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Modeling and Numerical Investigation on Frontal Airbag by Ls-Dyna : For Identify the Head Injury

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Abstract:- From the past few years there are many accidents happening passengers are getting injured even after the deployment of the airbag. This is mainly due to the out of position of passenger and not wearing seat belt. The Head Injury Criterion (HIC) is used to assess passenger safety during a collision. The Head Damage Criterion (HIC) model was created to quantify the risk of head injury in accident conditions. Using a computer algebra system (here LS-DYNA) capable of analysing results from a real-world car collision test.

In this project, Airbag simulation along with human head foam is carried out. Nylon material is used for Airbag and material properties are given to the airbag. Human head foam which is downloaded from LSTC website is used. The human head foam is aligned in the direction of airbag deployment and made to strike airbag at an initial velocity of 35mph at different positions of the airbag.

The primary goal of this research is to evaluate the performance of airbag deployment using finite element methods (FEM) to manage various collision scenarios while lowering the HIC value.

Keywords:- *FEM, Airbag, HIC, Crash analysis, LS-DYNA.*

I. INTRODUCTION

For years, our cars' only form of passive restraint was the reliable seat belt. There was discussion concerning their safety, particularly in relation to minors. However, over time, the majority of the country embraced seat-belt requirements. According to statistics, seat belts have saved thousands of lives that might otherwise have been lost in collisions. Air bags have been in the works for a long time. The appeal of a soft pillow to land against in the event of a disaster must be strong, as the first patent for an inflatable crash-landing device for aeroplanes was filed during WWII. The first commercial air bags emerged in autos in the 1980s.

Let's go over the laws of motion again before we get into the details. First, we know that moving objects have momentum (which is defined as the product of an object's mass and velocity). Unless an external force acts on an object, it will continue to move at its current speed and in the same direction. Cars are made up of a variety of components, including the vehicle itself, loose objects in the vehicle, and, of course, people. If these things are not secured, they will continue to move at the same pace as the car, even if the car comes to a halt due to a collision. To bring an object's momentum to a halt, a force must be applied over a period of time. Because the automobile's momentum has changed instantaneously and the occupants have little time to react, the force required to stop an object is extremely high when a car crashes. Any supplemental restraint system's purpose is to enable the passenger stop while causing as little damage as possible.

The following are the main components of an airbag:

An air bag is made up of three pieces that work together to achieve this goal:
1. Bag
2. Sensor
3. System of inflation

1)Bag
The bag is constructed of a lightweight nylon cloth that is folded into the steering wheel, dashboard, or, more recently, the seat or door. By the way, the powdered item ejected from their sir bag is normal cornstarch or talcum powder, which is utilised by air bag makers to keep the bags malleable and lubricated during storage.

2)Sensor
The sensor is what tells the bag when it's time to inflate. It collaborates with the control module to identify crash and non-crash events. The severity of the hit is measured by these sensors. When a collision force equal to running into a brick wall at 16 to 24 kilometres per hour occurs, inflation occurs. They're set up so that if there's a sudden negative acceleration, the contacts will close, alerting the control module that there's been a crash.

3)Inflation system
The air bag's inflating system produces a huge volume of nitrogen gas by reacting sodium azide (NaN_3) with potassium

nitrate (KNO_3). Hot nitrogen blasts inflate the air bag from its storage location at speeds of up to 322 kilometres per hour. The gas swiftly drains via a tiny hole in the bag a split second later, deflating the bag and allowing you to move.

