An Evaluation of Active Knee Bolsters

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Abstract

In the present paper, the impact between an active knee bolster system and occupant knees has been studied using finite element analysis. The active knee bolster system consisted of an inflatable molding part and a pair of EA supporting brackets. Also included in the FEA model was the entire vehicle cockpit. Both driver-side and passenger-side occupants were considered. The active knee bolster FEA model was first validated by test data including kinematics and femur loads. The performance of active knee bolsters was then compared with that of conventional structural knee bolsters

Introduction

The purpose to develop an active knee bolster (AKB) system was to free up space to improve egress and ingress for occupants while providing at least the same occupant protection as a corresponding conventional structural knee bolster does. The most important component in an active knee bolster system is the inflatable plastic molded knee bolster. Knee impact tests were utilized at Delphi Corporation to aid in developing the active knee bolsters. In reality, the active knee bolsters are triggered by crash sensors and inflated by airbag inflators to occupy the space between the knees and the instrument panel of vehicle, thus slowing down the knees in much the same way a conventional structural knee bolster (SKB) interacts with the occupant. In a knee impact test, however, the knees are propelled into the active knee bolsters by bungee cords. This test can be run instead of a much more costly sled test for the development of active knee bolsters.

Finite element analysis (FEA) has long been a powerful tool to simulate engineering tests. Among other FEA software, LS-DYNA has been widely used in the automotive industry, especially in the area of crashworthiness engineering. This paper presents an evaluation of a newly designed active knee bolster system using FEA in conjunction with lab knee impact tests. The finite element analysis was carried out using LS-DYNA.

Analysis Models

The FEA model was comprised of occupant knees and a cockpit structure with knee bolsters. The knees were basically the lower half part of occupant and were created based on the 50% FTSS LS-DYNA dummy model. The vehicle structure was modeled with shell and solid elements. And the active knee bolsters made of plastics were characterized with the piecewise linear plastic material model in LS-DYNA. In a knee impact test, the occupant knees were subjected to an initial impact. In the simulation, however, this initial impact was represented either by an equivalent force-displacement curve or by an initial velocity. Two vehicle models were considered in the present study.

Vehicle Model I

Figure 1 shows the passenger side of a vehicle FEA model with the conventional structural knee bolster being replaced by a deployed active knee bolster. The EA brackets, which support the knee bolster, remained unchanged. A force-displacement curve generated based on knee impact tests at 23 km/h was adopted and applied to the H-point of the occupant knees.

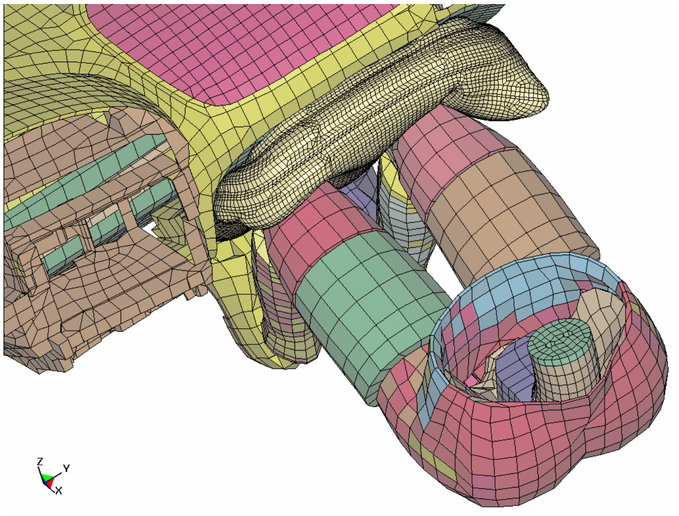

Figure 1 Passenger-side FEA Model of Vehicle I

Vehicle Model II

New active knee bolsters and associated instrument panel components were designed for Vehicle II, as shown in Figure 2.

