OCCUPANT PROTECTION BY A MOVEABLE SEAT SYSTEM

B. Fachbach / H. Steffan; Institute for Mechanics, University of Technology Graz
G. Staska; Institute for Automotive Engineering, University of Technology Graz

ABSTRACT

Today's requirements of occupant protection have been a limitation to the reduction of the size of a car for a long time. Small urban vehicles do not offer sufficient space for a crash zone. Additionally the risk of severe injuries is increased by the incompatibility of light and heavy weighted cars during an impact.

The project of the Institute for Mechanics at the University of Technology in Graz is based on recent results of research and development on small hard shell vehicles. The aim of the project is an investigation of the concept of a moveable seat system which enables a moderate deceleration for the occupants during front or rear impact although the vehicle itself suffers a quite high deceleration.

ROAD TRAFFIC TENDS even more to small economic and ecologically beneficial vehicles in these days. Nevertheless people want to be sure of riding safe cars, too. Until now a high potential of crash safety has been reached by large deformation zones at least for front and rear impacts. A negative effect is the increasing weight of additional structures. This is clearly contradictory to the demand for small lightweight vehicles. Especially electric cars may be efficient only if their total weight can be kept low.

Swiss research projects (Kaeser, 1995; Walz, 1996) have shown a high amount of safety potential even in small, low mass vehicles (LMV). They dealed with small cars that have been equipped with a rigid crash belt. This crash zone can be deformed under a high load level without serious intrusions inside the car. The place inside the passenger safety cell can therefore be used for the occupant deceleration. The project at the Institute for Mechanics in Graz is based on these experiments and deals with a new complex restraint system.

There are two disadvantages of LMV's in a crash situation especially with a heavier car that cause a high level of deceleration:

- The deformable area is very small and therefore has to be rather stiff.
- Because of the low mass the delta-v (velocity change during the accident) is much higher than that of a heavier car.

MOVEABLE SEAT SYSTEM

The injury tolerances of the human body do not allow such high accelerations. The body of the passenger has to be slowed down more gently. This can be achieved by a moveable seat system. The seat can be moved forward (or backward). The passenger is restraint to the seat by a 3-point safety belt system. If the car body is decelerated rapidly, the passenger clings to the seat and the seat will move slowing down as softly as possible. The seat is restraint to the car structure by a brake system. The restraint force is adjustable depending on the weight of the passenger.

By slowing down the occupant in an optimal way a much shorter deceleration distance is needed to meet the injury tolerances of the impacting body parts.

MATHEMATICAL MODEL

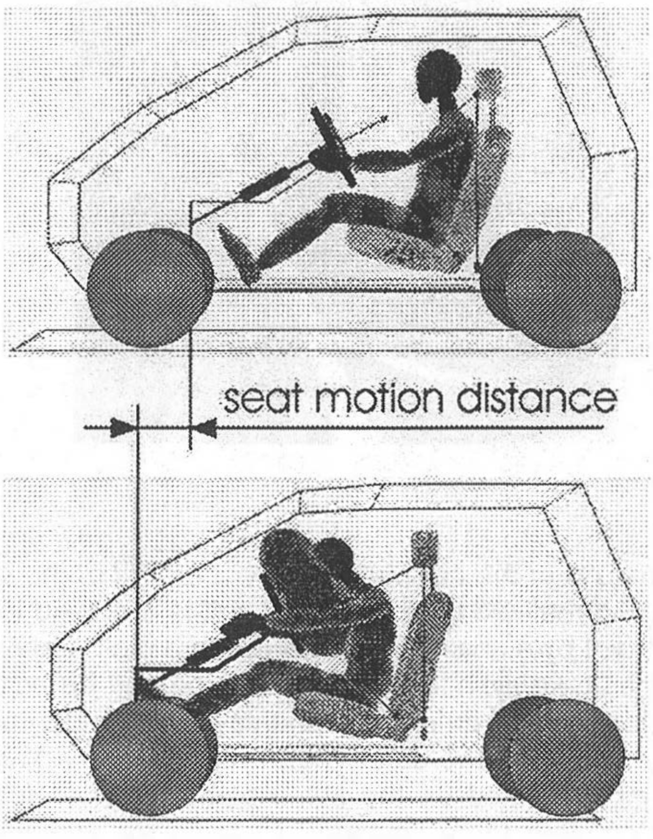
For analysing the combination and co-operation of the car's deformation load level and the seat system's restraint force level a three-dimensional mathematical model of a small low mass hard shell car has been generated using the rigid body calculation method of MADYMO™. A simple translation of the car's front part combined with a loading force characteristic simulates a short stiff deformation zone (hard shell belt system). The seat system can be moved on the vehicle's platform. The motion is limited after 350 mm. The restraint force depends on the occupant's weight. For the simulations and for the sled tests a HYBRID III 50% male dummy is used. The model is designed for this database.