A. *Chemistry of Airbag:*

A gas generator containing a mixture of NaN3, KNO3, and SiO2 is located inside the airbag. A series of three chemical reactions inside the gas generator produce gas (N2) to fill the airbag and convert highly hazardous NaN3 to innocuous glass in the event of a head-on collision. At 300°C, sodium azide (NaN3) decomposes into sodium metal (Na) and nitrogen gas (N2). The electrical impulse generated by the deceleration sensor ignites the gas-generator mixture, generating the high-temperature environment required for NaN3 decomposition. The resulting nitrogen gas subsequently fills the airbag. The sodium metal (which is highly reactive and potentially explosive) is removed by turning it to a safe substance using KNO3 and SiO2. To begin, the sodium combines with potassium nitrate (KNO3) to form potassium oxide (K2O), sodium oxide (Na2O), and more N2 gas. The N2 produced in the second reaction also fills the airbag, and the metal oxides mix with silicon dioxide (SiO2) in a final reaction to make safe and stable silicate glass. Because first-period metal oxides like Na2O and K2O are very reactive, allowing them to be the end product of an airbag detonation would be dangerous.

TABLE I. CHEMICAL REACTIONS IN AN AIRBAG

Reaction 1	$2NaN_3$ □ $2Na + 3N_2$
Reaction 2	$10Na + 2KNO_3$ □ $K_2O + 5Na_2O + N_2$
Reaction 3	$K_2O + Na_2O + SiO_2$ □ $Na_2K_2SiO_4$ (alkaline glass)

B. *Airbag raw materials:*

Nylon 6, 6 yarns with deniers ranging from 420 to 840 are the most commonly used raw materials for airbag fabric. 1880 D nylon-6.6 was utilised in the side impact airbags.

C. *Sensors used in Airbags:*

Crash sensors can be found at the front or back of the vehicle, as well as in the passenger compartment. One or more collision sensors may be installed in a vehicle. Only forces generated in large frontal or near-frontal impacts activate the sensors; they are not engaged by quick braking or driving on rough or uneven pavement. There are two types of functions. Impact sensors and Safing sensors are two types of sensors. Forward sensors can be found in a variety of positions in the passenger compartment. Depending on the manufacturer, rear safety sensors are installed in various positions across the passenger compartment. Some of them are linked to the Control and Diagnostic Module. To avoid airbag deployment in circumstances where the impact is not powerful enough to warrant deployment, the rear safing sensor must close before the forward sensors. Airbag impact sensors, also known as crash sensors, are critical safety elements for your vehicle.

D. *Deployment of Airbag:*

The accident itself is the first stage of airbag deployment. A variety of sensors in the car, including accelerometers, impact sensors, side pressure sensors, brake pressure sensors, and seat occupancy sensors, are activated when a collision occurs, whether it is frontal or lateral. The rear safety sensor must close before the forward sensors to prevent airbag deployment in situations where the impact is not strong enough to warrant deployment. Crash sensors, also known as airbag impact sensors, are important safety components for your car. The unit determines whether and how the airbags should be deployed. The inflation step begins when the ACU detects that the deployment threshold has been met. Because a compressed air system would have been impractical and inefficient, engineers devised a system based on the solid rocket booster's operating principle. Each airbag has a pyrotechnic device called an initiator or electric match, which is made out of an electrical conductor encased in combustible material. The conductor is heated by a current pulse, which ignites the combustible material. The chemical reaction that fills the nylon fabric airbag with gas is triggered by this igniter. The massive amount of gas then forces the airbag out of the steering wheel and/or dashboard at speeds of up to 200 mph or 322 mph, requiring around 0.04 seconds to complete. When you consider that the blink of an eye takes about 0.2 seconds, it's a rather quick procedure. The final stage of the airbag process is deflation, which happens virtually immediately after the inflated. Special vents allow the gas to escape.