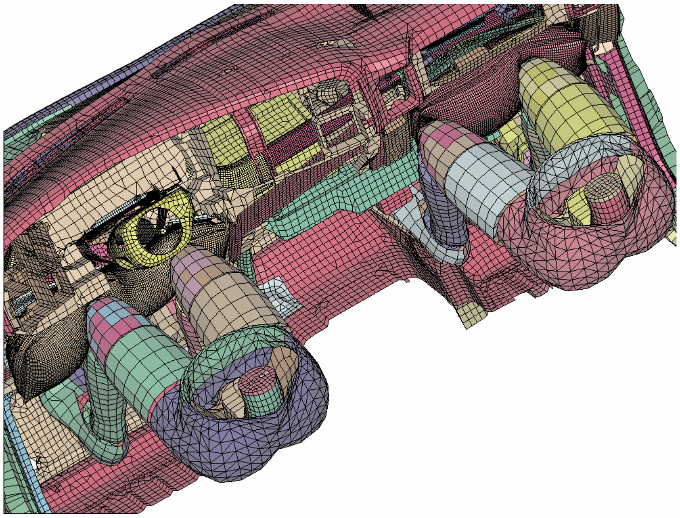

Figure 2 FEA Model of Vehicle II

The active knee bolsters were supported by redesigned shorter EA brackets such that the active knee bolsters were 50 mm farther away from the occupant knees when compared with the conventional structural knee bolsters. Both driver side and passenger side of the vehicle were modeled in FEA. Design iterations of the knee bolsters were tried in the FEA model. The entire knees were subjected to an initial velocity of 22 km/h. A presumed prescribed velocity-versus-displacement motion at this specific speed was applied to the feet such that the kinematics of the knees looked right.

Results and Discussion

Simulations were run for 80 ms. Figures 3 and 4 show the passenger-side H-point velocity and the pressure in the active knee bolster in Vehicle Model I, respectively. The active knee bolster with a vent of 20 mm in diameter was inflated at 25 ms. Both simulation and lab test results are plotted. It is seen that the peak values and history shapes are well correlated.

Figures 5 and 6 show the comparisons of occupant femur loads from simulations and physical tests. The right femur loads correlate very well while the left femur loads follow the same trend up to 80 ms though there is a discrepancy in magnitude. Also plotted in Figures 5 and 6 are the femur loads associated with the conventional structural knee bolster. It is clearly seen that the active knee bolster can significantly reduce the passenger-side femur loads when compared to the conventional structural knee bolster.