The belt characteristic is rather stiff (6% strain) to guarantee a strong coupling of the occupant to the seat when being decelerated. For an optimised use of the short ride down distance the occupant has to be decelerated as early as possible. Therefore also two pretensioners are attached to the system (at retractor and at anchor point). With this solution lap and shoulder belt are tensioned rapidly. The required pretension distance is rather short. Furthermore, at the same places belt force limitation systems are attached to reduce the maximum forces of lap and shoulder belt.

Two variations have been carried out for the driver: The first concept deals with a steering wheel that is connected to the seat system. The steering assembly moves forward together with the seat. Within the second solution the steering wheel is fixed to the car structure but can be moved forward and deformed when being forced. In both cases an airbag is fitted to the steering wheel. The footroom is moved together with the seat. This might not be necessary, because the lower regions of the human body (legs and feet) are able to withstand much higher load and deceleration levels than the upper regions. Therefore it would be another solution to break apart the footroom from the seat system and to put a higher level of deceleration on the feet.

It was the aim to validate the simulations by sled tests. Focus has been laid on the front impact with 100% overlap against a rigid wall or a deformable barrier. The system has been tested at different crash velocities and with variations of restraint parameters and characteristics. Figure 1 shows two steps of the simulation animation. The relative movement of the seat system can be seen.

Fig. 1 - two steps of simulation animation (MADYMO™) (before and after seat motion)

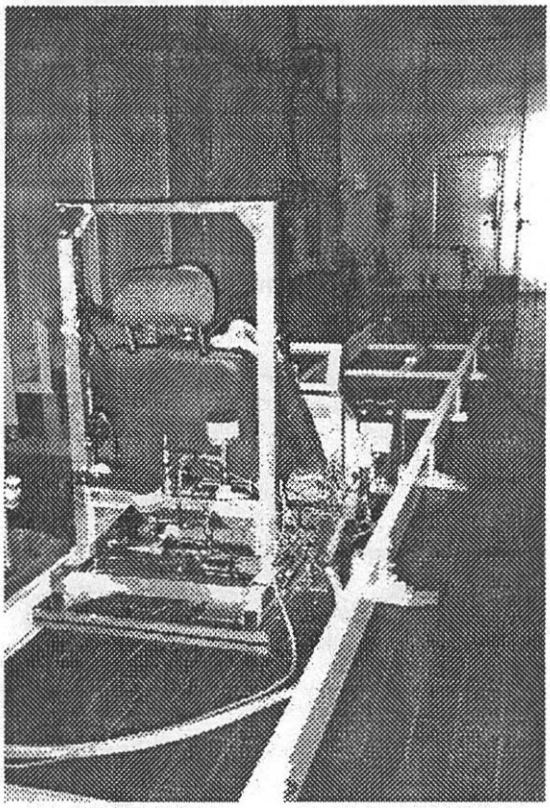


The aim of the numerical simulations was to get some optimised parameters for the restraint system components.

SLED TESTS

For carrying out various studies on restraint systems a crash sled was designed by members of the Institute for Mechanics earlier. It is a platform where experimental constructions can be placed. It can move on guide rails. The sled is pulled by a bungy rope towards a barrier where several brake systems or deformation elements can be fixed (see Figure 2).