II. HEAD INJURY CRITERION

Although significant progress in the understanding of head injury processes and the introduction of airbag restraint systems has resulted in a reduction in the number and severity of head injuries, head injury remains a primary cause of death and disability. Despite these developments, the Head Injury Criterion (HIC), which was adopted over twenty-five years ago, remains the only injury criteria in widespread use. NHTSA recommended HIC as a substitute for the GSI in FMVSS No. 208, and it is calculated using the formula below:

$$\text{HIC}= \max\left[\frac{1}{t_2-t_1}\int_{t_1}^{t_2} a(t)dt\right]^{2.5} (t_2 - t_1)$$

For all dummy sizes, the agency proposes evaluating the HIC over a maximum 15 millisecond time interval, with a requirement that it not exceed 700 for the 50^{th} percentile male and 5^{th} percentile female. This will allow for a more stringent review of long-duration events while also increasing the rig our of short-duration events where biomechanical assurance is lacking. Based on a scaling from the proposed new limit for the 50th percentile adult male dummy, we recommend changing the HIC time interval to a maximum of 15 milliseconds for all dummy sizes and revising the HIC limits by proportionate amounts.

The AAMA's approach for scaling HIC_{15} based on tissue failure stresses was reviewed by the agency, and it was judged to be roughly similar to both the scaled HIC_{15} values established by finite element analysis and the scaling technique used in the NPRM, which employs tendon strength. Furthermore, because the AAMA members agreed to employ the scaling strategy based on tissue failure stresses, the agency recommends to scale the HIC_{15} performance limits using this method. The AAMA, on the other hand, proposed performance criteria of more than 700 for a six-year-old child and a girl in the fifth percentile. Given the uncertainties in the scaling approaches, the agency feels it would be unwise to enable a child to have a higher limit than an adult, and hence proposes that the six-year-performance old's limit be set at 700 for HIC_{15}. Furthermore, because the biomechanical data used to produce HIC included both male and female skulls of varied sizes, and because head size and body size are not highly associated, the agency is suggesting a single HIC_{15} value of 700 for all adult dummies. The HIC_{15} limit is mentioned for completeness, even though the large male Hybrid III dummy is not included in the proposed testing for the advanced air bag SNPRM.

III. METHODOLOGY

CATIA V5's associativity allows users to make design modifications at any point during the product development process, and downstream deliverables are automatically updated. This capacity streamlines product development processes by allowing concurrent engineering design, analytical, and manufacturing engineers to work in simultaneously.

A. Dimensions for the Airbag:

Outer diameter	=	330mm
Inner diameter	=	30mm
Thickness	=	0.38mm
Segment length	=	30mm

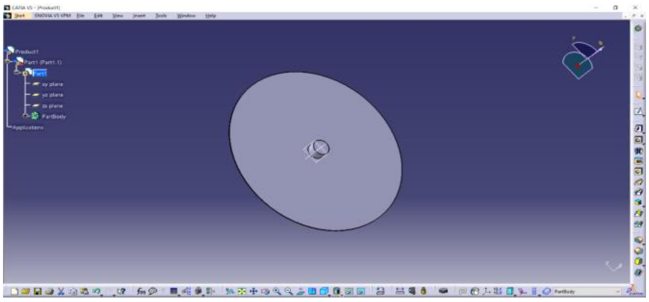

Fig 1. Airbag model in CATIA V5 Software

By importing the Airbag model and head model in Hypermesh then it will appear in interface. Then have to mesh the Airbag with shell mesh and Head model was already meshed by biotechnology field persons by Hexa mesh.

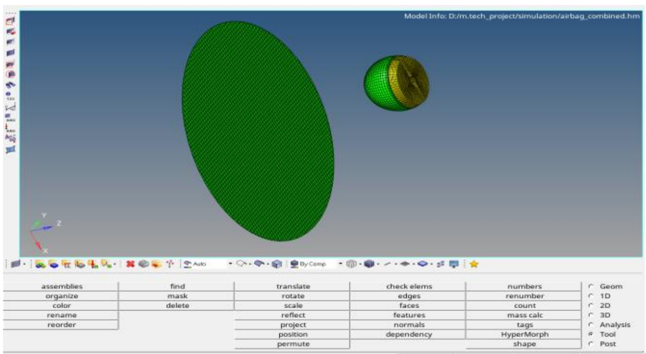

Fig 2. Meshed components

Airbag mesh criteria:

