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Driver Side Knee Injury Assessments Using Finite Element Analysis and Crash Dummy

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Abstract: *This project is about designing and analyzing a Knee Airbag that can be employed in passenger cars to safe occupants during a vehicle frontal crash. Several fatalities and injuries are occurred every year due to vehicle accidents. Out of several different directions of crashes front impact is very dangerous and common. In the frontal impact passenger vehicle hits to any other object. In this event velocity of vehicle abruptly reduces by zero within very short period of time. This causes sudden movement of occupant against the vehicle and damage to the passenger and sometimes death. In this case, knees can be injured severely and occupants can lose their ability to walk for lifetime. Knee airbag can play an imperative role to protect human legs during frontal accidents.Airbags are the lifesavingequipment of the vehicle. These devices play an imperative role to reduce the occupant acceleration at the time of crash or accident. The main aim of this study is to evaluate the performance of knee airbag using Finite Element Methods (FEM).As FEM is a very advance tool to analyze stress-strain and acceleration response behavior of the vehicle and its occupants. The detailed airbag modelling was performed using FEM. Finite Element Analysis is used tosimulate crash event. This study includes the effect of knee airbag during crash. Hypermesh (Product ofAltair Engineering) is used to simulate and analyze the frontal impact scenario.*

Keywords: *Knee Injury, Airbag, Crash Dummy, Hypermesh, LS-Dyna*

I. Introdution

The bulk of occupant injuries are caused by forwardcrashes [1]. The knee is one of the more frequently injured parts of the lower limbs with femur and patella fractures that represent more than 30% of lower limb injuries in a UK research report [1,2]. Study performed by Mark R. Socher et al [3] found that hip injuries tend be more devastating than knee and thigh injuries. Some research group also presented information aboutknee airbag development. Raj S. And developed a “Blow-Molded Active Plastic Knee Bolster” using TPO (Thermoplastic Poly Olefin) material [4]. Pyrotechnic Knee Bolsters were analysed group by Patrick Borde using MADYMO [1].Kia Sportage is the first vehicle which was equipped with knee airbag at driver side. The knee airbag can be categorized by Inflatable Knee Bolster (IKB) type and Knee Airbag (KA) type. The IKB type deploys the knee airbag cushion within the Instrument Panel Lower and indirectly restrains the occupant’s knees using the IP lower panel. The KAB restrains the occupant’s knees using the knee airbag cushion directly.

Presently more than 40% injuries for occupants occurred in frontal impacts in the lower extremities. However significant work and research have been performed to reduce chest and head injuries in last two decades, very limited improvement can be seen in lower extremities injuries.

This study is mainly focused on the knee injuries during frontal impact. The sled model was developed and integrated with 50th percentile hybrid III dummy. A FE model of airbag was developed using Hypermesh. The airbag model was mounted at the front bottom of instrument panel. Finally effect of airbag was analysed by comparing the knee forces with baseline case.

II. Methodology

Airbags, sled and crash dummy are the essential members of this research work. Initially it is necessary to understand all three.

An airbag is a safety device used in the vehicles. It is a type of occupant restraint system having a fabric designed to inflate quickly during an automobile collision. Generally, airbags are designed to deploy in a crash that is equivalent to a vehicle crashing into a solid wall at 8 to 14 miles per hour. Airbags most often deploy when a vehicle collides with another vehicle or with a solid object like a tree.There are various types of airbags; frontal, side-impact, curtain and knee airbags. Advanced frontal air bag systems automatically verify if and with what level of power the driver frontal air bag and the passenger frontal air bag will blow up. The suitable level of power is based upon sensor inputs that can typically sense:

1) Occupant size,
2) Seat position,

3) Seat belt use of the occupant, and
4) Crash severity

Figure1 shows the typical knee airbag. The main purpose of knee airbag is to protect knees at the time of frontal impact.

Fig. 1: Knee Airbag with Crash Dummy and Sled Environment [5]

Sled impact is one of the best method to analyse the crashes of the vehicle with simplified way. In a typical sled, a vehicle & its dummies are moving at a constant velocity from prior to an actual crash they are decelerated very rapidly. The test vehicle & dummies are at zero velocity according to HYGE principle that situation simulates the constant velocity at an actual crash. During a deceleration of a moving automobile or aircraft the program, rapid acceleration of HYGE thrust column acceleration the sled with attached test articles& produces an impulse similar to that generated. At any axis the crash loaded may be applied depending upon orientation of the test article[6]. Figure 2 shows the typical sled configuration [7].

Fig.2: Sledenvironment [7]

Finite element analysis is often a favourable tool to analyse injury biomechanics of the occupants. Ls-Dyna which is an advanced software to simulate crash dummy kinematics [8]. Figure 3 shows the FE model of crash dummy developed by LSTC. Head, Chest and Knees are the most vulnerable site in the human body in frontal accidents. Figure 4 also shows the locations which can be affected severely during frontal crash of any vehicle.

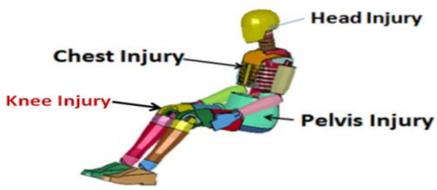

Fig. 3: Crash Dummy and Injury measurement locations

Finite element model of sled environment is shown in figure 4. The acceleration impulse of 25 g was applied to the system to simulate frontal impact scenario. Knee injury parameters were measured with and without airbag to understand the performance of airbag.

