simulations of folding. Following properties of the airbag fabrics are considered for simulations of folding and other properties are kept as above.

Density of fabric = 746 Kg/m^3

Young's modulus = 1e6 N/mm^2

Shear modulus = 5e5 N/mm^2

CONTACT DEFINITION - Contact type 37 of PAMCRASH™ is used for defining the contact between different layers of airbag mesh and self contact for layers. This contact type is called enhanced self contact specially designed to handle airbag mesh contact problems. This contact type is for surface to surface contact. Airbag mesh is taken as surface. For all simulations self contact thickness of airbag mesh is kept at 0.2 mm.

Contact type 34 of PAMCRASH™ is used for defining contact between airbag mesh and rigid planes. This contact type is between node and surface. Airbag mesh is treated as nodes and rigid planes are taken as surface. The contact thickness for airbag mesh and rigid planes is kept 0.5 mm.

ANNEALING – Appropriate state of *.DSY file for previous simulation of fold is selected. This file is opened in GENERIS™ and exported as mesh file *.unv. This *.unv file is again opened in GENERIS™ and saved as *.pc file by giving certain definitions. In this *.pc file planes are defined as fixed rigid body and airbag mesh is allowed to move inside the fixed planes. Thus during the simulation contact forces between the airbag mesh gets reduced as it relaxes inside the rigid planes. This simulation is called as annealing as it resemble real annealing process in metallurgy. This simulation of annealing is carried out after each simulation of folding for reducing contact forces between airbag materials.

BOUNDARY CONDITION – Bottom most nodes of airbag mesh are fixed in X,Y and Z direction but rotation about these axes is allowed. By doing this the airbag mesh does not gets pulled out while folding of other portion of airbag mesh. For all simulation this boundary condition is defined except the simulation of moving bottom nodes apart.

SIMULATIONS FOR FOLDING OF PASSENGER SIDE AIRBAG MESH

FLATTENING – Airbag mesh is flatten by keeping the airbag mesh in between rigid plane and the rigid planes are given certain velocity towards each other in the direction of airbag thickness. The thickness of the squeezed airbag is between 4 to 5 mm.

FIRST FOLD – Squeezed airbag mesh is kept in between right and left hand side planes from both sides of airbag mesh. The middle portion of the airbag mesh is kept between the fixed rigid planes. Right and Left hand side planes are given rotational velocity about Y-direction of the airbag mesh. Final state of the simulation gives Right hand side airbag mesh at back side of the middle portion of airbag mesh and left hand side airbag mesh at front side of the middle portion of the airbag mesh along with rigid planes. Final state is shown in the following figure.

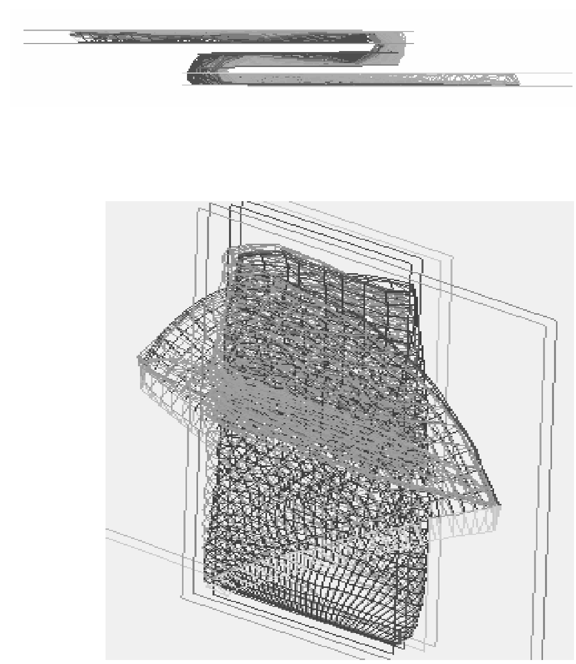


Figure.2 Top view and isometric view for first fold

SECOND FOLD – Some portion of folded airbag mesh goes beyond the middle portion of airbag mesh. To make it in the line of the middle portion of the airbag mesh second fold is given. Side portion of the airbag mesh which is not in the line of the middle portion of airbag mesh is kept in between rigid planes and the rigid planes are given rotational velocity about global Y-direction. Final state of the simulation is shown in below figure.