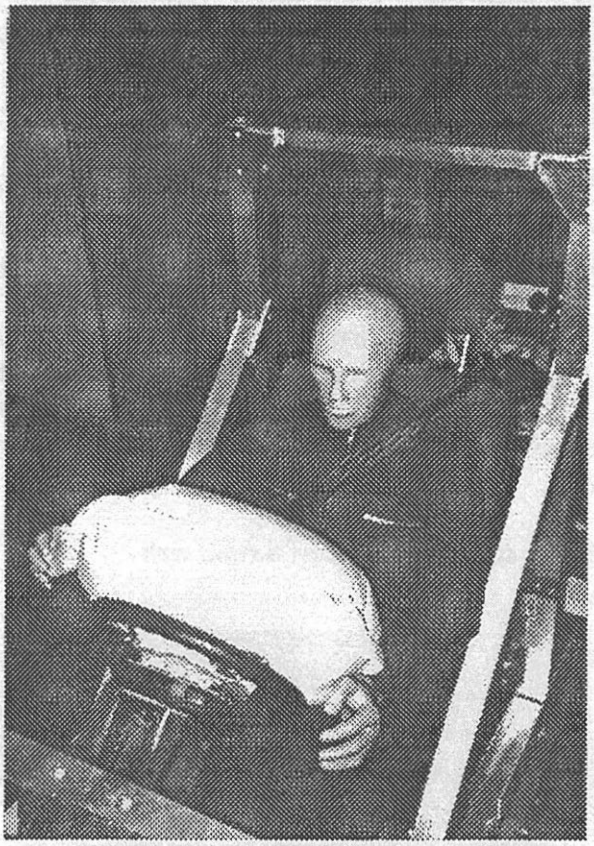
Fig. 2 - crash sled with platform, guide rail and barrier zone



Regarding the results of the calculations a real model of the seat system has been constructed and realised by a seat sled that is attached to the main sled. The system is restraint by a chain that winds up on a disk brake. By varying the fluid pressure in the brake cylinders the brake force can be adjusted. The seat sled is also a platform where different elements can be mounted: the seat, the steering assembly, a bar for the safety belt system. In this first testing phase the steering assembly is fixed on the same platform. Therefore it is coupled with the seat motion. Belt force limitation systems for shoulder and lap belt have been realised by hydraulic cylinders. The limitation force can be adjusted by over pressure valve.

The airbag is blown up stationary by compressed air because of the possibility of using it for several times. Additionally an explosive airbag generator can also be used if the system is proved adequately. Figure 3 shows the restraint systems on the sled.

Fig. 3 - restraint systems on the seat sled



Until this paper was written only tests with low crash velocities of up to 25 km/h have been carried out because the system has to be checked first. At nearly constant ambient temperature the bungy rope offered good reproducible tension characteristics.

For a high deceleration level crash tubes are used as a deformable barrier. The disk brake for the chain restraint system can be adjusted easily but showed a considerably high peak of break off force resulting from the moment of inertia and from coulomb friction. But the seat sled for the test is heavier than it would be in reality, so this is more or less a positive effect.

According to the results of the numerical simulation at different speeds (up to 25 km/h) sled tests have been executed for reasons of comparison and adjustment.

COMPARISON WITH REAL TESTS

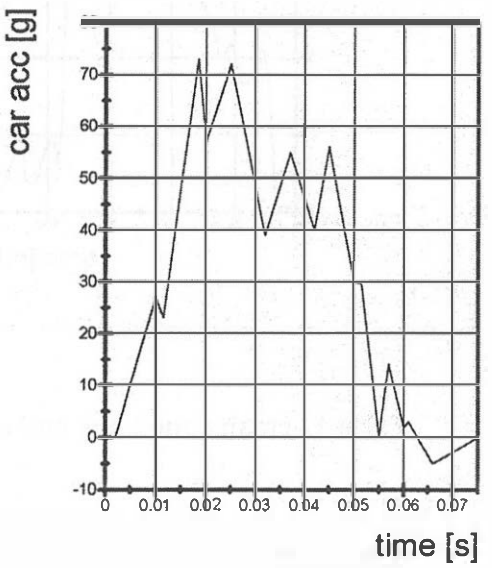
The results of the sled tests have been used to validate the mathematical model. Therefore the measured acceleration of the sled test was used as a crash pulse acceleration field being effective on the occupant. With the updated model further studies and variations have been calculated.