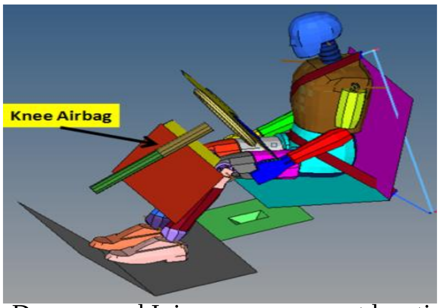

Fig. 4: Crash Dummy and Injury measurement locations

III. Results

Figure 5-a shows the initial position of dummy i.e. at time 0ms. Figure 5-b shows the dummy posture at the time of knee impact. It can be seen clearly that femur experienced maximum injury at the time of knee impact when it strikes with instrumentation panel.

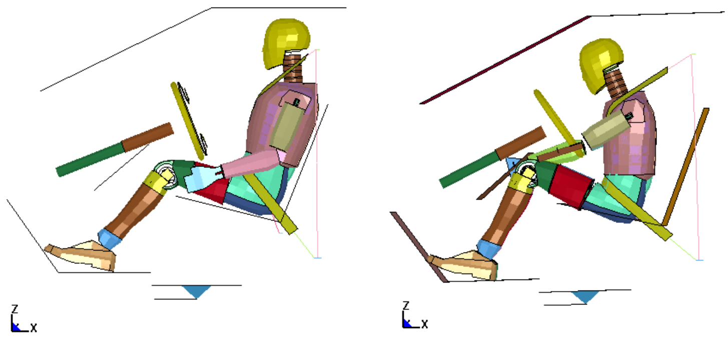

Fig.5-a: Initial positionFig.5-b: At the time of knee impact

Figure 6 shows the knee force variation with time during the entire impact process. The peak femur force was found to be as 17.5kN at 50ms.

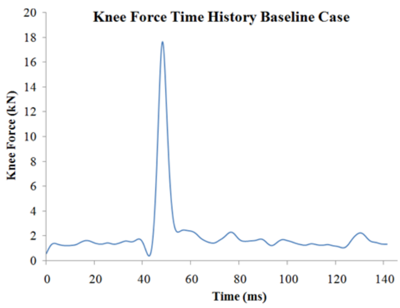

Fig. 6: Knee force variation during impact process

Figure 7-a shows the initial position of dummy i.e. at time 0ms, with airbag case. Figure 7-b shows the dummy posture at the time of knee impact. It can be seen clearly that femur experienced maximum injury at the time of knee impact when it strikes with airbag. Airbag was able to provide proper cushion to the knees at the time of impact.

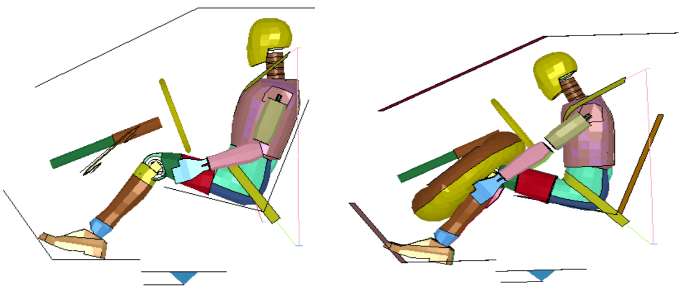

Fig. 7-a:Initial positionFig. 7-b: At the time of knee impact

Figure 8shows the knee force variation with time during the entire impact process in airbag case. The peak femur force was found to be as 5.5kN at 50ms.

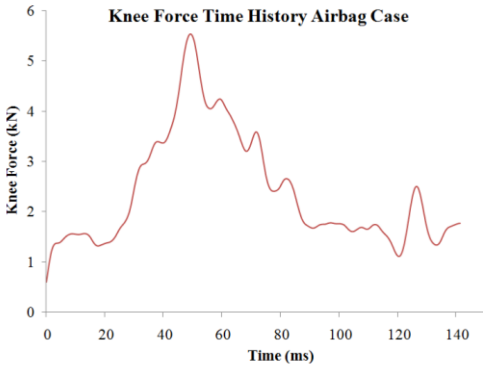

Fig. 8: Knee force variation during impact process in airbag case

Figure 9 below shows the cross section view of dummy, instrumentation panel and airbag. With figure 9-a, it is clear that the knees were loaded with knee panels directly and caused the very high knee loads. While in case of airbag, there was no direct impact observed between knees and instrumentation panel, hence the peak knee force was reduced with great extent.

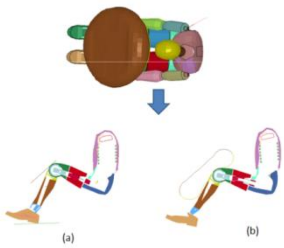

Fig. 9: Cross section view of dummy

IV. Conclusion

The finite element modelling of airbag was performed using Hypermesh. The performance of airbag was emulated by comparing the results with baseline case i.e. without airbag case. Figure 10 shows the comparison in peak knee forces with and without airbag at the time of frontal impact. 68.5% reduction in peak knee forces was achieved with the help of airbag.

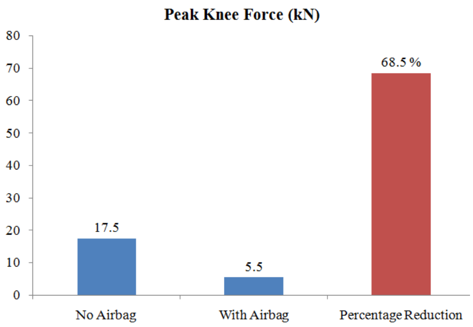

Fig. 10: Comparison in peak knee forces

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