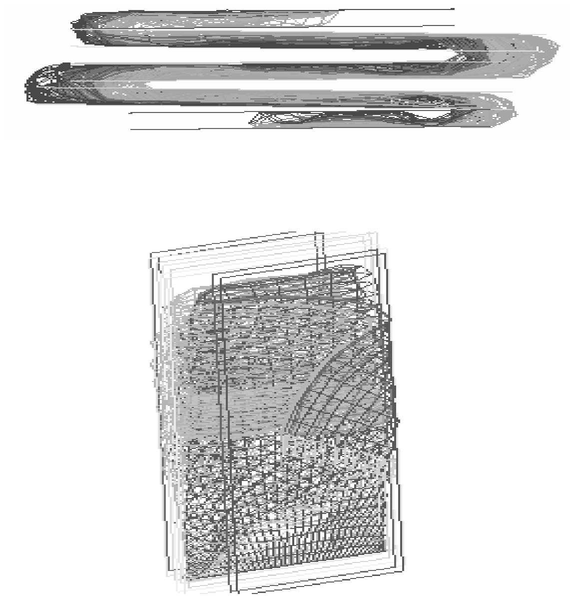


Figure. 3. Top and Isometric view of second fold

SECOND FLATTENING – Four layers of airbag mesh are squeezed by rigid planes. The rigid planes are defined like closed box and the airbag mesh is kept in between the box. Four planes are given velocity towards each other so that it gets pressed by all planes.

FOLDING FROM TOP SIDE OF AIRBAG MESH – Small top portion of airbag mesh is defined as a rigid body and the rotational velocity is given to it about top corner node of rigid planes defined below the top portion. The rigid bottom planes are kept so that the squeezed airbag mesh should not expand due to contact forces between different layers of airbag mesh.

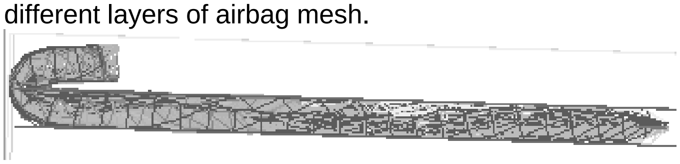


Figure. 4 Side view of airbag mesh showing folded top portion of airbag mesh.

SECOND FOLD OF TOP PORTION – The first top folded portion of airbag mesh is defined as rigid body and the rotational velocity is given to this rigid body about the top corner node of bottom plane which enclose the rest of the portion of the airbag mesh from front side.

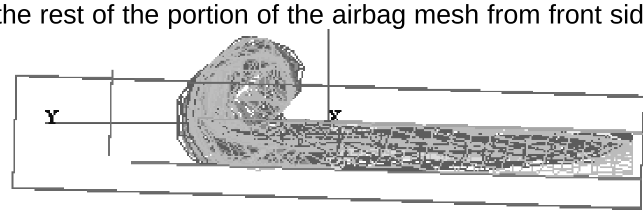


Figure. 5 Side view of airbag mesh showing second fold of top portion of airbag mesh.

FLATTENING OF FOLDED TOP PORTION – Top portion of airbag mesh is squeezed by defining box of rigid planes and giving certain velocity towards each other. Box of rigid bottom planes is fixed so that airbag mesh does not expand beyond the box of rigid planes.

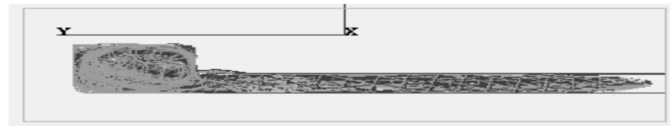


Figure. 6 Side view of squeezed top portion of airbag mesh.