For comparison the crash pulse of a real test conducted by the Working Group of the Swiss Federal Institute of Technology and the University of Zurich has been used: It was a front crash of a low mass hard shell vehicle (called "Crashy") against a deformable barrier (US side impact barrier) at a speed of 71 km/h (Kaeser, 1995). This test has been carried out to analyse the behaviour of a stiff lightweight structure with a rigid crash belt system (crash or deformation zone around the vehicle) and the effectiveness of the restraint systems inside the car. Figure 4 shows the vehicle at an earlier test at 40 km/h against the rigid wall.

Fig. 4 - LMV crash test at 40 km/h against a rigid wall

For calculation the concept of the structure of this low mass vehicle has been taken over by applying the measured crash pulse on the MADYMO™ model with the moveable seat system (see figure 5).

Fig. 5 - deceleration of LMV crash test
(test at 71 km/h against a deformable barrier)



For the model a 60 litre airbag is used. Pretensioners and force limitation systems are applied to the retractor and to the anchor of the safety belt system. Each of them can be switched on or off to analyse the influence. The force limitation of the lap belt is about 3.5 kN, the maximum distance is 100 mm. The limitation of the shoulder belt is about 6.6 kN, the maximum distance is 160 mm. The maximum seat sled riding distance is limited at 350 mm.

In the first model the steering system is attached to the seat system which means that it is moved strictly together with the seat and with the occupant. The results can be seen in figure 6 to 8.

Fig. 6 - resultant acceleration of pelvis (steering assembly on seat system)

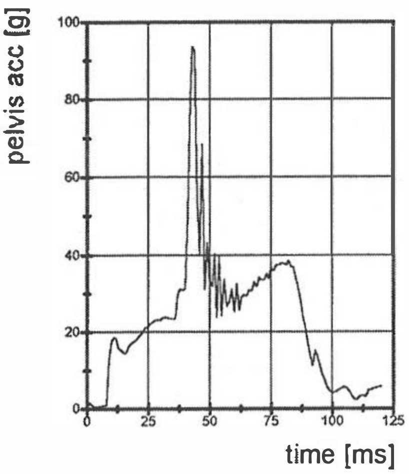


Fig. 7 - resultant acceleration of chest (steering assembly on seat system)

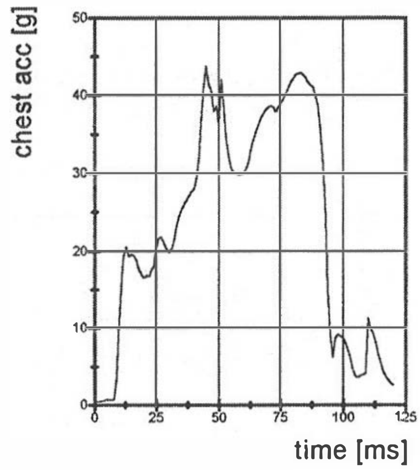


Fig. 8 - resultant acceleration of head (steering assembly on seat system)

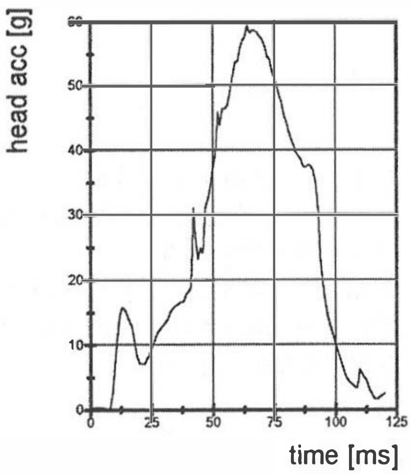


Table 1 - crash conditions and results

conditions:	
crash velocity	71 km/h
total deformation (barrier + front structure)	450 mm
results:	
seat motion	290 mm
pelvis (3ms)	530.9 m/s²
chest (3ms)	418.1 m/s²
head (3ms)	571.7 m/s²
HIC (36ms)	633.9

In the second calculation model the steering assembly is attached to the car body but it can deform when being forced by the upper torso and head. This solution may be easier to realise within a vehicle.