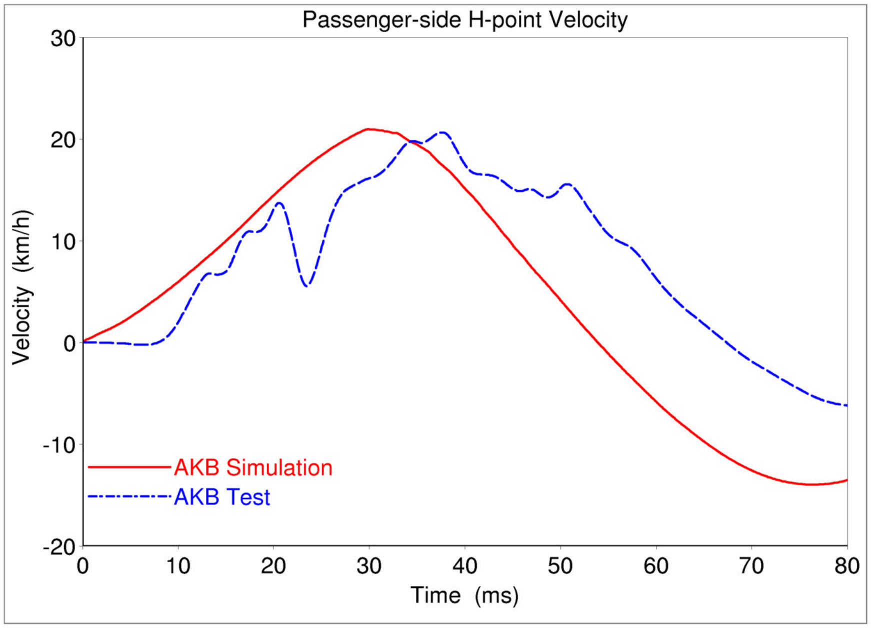

Figure 3 Passenger-side H-Point Velocity in Vehicle I

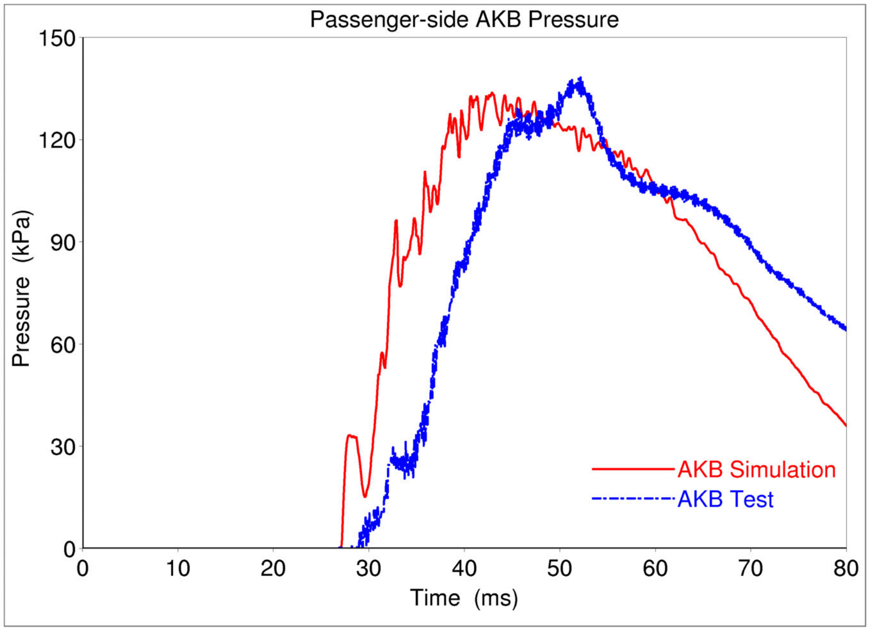

Figure 4 Passenger-side AKB Pressure in Vehicle I

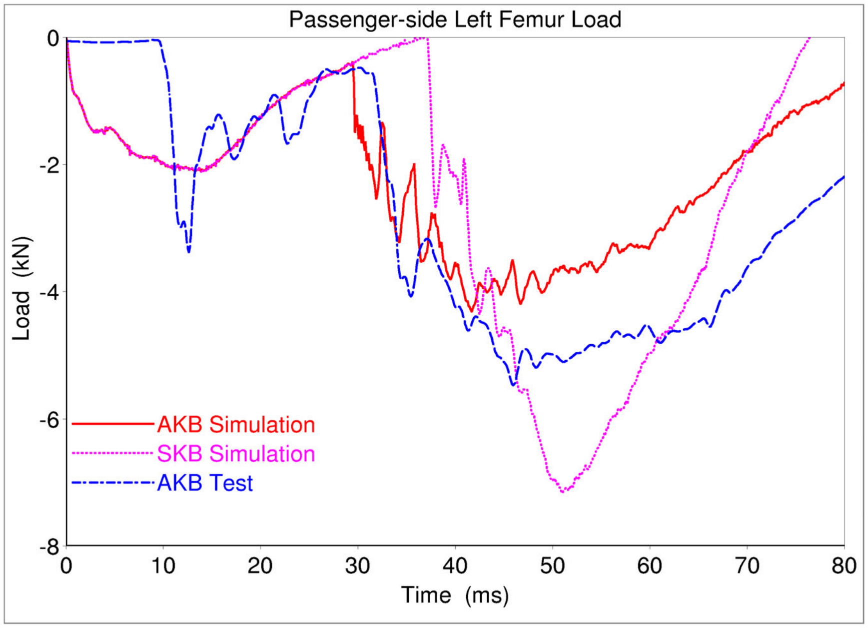

Figure 5 Passenger-side Left Femur Load in Vehicle I

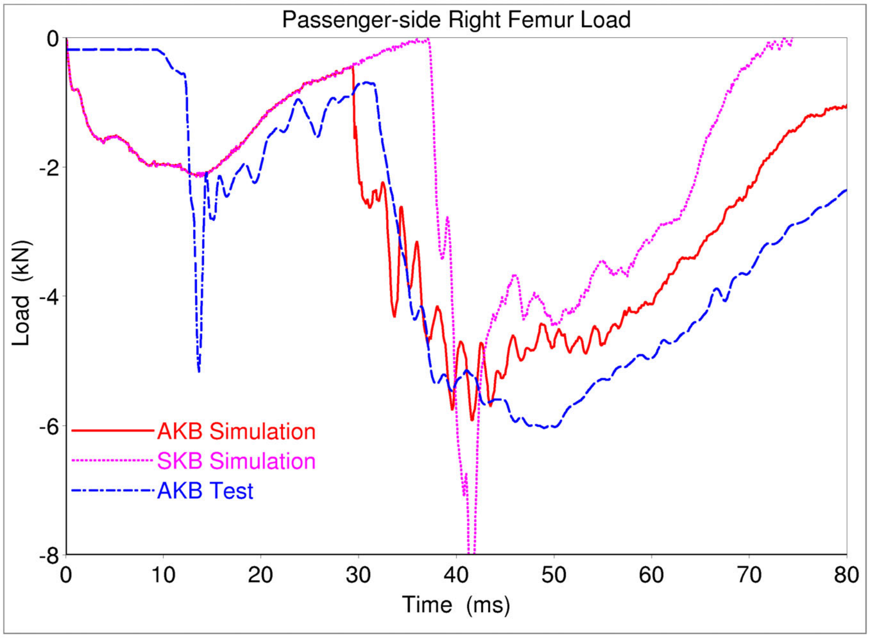

Figure 6 Passenger-side Right Femur Load in Vehicle I

To further show the advantages of the active knee bolster over the conventional structural knee bolster, the internal energy in a portion of the knees, as shown in Figure 7, was calculated and is plotted in Figure 8 for Vehicle Model I. It's noted that this portion of knees, where the femur loads were measured and computed, absorbs much less energy if the active knee bolster is utilized, thus reducing the severity of knee injuries during a crash.