THIRD AND FOURTH FOLD OF TOP PORTION OF AIRBAG MESH – Squeezed top portion of airbag mesh is defined as rigid body and this rigid body is rotated about global X-axis. The point of rotation is kept away from box of bottom planes. By doing this, penetration near the region of point of rotation is avoided. For the fourth fold above mentioned procedure is repeated. In this top rigid body portion includes third fold. This rigid body portion is rotated. For fourth fold point of rotation is kept away from the bottom fixed rigid planes. By doing this we could get sufficient distance between rotated portion of the airbag mesh and stationary box of rigid planes. Following figure shows fourth fold.

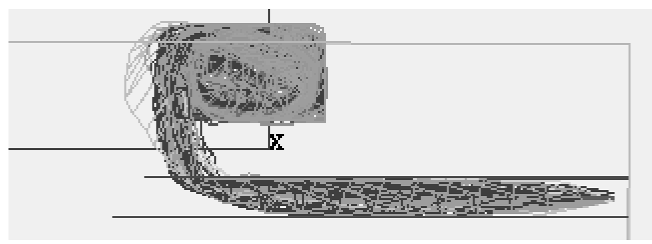


Figure. 7 Side of airbag mesh showing fourth fold at top portion.

FLATTENING OF FOLDED TOP PORTION – Box of rigid planes is defined enclosing the airbag mesh at the top. Rigid planes are given certain velocity such that folded portion of the airbag mesh gets squeezed.

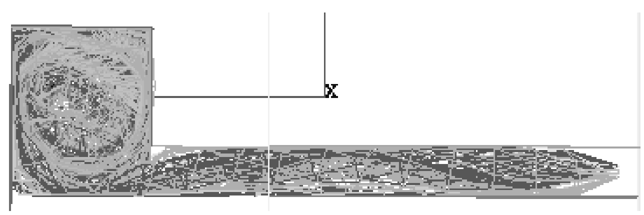


Figure. 8 Side view of airbag mesh showing squeezed top folded portion.

ROTATION OF TOP PORTION – Top folded portion of airbag mesh is defined as rigid body. The box of rigid planes used for squeezing is included in rigid body definition along with folded top portion of the airbag mesh. Rest of the portion of airbag mesh was kept inside fixed box of rigid planes insuring movement of rest of the portion of airbag mesh inside this box. Top corner of fixed bottom plane at front side is taken as a point of rotation for airbag mesh. Simulation is stopped when the rotated portion of airbag mesh touches stationary bottom portion of the airbag mesh at front side.

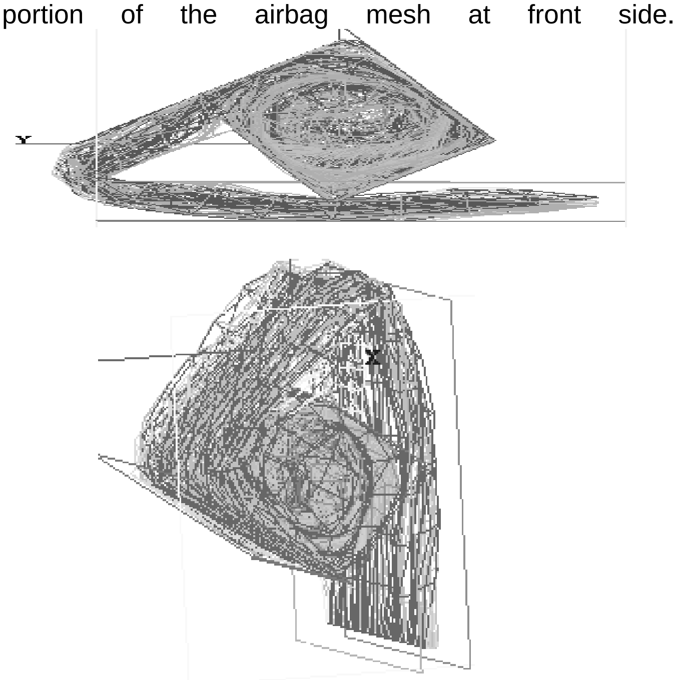


Figure. 8 Top and Isometric views of rotated top portion of airbag mesh.

