OCCUPANT KINEMATICS DURING EMERGENCY BRAKING

An investigation with regard to the Out of Position issue for Passengers

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ABSTRACT

This study investigates kinematics of a belted passenger during emergency braking. In a test series it was experienced how close a belted occupant on the passenger seat could come to the instrumental panel with the undeployed airbag during an emergency braking. Two driving manoeuvres with different seating postures which were judged to be very likely in pre impact phases were simulated with a volunteer test person on the passenger's seat. Purpose of this study was to gain experimental data about occupant kinematics in pre crash situations rather than re-run real world incidents and injuries.

SINCE THE AIRBAG HAS BECOME more popular not only for drivers of motor vehicles but also on passenger side – and in the U.S. legislation requests a passive protection system for forward facing outboard seating positions in passenger cars – airbag induced injuries and even fatalities caused by the deploying airbag have been reported with increasing figures. Looking to the development process of airbag systems, it is found that this is performed using standard dummies in standard seating positions i.e. mid seating position for the 50th percentile male, front seating position for the 5th percentile female and rearward seating position for 95th percentile male dummy. Additionally static "Out of Position" testing is conducted to demonstrate that there is no harm from the airbag.

Monitoring real world crashes, it is found that in a vast majority of cases the actual crash follows some kind of emergency reaction from the driver, mostly hard braking and/or a deviation manoeuvre.

How would a belted passenger who is "passive victim" move in these manoeuvres and which position related to the passenger airbag would he be in at the time of deployment? Could it result in a dynamic Out of Position condition the passenger is exposed to?

To answer the questions above a test program was established and performed.

GENERAL CONDITIONS

The overall objective within the limitation of a study was to most closely simulate real world pre-crash conditions. This means that from the variety of possible driving manoeuvres, the most likely ones needed to be selected. Another item to be discussed was who should be the "passenger". Taking into account all advantages and disadvantages of using a dummy it was decided to run the test program with a volunteer. Main aspect for this decision was that the movements of a crash test dummy under low loading condition would not be adequate to represent the movements of a human body under same conditions.

TEST MATRIX

The test matrix was established taking into account driving manoeuvres, seating positions and seat belt usage. In order to keep the program practicable two most likely driving manoeuvres were selected: Emergency braking from 80 km/h to stand still and emergency braking from 80 km/h to stand still including a deviation manoeuvre. They would each be performed on an even and uneven road surface. In pilot tests 80 km/h was found to be an appropriate initial speed which would not cause an extensive risk for the occupant i.e. impact to interior parts of the test vehicle forward of the occupant.

Driving Manoeuvre 1	Emergency braking from 80km/h, no deviation, even road surface
Driving Manoeuvre 2	Emergency braking from 80km/h, deviation, even road surface
Driving Manoeuvre 3	Emergency braking from 80km/h, no deviation, uneven road surface
Driving Manoeuvre 4	Emergency braking from 80km/h, deviation, uneven road surface

Figure 1: Driving Manoeuvres

For several reasons and after long discussions it was decided to use only one adjustment position for the seat. Seating positions from respective European and American standards were considered. As the tests were carried out on an outdoor proving ground, the adjustment of the seat with an H-point-measuring-machine was not practicable. Therefore the positioning of the seat as described for a 50^{th} percentile male dummy in FMVSS 208 was chosen. In the following this seat adjustment will be called "standard adjustment".

With regard to real life the occupant should take different postures in the seat. Also the influence of belt slack should be considered. In an earlier study (K. Pilatus, D. Oertel, J. Fischer: Seat Belts and Head Restraints: The Daily Use, 1997 International IRCOBI Conference, Hannover) a slack of 80 mm was found to be a reasonable average.

Seating Posture 1	Standard seat adjustment, no belt slack
Seating Posture 2	Standard seat adjustment, 80 mm belt slack
Seating Posture 3	Standard seat adjustment, passenger turned to the rear
Seating Posture 4	Standard seat adjustment, incorrect guidance of diagonal belt
Seating Posture 5	Standard seat adjustment, diagonal belt slipped off the shoulder

Figure 2: Seating Postures

In addition other seating postures were examined but they were judged too risky as to be included in the actual test matrix. In the posture shown in the left example below the occupant would contact his knees with his head. In the second example the initial position is already close to the instrument panel and head impact to the instrument panel must be expected during test causing possible injuries to the volunteer.

Figure 3: Examples of not tested seating postures

TEST SETUP

As a test vehicle an Audi A4 would be used. In order to receive sufficient information about the kinematics of the passenger the needed some preparation i.e. cameras and transducers.