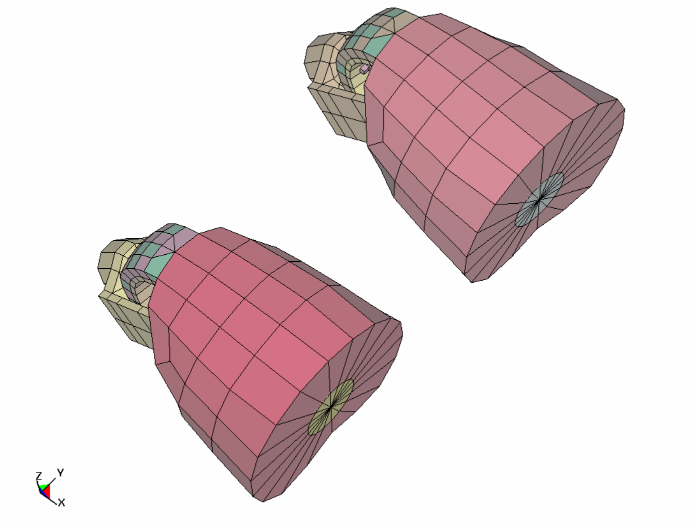

Figure 7 Portion of Knees Used for Calculating Internal Energy

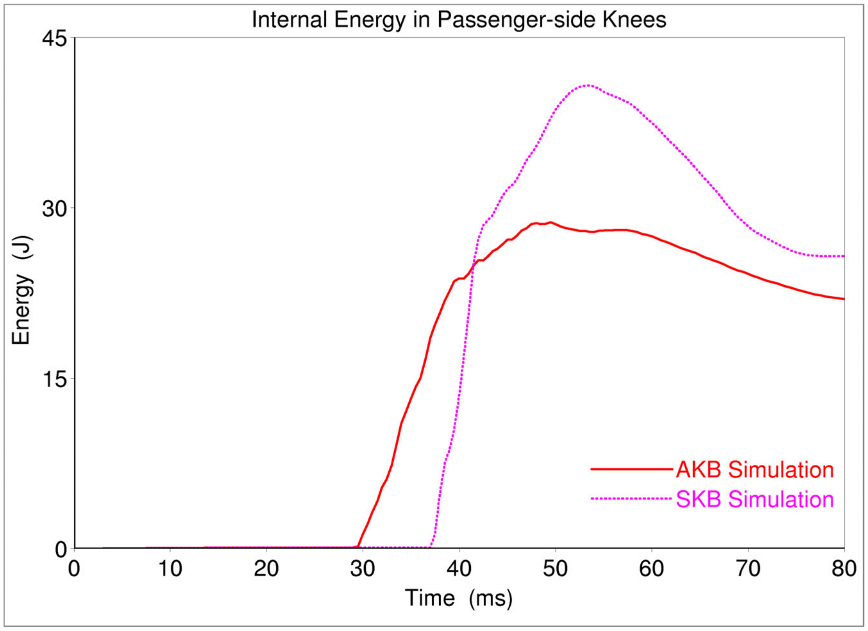

Figure 8 Internal Energy of Knees in Vehicle I

For Vehicle Model II, a number of cases with various vent sizes and inflator time to fire were run. In addition to the AKB loading, a force of 10 kN was applied to the steering column and 7 kN to the passenger-side airbag housing to represent the loading from the upper part of occupants during a crash.

In the case where the driver-side and passenger-side active knee bolsters both had a vent of 20 mm in diameter and were triggered to deploy at 15 ms, the femur loads are plotted in Figures 9 to 12.