<u>FLATTENING OF INCLINED PORTION –</u> Rotated inclined portion of airbag mesh is squeezed by two vertical rigid planes. Upper vertical plane at front side is used to flatten the inclined portion of airbag mesh. Flattening of this inclined portion is achieved by pressing it against the vertically straight portion of airbag mesh supported by fixed vertical plane at the back side of it. Lower vertical plane at front side is used to press the rolled folded portion of airbag mesh. For both vertical planes velocity in negative Z- direction is given. Upper vertical plane flattened inclined portion of the airbag mesh whereas the lower vertical plane squeezed folded portion of the airbag mesh. Side rigid planes are fixed insuring no movement of airbag mesh in sideward direction. Folded portion of airbag mesh is prevented from unfolding by the box of rigid planes which was defined as a rigid body along with top portion of airbag mesh in previous simulation. In this box of rigid planes one inclined plane is made horizontal plane. This arrangement of rigid planes provides the path for folded airbag mesh for getting pressed against the vertical portion of airbag mesh. One plane is kept purposefully to penetrate airbag mesh. This plane is part of the box of rigid plane which is used for preventing unfolding of folded portion of airbag mesh. Inclined portion of airbag mesh passes through this plane.

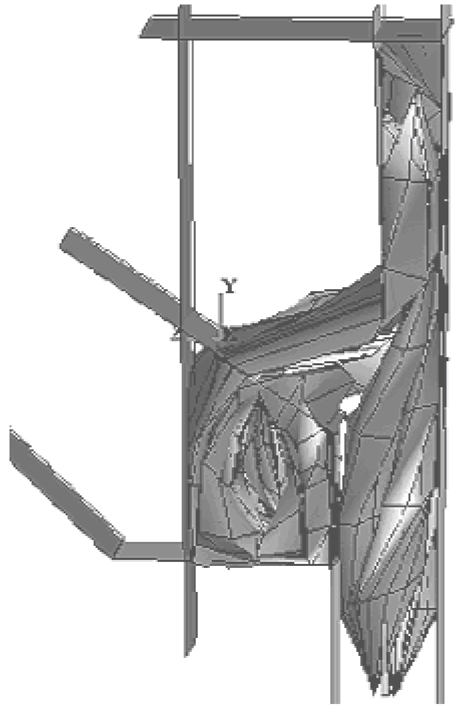
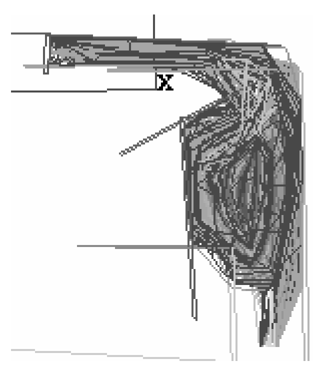


Figure. 10. Shows arrangement of planes guiding the airbag mesh to get pressed against the rest of the portion of airbag mesh supported by fixed rigid vertical plane kept on the other side of airbag mesh.

<u>FOLDING OF UPPER VERTICAL PORTION</u> - Upper vertical fatten airbag mesh is kept inside the box of rigid planes. This box is defined as a rigid body. For this rigid box rotation is given about X-direction. Point of rotation for this rigid body is taken just above the rolled portion of airbag mesh at front side. Fixed side planes insure no movement of airbag mesh in sideward direction. Rest of the airbag mesh is kept inside the fixed rigid planes allowing the airbag mesh for movement inside the fixed planes.



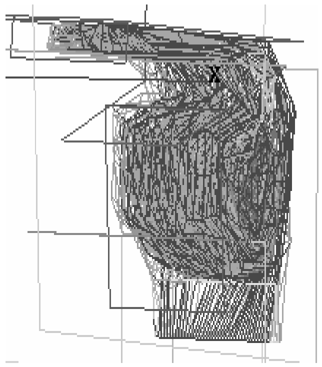


Figure. 11. Side and Isometric view of airbag mesh showing rotated portion of flatten upper part of airbag mesh.