Nodes	=	6834
Elements	=	6920
Mesh type	=	Shell mesh
Elements type	=	Mixed elements

Head model mesh criteria:

Nodes	=	25657
Elements	=	20027
Mesh type	=	Hexa mesh
Element type	=	Hexa

Open the .K file of Airbag and Head model in Ls-dyna:

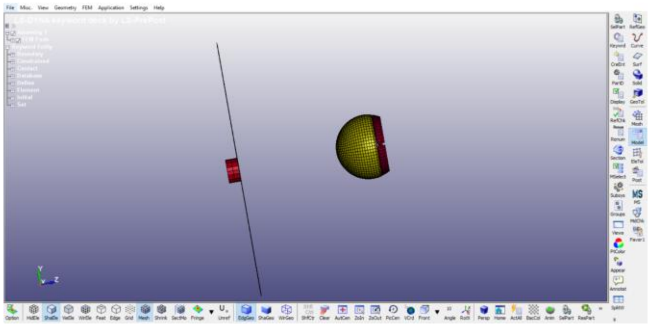

Fig.3. Airbag and Head model in Ls-prepost

B. Boundary conditions for Airbag and Head model:

Material inputs:

Material used	=	Nylon 6.6 yarn
Density	=	7.8×10^{-7}kg/mm^3
Poisson's ratio	=	0.3
Damping coefficient	=	0.30

Shell inputs:

Shear factor	=	1.0
Thickness	=	0.38mm
Temperature	=	800°C

Head model inputs:

Velocity	=	35mph

Mass flow rate inputs graph:

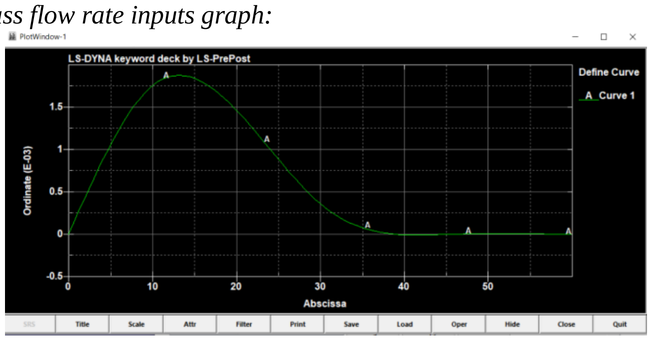

Fig.4. Mass flow rate curve

Output requests:

Termination time	=	30ms
Database>ASCII-option	=	Airbag statistics (DT 0.1) Global statistics (DT 0.1) Material energies (DT 0.1)
BINARY_D3PLOT	=	DT 0.1

C. Analytical calculations:

The expression to calculate HIC value

HIC(d) = 0.75446 (Free motion of head form HIC) + 166.4

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$$HIC = \max_{t_1,t_2}\left\{\left[\frac{1}{t_2-t_1}\int_{t_1}^{t_2} a(t)dt\right]^{2.5}(t_2-t_1)\right\}$$

From the plot, the average value of acceleration for the time interval of t_1= 12 ms and t_2 = 27 ms is 51 mm/ms^2 from the graph.

$$HIC = \max_{t_1,t_2}\left\{\left[\frac{1}{27-12}\int_{12}^{27} 51\right]^{2.5}(27-12)\right\}$$

$$HIC = \max_{t_1,t_2}\{[0.0666 \times 765]^{2.5}(27-12)\}$$

HIC = 278.55

By using this HIC value, Calculate HIC(d) value

HIC(d) = 0.75446 (Free motion of head form HIC) + 166.4

HIC(d) = 0.754446 (278.55) + 166.4

HIC(d) = 376.55

The HIC_{36} value obtained from LS-PrePost for third case is 285.36 and HIC(d) value is 381.7.