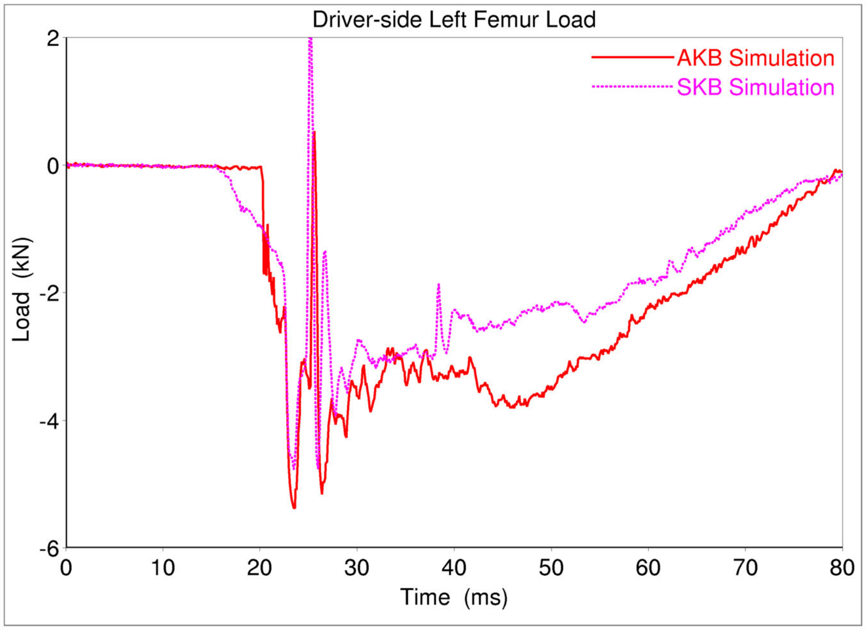

Figure 9 Driver-side Left Femur Load in Vehicle II

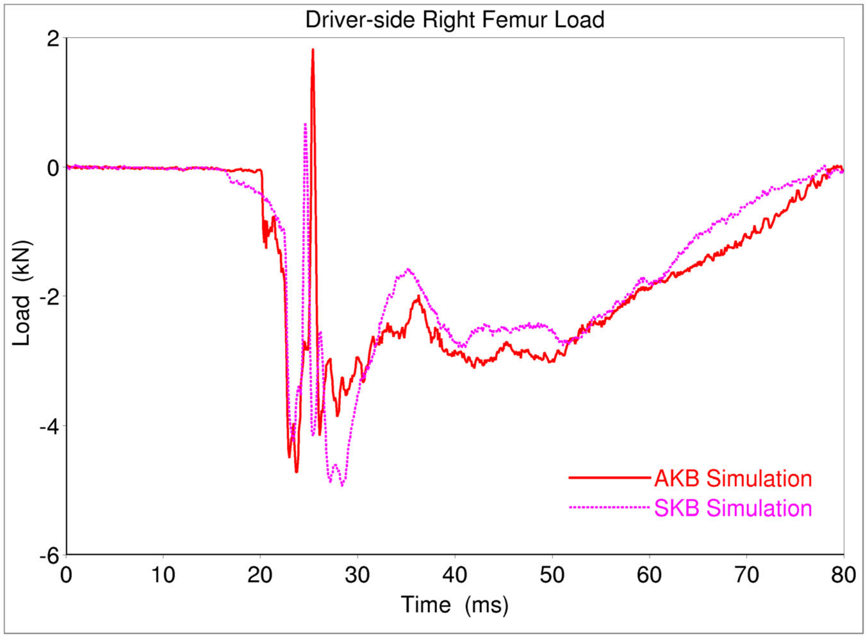

Figure 10 Driver-side Right Femur Load in Vehicle II

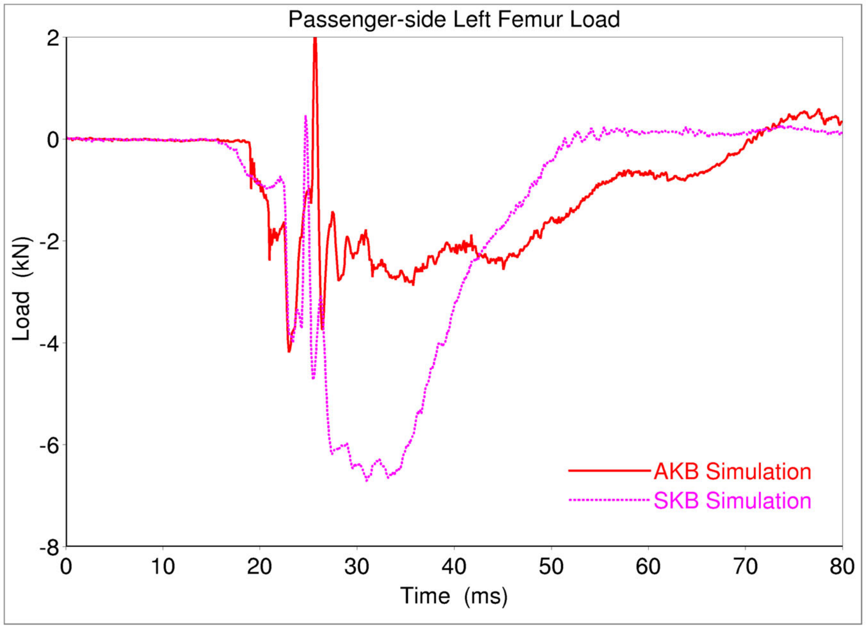

Figure 11 Passenger-side Left Femur Load in Vehicle II

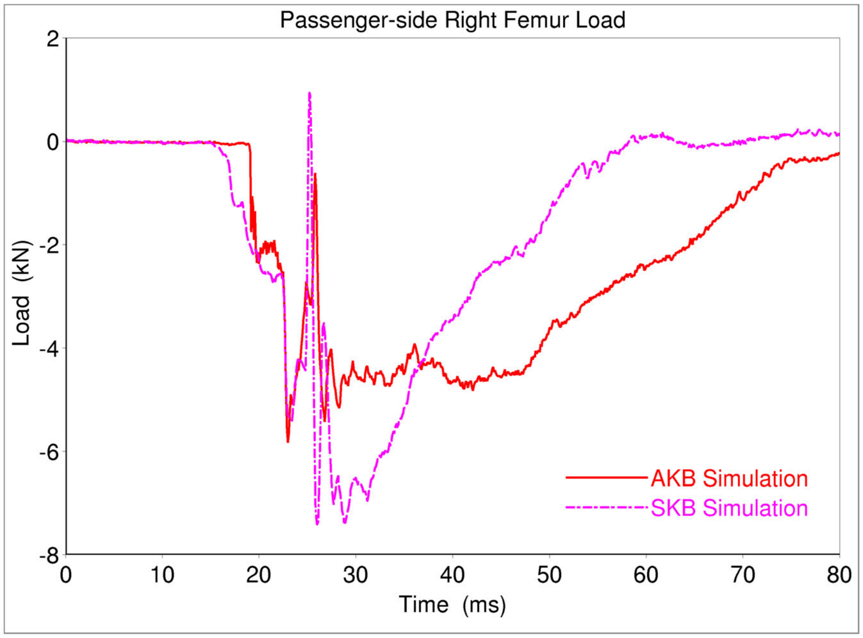

Figure 12 Passenger-side Right Femur Load in Vehicle II

It is seen from Figures 9 and 10 that the driver-side femur loads with active knee bolsters are at the same level as those with conventional structural knee bolsters. It's also observed that there is a tensile spike in the femur loads at 26 ms, at which the knees start to rotate. Obviously, this behavior should not affect the comparison of results as long as the same occupant knees are