MOVING OF BOTTOM NODES – Bottom nodes of front layer of airbag mesh are given velocity in Z-direction. Bottom nodes of backside layer of airbag mesh are fixed in X,Y,Z direction but rotation about these axes is allowed. Rigid planes defined in previous simulation are fixed insuring movement of airbag mesh inside these planes only. Vertical rigid plane which is used in previous simulation for pressing the folded portion of the airbag mesh is removed in this simulation. Due to this change folded portion of airbag mesh starts unfolding while bottom nodes move. Unfolding of the folded airbag mesh up to certain limit is allowed resembling realistic folded airbag mesh. Bottom nodes of front layer of airbag mesh are moved apart from bottom nodes of backside layers with distance of 114 mm. In real situation airbag is attached with airbag module having certain distance between its two layers. This movement of bottom nodes insures the clamping of airbag at bottom side to airbag module giving space for accommodating inflator to inflate the airbag.

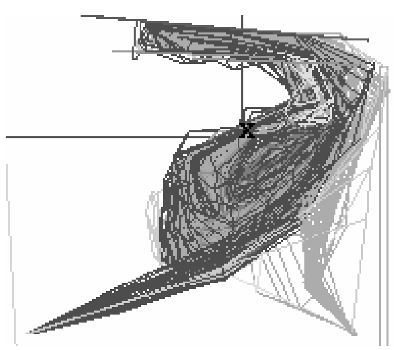


Figure. 14. Side view of airbag mesh showing bottom nodes moved apart.

PRESSING OF TOP PORTION – Top portion of the airbag mesh is pressed by inclined rigid plane keeping airbag mesh inside the boxes of rigid planes. Also backside vertical rigid plane is given certain velocity in Z-direction so that the back side portion of the airbag mesh gets pressed. Movement of bottom nodes of airbag mesh is fixed in X,Y and Z direction but rotation about these axes is allowed. This is the last simulation of the folding of airbag mesh.

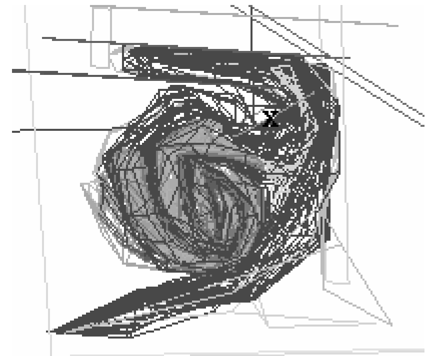


Figure. 13. Side view of final state of folded airbag mesh.

INFLATION OF FINAL STATE OF FOLDED AIRBAG MESH – In the definition card of Advanced Airbag Module of PAM-SAFE™ final state of the folded airbag mesh is considered as airbag surface. Initial bag conditions are taken as follows:

Pressure: 100000 Pa

Temperature: 300 K

Universal gas constant: 8.314 Kg/kmol K

Initial pressure: 101000 Pa

Initial Temperature: 300 K

Added initial volume: 3.33e-04 m^3

Single gas:

Molecular weight: 0.029

First Heat Capacity: 29

The mass flow rate is given as curve of mass flow per sec having maximum value of 5 kg/s. The Nitrogen gas is taken for inflating the airbag. Properties of nitrogen gas are taken as follows:

Molecular weight: 0.02802 kg/mol

First Heat Capacity: 28.9

Second Heat Capacity: -0.00157

Error of “Negative volume” is removed by adding initial volume of 3.33e-04 m^3. Boundary condition for bottom nodes is defined as no displacement in X, Y and Z direction but the rotation about these axes is allowed. Simulation of inflation of airbag mesh is run for time of 50 msec. Following are the inflated pictures of folded airbag mesh.