The HIC_{36} value obtained from Analytical calculations for third case is 278.55 and HIC(d) value is 376.55. There is small variation in the HIC value obtained from LS-PrePost and Analytical calculations which is acceptable.

IV. RESULTS

In this study, the use of LS-DYNA simulation to analyse airbag deployment and HIC value was attempted. The airbag has two sections and is generic. The inflator is attached to the inner compartment, which has a hole in the middle of the rear. The inner compartment and the outer compartment are connected by this aperture. The air bag fully inflates in 26 milliseconds. The simulation takes 30 milliseconds in total. Figures 5,6 and 7 demonstrate the findings of the multi-domain technique for this deploying airbag at a certain period and at the end of the analysis.

The Head Injury Criterion (HIC) value of 381.7 was produced using the LS- PREPOST programme, and LS-POST was used to view the data after post processing. The output values of velocity, pressure, internal energy, mass flow rate, temperature, kinetic energy, internal energy, and total energy are observed, as well as the velocity, pressure, internal energy, mass flow rate, temperature, kinetic energy, internal energy, and total energy values.

A. *Airbag deployment:*

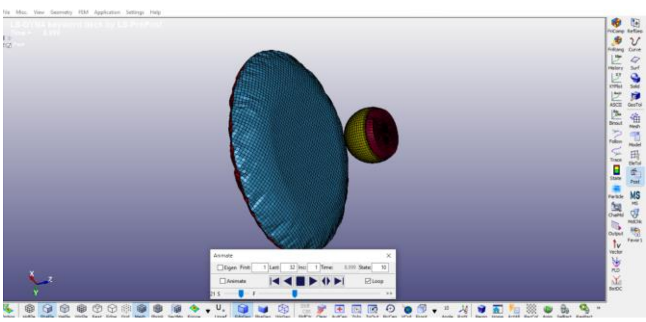

Fig.5. Air bag deployment at t = 9ms

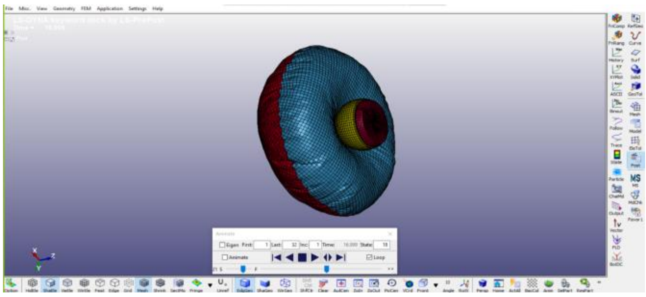

Fig.6. Air bag deployment at t = 17ms