Fig. 9 - resultant acceleration of pelvis (decoupled steering assembly)

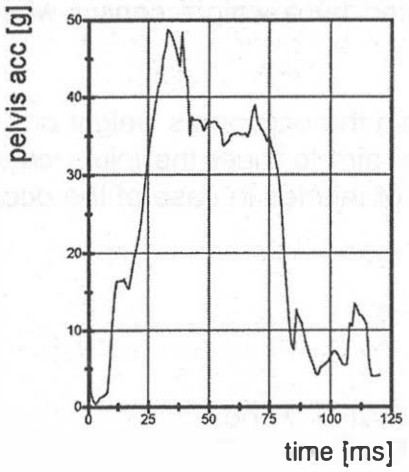


Fig. 10- resultant acceleration of chest (decoupled steering assembly)

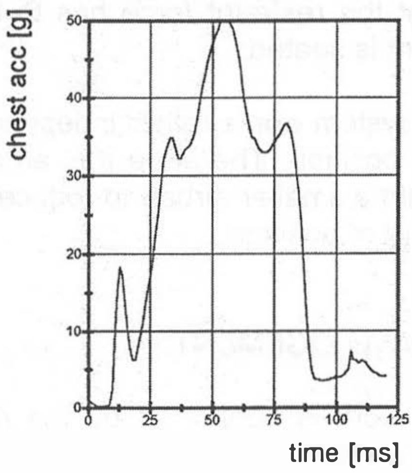


Fig. 11 - resultant acceleration of head (decoupled steering assembly)

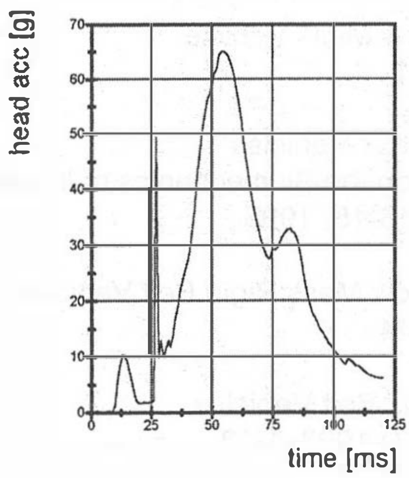


Table 2 - crash conditions and results

conditions:	
crash velocity	71 km/h
total deformation (barrier + front structure)	450 mm
results:	
seat motion	280 mm
pelvis (3ms)	457.9 m/s²
chest (3ms)	488.0 m/s²
head (3ms)	632.2 m/s²
HIC (36ms)	542.8

The second concept offered better protection to the pelvis region by distributing the deceleration load on chest and pelvis.

This test can be compared with the conditions of the US NCAP test (impact speed of 35 mph against rigid wall, 100 % overlap). The results would clearly fulfil the injury criterions of this test condition.

CONCLUSIONS

The results of the calculations and of the sled tests that have been carried out until now seem to prove the high potential of increasing the occupant safety by a moveable seat system inside a car. As far as no uncontrolled intrusions occur within a hard shell vehicle the passengers surrounding area stays intact and can be used for optimised deceleration of the occupants. Only a short distance is necessary to achieve that. Because of the influence of the load on the seat the restraint force has to be adjusted by a weight sensor when the occupant is seated.

The system works rather independently from the occupants weight or size or seating position. Therefore it is an additional aim to meet the injury criterions even with a smaller airbag to reduce the risk of injuries in case of the occupant being out of position.

ACKNOWLEDGEMENT

This work is supported by the Austrian FWF - Fonds zur Förderung der wissenschaftlichen Forschung (FWF-Project P-10788-ÖTE).

REFERENCES

Kaeser, R. et al
Collision Safety of a Hard Shell Low Mass Vehicle
IRCOBI Proceedings 1992, 133-142

Kaeser, R. et al
Passive Safety Potential of Low Mass Vehicles
International IRCOBI Conference on the Biomechanics of Impact, Brunnen/Switzerland, September 13-15, 1995

Niederer, P. et al
Compatibility Considerations for Low Mass Rigid Belt Vehicles
IRCOBI Proceedings 1993, 434-444

Niederer, P. et al
Occupant Safety of Low Mass Rigid Belt Vehicles
Stapp Conference Proceedings (37) 1993, 1-13

Spieß, O.:
Wie kann die passive Sicherheit von Leichtfahrzeugen erhöht werden?
Haus der Technik, Essen, May 22/23, 1995

Walz, F.:
Results of the Crash Test of the AGU-Light Weight Vehicle CRATCH Against Renault Laguna; September 24,1996