employed in the analysis. Figures 11 and 12 indicate that the active knee bolsters have greatly reduced the passenger-side femur loads. Furthermore, Figure 13 again shows that the knees absorb less energy in the case of active knee bolsters.

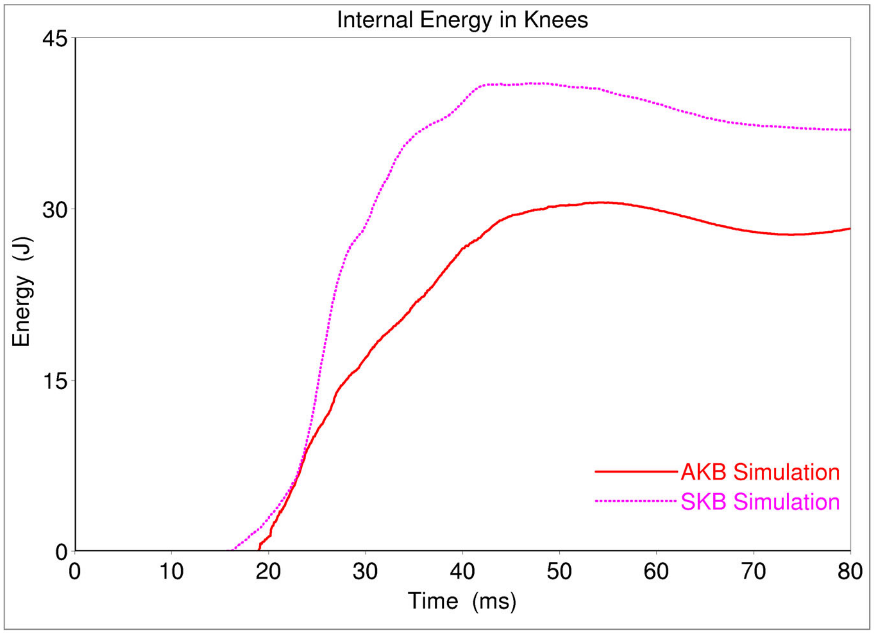

Figure 13 Internal Energy of Knees in Vehicle II

Shown in Figures 14 to 17 are the comparisons of femur loads with the structural knee bolsters and undeployed active knee bolsters. No airbag loading from the upper part of occupants was applied to the cockpit in this scenario. It is noted that the femur loads for both driver side and passenger side when the active knee bolster are not activated are comparable to, if not better than, those with the conventional structural knee bolsters.