CAMERA EQUIPMENT

The initial question about the camera equipment was whether or not high speed film cameras had to be used. During some pre-test it was found that the events to be monitored would not require HS-cameras so it was decided to use ordinary VHS camcorders. However they had to be mounted on the vehicle. Two cameras were found to be necessary: One to take pictures from the rear (lateral movement of the occupant) and a second one to monitor any occupant motion in the x/z plane. The camera for the lateral motion of the occupant was mounted on a rig in behind the rear seats.

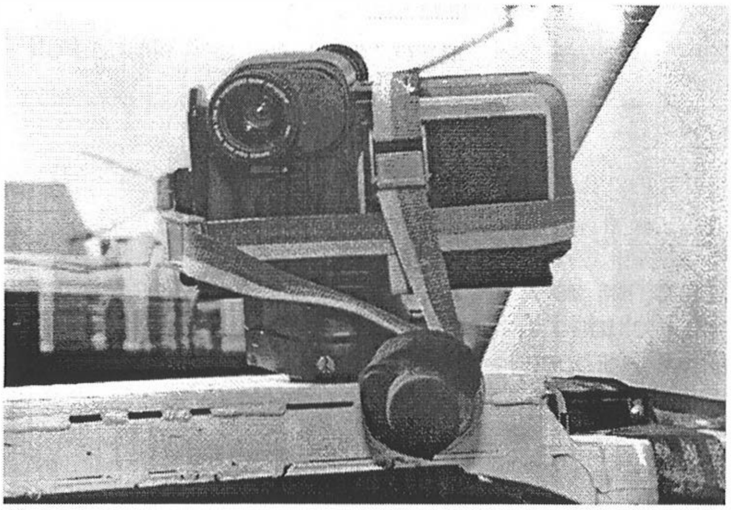

Figure 4: Rear View Camera

The second camera which should monitor the horizontal movement of the occupant had to be mounted on a frame work outside the vehicle.

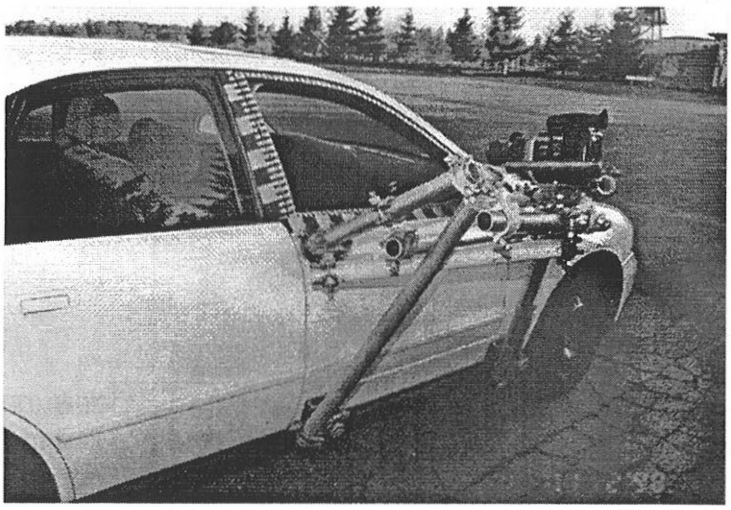

Figure 5: Side View Camera

INSTRUMENTATION

In addition to optical records accelerometers and belt load cells were used to collect data from the test. Two accelerometers recorded vehicle accelerations in x- and y-direction and the belt load cell recorded the response of the belt system. Another important figure to record was the forward displacement of the occupant or the remaining distance head to instrument panel respectively. For this purpose a string method was used which is quite common in the field of ECE-R16 dynamic tests. In order to fix the string to the occupant some kind of harness was designed and sewn which the occupant would wear during the tests. Three displacement figures were collected: left and right shoulder and head.

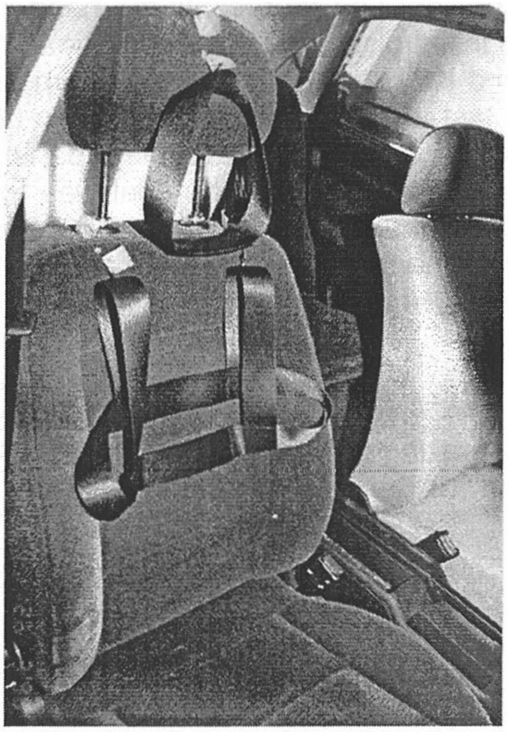

Figure 6: Harness

TEST VEHICLE AND PROVING GROUND

For the tests an Audi A4 was used which is quite a common mid size family car. All test were carried out on a proving ground near Munich which offers the sufficient space for the driving manoeuvres.