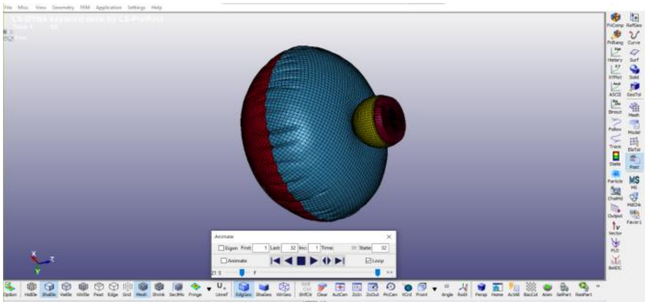

Fig.7. Air bag deployment at t = 30ms

B. *Output graphs:*

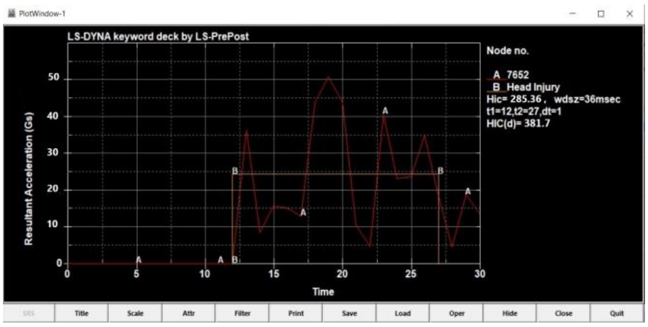

Fig.8. HIC value curve

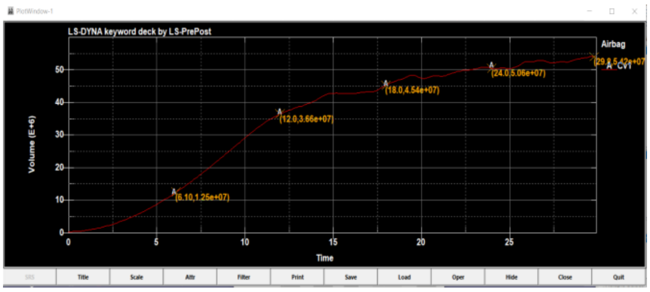

Fig.9. Velocity output curve

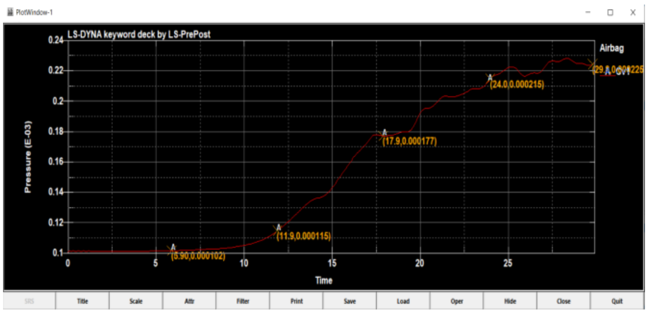

Fig.10. Pressure output curve

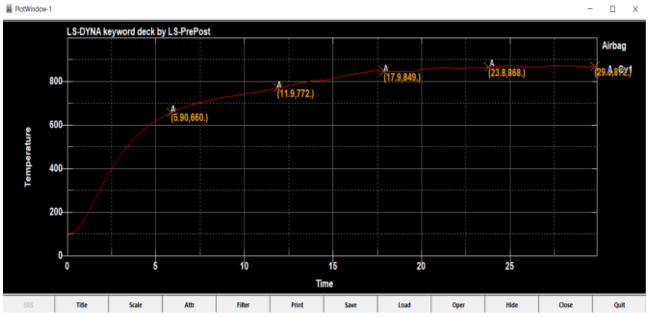

Fig.11. Temperature output curve

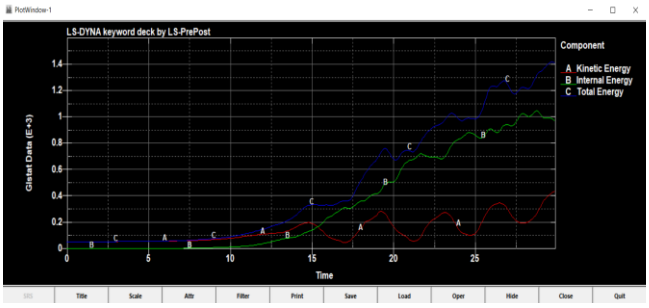

Fig.12. Kinetic, Internal and Total energy curve

V. CONCLUSION

Head acceleration is one of the major characteristics used to assess occupant safety (HIC) in crashworthiness investigations, the research of the different placements of the head foam on the airbag was chosen as an essential aspect in this thesis.

According to the graphic, the resultant acceleration vs time of the head contacting the airbag is safe about the radius of 100 mm. The HIC (d) produced in the simulation, 381.7, is less than the ECE R94 norm of 650. When the findings for the head foam from analytical and numerical simulations were compared, it was obvious that the results exhibited a similar pattern with practically the same extreme point.

In this thesis, various ways to estimating an impact were examined and simulated in LS-DYNA. The influence of the head foam on different placements of the airbag has been studied using various methodologies.

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