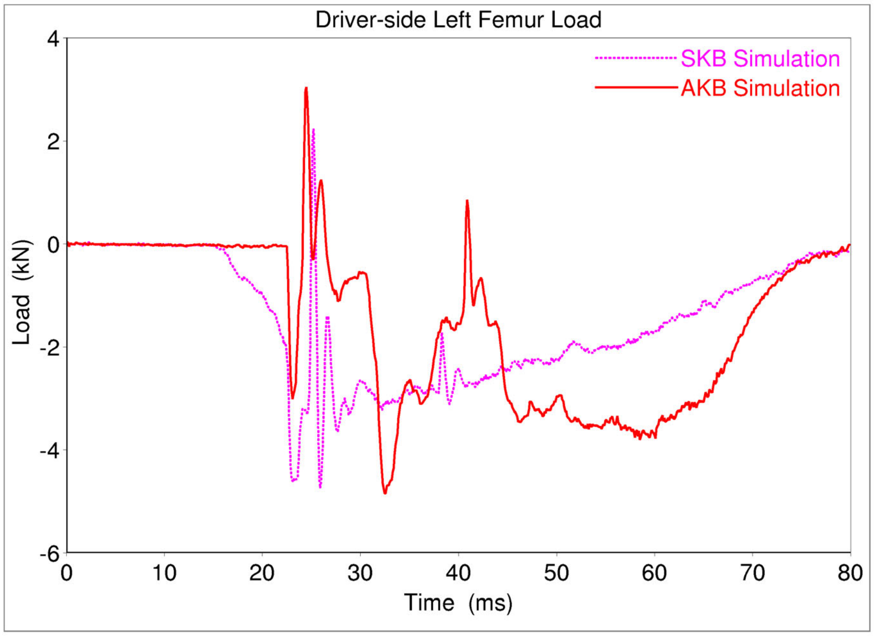

Figure 14 Driver-side Left Femur Load in Vehicle II: Undeployed AKB

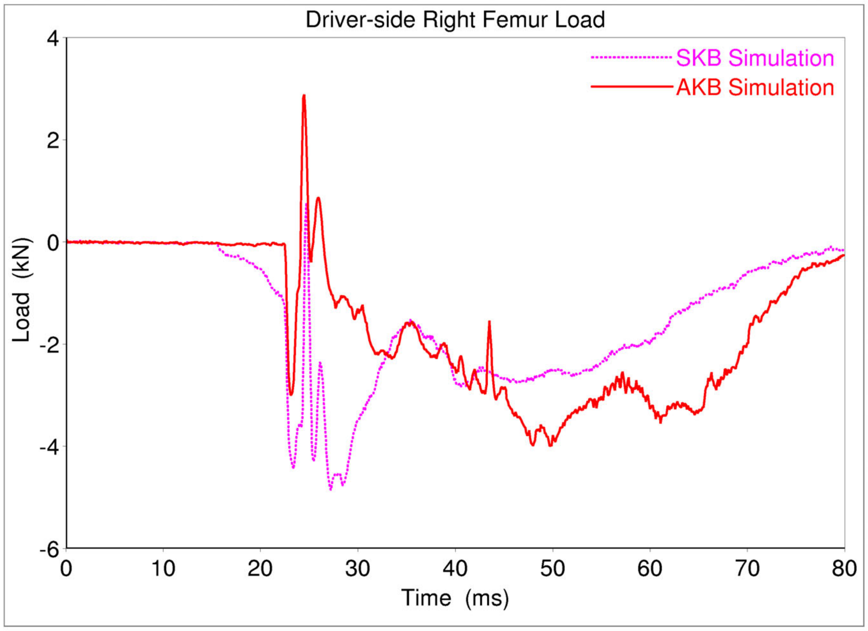

Figure 15 Driver-side Right Femur Load in Vehicle II: Undeployed AKB

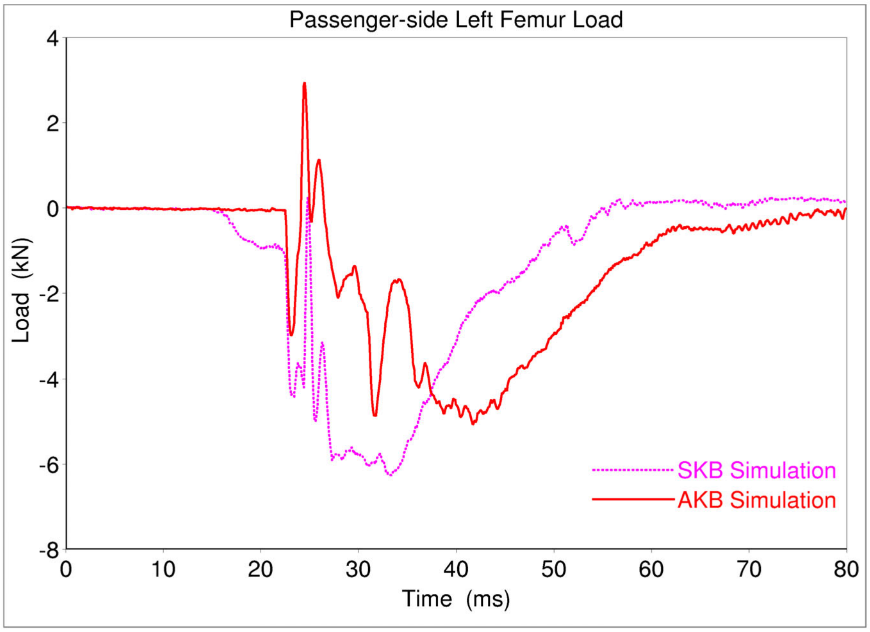

Figure 16 Passenger-side Left Femur Load in Vehicle II: Undeployed AKB

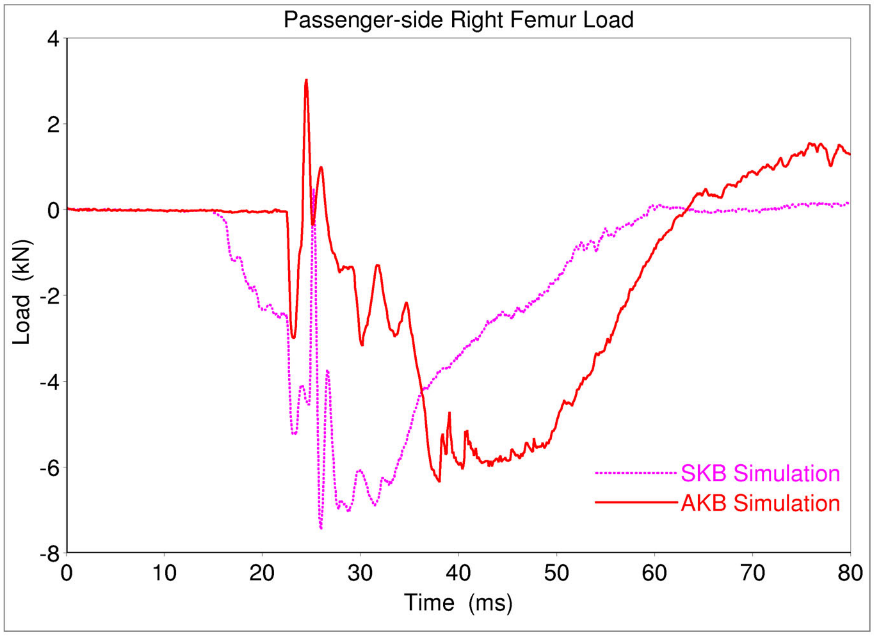

Figure 17 Passenger-side Right Femur Load in Vehicle II: Undeployed AKB

As a consequence, with an additional room of 50 mm for the occupant knees, the active knee bolsters still have at least the same level of performance in terms of femur loads as the conventional structural knee bolsters. It's also concluded that the design of an active knee bolster system could be optimized to achieve desired performance through varying design parameters such as the vent size, time to fire, and inflator data.

Conclusions

The impact between an active knee bolster system and occupant knees has been investigated using finite element analysis. Based on the results, the following conclusions can be drawn.

- The FEA model for Vehicle I is well correlated to the knee impact tests.
- The active knee bolster system can significantly reduce the femur loads of occupants.
- The active knee bolster system can greatly improve occupant egress and ingress.
- The design of an active knee bolster system can be optimized.

Acknowledgments

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References

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James Conlee, Deployable knee bolster, Delphi Safety and Interior Systems, internal document, 2001.