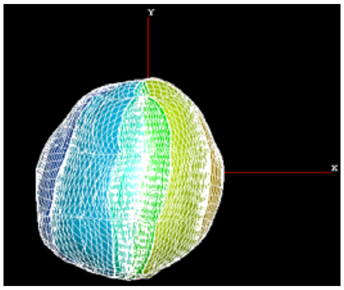


Figure. 14 Top view of inflated folded airbag mesh

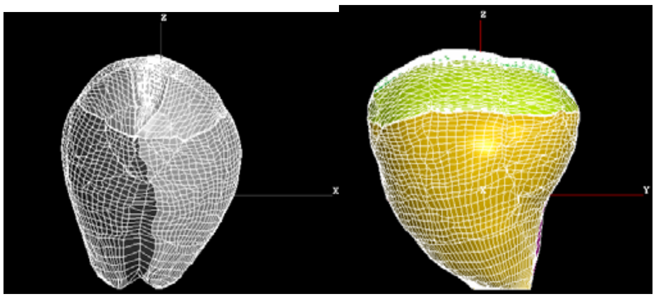


Figure. 14. Front and side view of inflated folded airbag mesh.

Folding lines are observed on the airbag mesh due to folding of the airbag mesh.

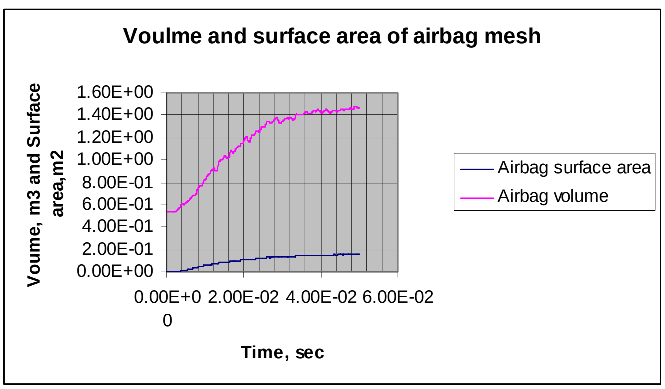


Figure. 15. Airbag volume for folded airbag mesh.

Maximum volume of airbag mesh during the inflation is observed at 160 L and the surface area of airbag mesh is observed 0.156 m^2. Peak value of airbag pressure is 270 KPa.

is duplicatesd

Method of simulation for modeling folded airbag mesh is discussed for modeling passenger side airbag folding. Though the method of simulation is time consuming but there is no better method to model complex folding as discussed in this paper. It is impossible to model complex folding discussed in this paper using the tools provided by commercial software. There are limitations for other methods of modeling folding of passenger side airbag. It is very important to model proper folding for airbag mesh for studying contact interaction of out-of-position rider/occupant with an inflating airbag. The posture of motorcycle rider is not fixed so many times it is coming inside the region of inflating airbag. To study response of rider of motorcycle with inflated airbag in realistic way it is important to model folded airbag mesh in realistic way. Passenger side airbags are considered for airbag research for motorcycle. For getting realistic modeling of folding of passenger side airbag mesh simulation method is most appropriate.

ACKNOWLEDGMENTS

Here is the Acknowledgment section. This is an optional section.

REFERENCES

1. World Report on Traffic Injury Prevention Summary, World Health Organization , Geneva, 2004.
2. Iijima, S, Hosono, S, Ota, A, Yamamoto, T, “Exploratory study of an airbag concept for large touring motorcycle”, The 17th International Technical Conference on the Enhanced Safety of Vehicles (ESV) - Amsterdam, The Netherlands, June 4 - 7, 2001.
3. Anon, Motorcycles – Test and Analysis procedures for research evaluation of rider crash protective devices fitted to motorcycles, ISO 13232:2002, International Organization of Standardization, Geneva, 2002.
4. Gartner, T, Ericsson, M, Faltstorm, J,” Advanced Technology for the Simulations of Folded Airbags”, 2nd European LS-DYNA Conference, Gothenburg, Sweden, June 1999.
5. Chawla, A, Mukherjee, S, Sharma, A, “Mesh Generation for Folded Airbags “, CAD Conference, Thailand, 2004.
6. PAMCRASH^{TM} Manuals, 2000.

CONTACT

A Chawla
Associate Professor
Department of Mechanical Engineering
Indian Institute of Technology,
New Delhi 110 016(India)
Email: achawla@mech.iitd.ernet.in