EVALUATION PARAMETERS

The evaluation of the remaining head to instrument panel distance was based on a method demonstrated below.

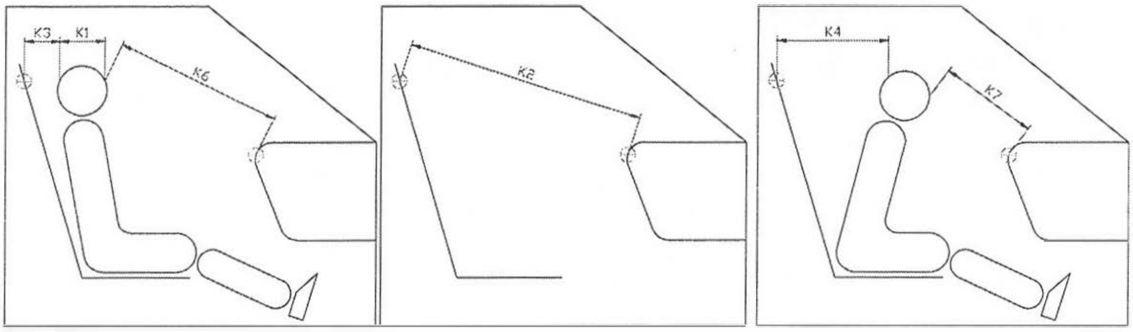

Figure 7: Evaluation Parameters

Distance K1 is constant and represents the head diameter of the volunteer. K3 represents the initial distance from the aft head to the reference point on the head restraint and K6 is the initial distance from the forehead to the instrument panel prior to test. K2 is the shortest distance between the reference points on the head restraint and on the instrument panel. When the volunteer took position in the vehicle for each test the goal was to keep K3 and K6 as constant as possible during the test series. K4 and K7 finally are figures which will demonstrate the movements of the occupant during the tests where K7 is calculated with the following equation:

$$K7 = K2 - (K1 + K4)$$

In an emergency braking the head and shoulder excursion occurs in an arc about the pelvis, but for the purpose of this analysis linear behaviour has been assumed.

TEST RESULTS

Referring to the test matrix above the total number of test scenarios amounts to 20. In order to achieve some kind of continuity with the results the objective was to perform 3 test for each of the 20 scenarios. However when running the test it appeared that for some scenarios the occupant got almost in contact to the instrument panel and it was decided to skip a repetition in order to avoid any injuries. The test results reported in this study can not give – and do not want to – firm values about forward displacements of an occupant but they show tendencies.

TEST SERIES 1

In the first test series the driving manoeuvre was a straight emergency braking on an even road surface from 80 km/h to stand still. The occupant sat in a standard position. So this series can be looked at as base tests.

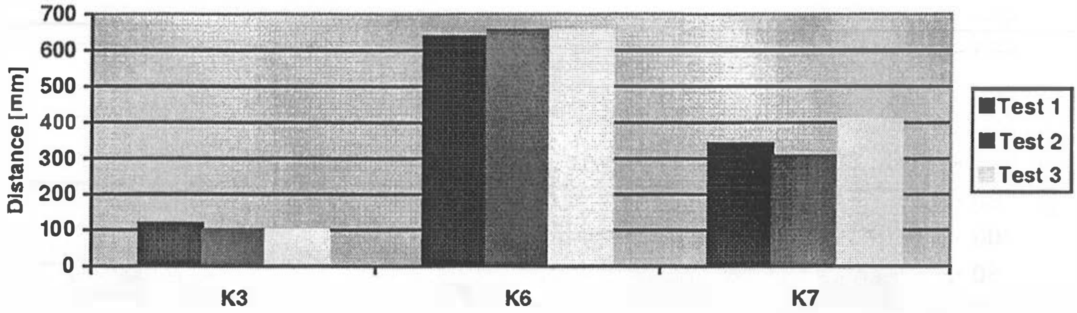

FIGURE 8: REPEATABILITY OF INITIAL SEATING POSTURES

K3 and K6 in the diagram above indicate the initial seating position and show that in a small tolerance band it was the same through all tests of this series. K7 represents the shortest head to instrument panel distance during the tests.

Figure 9: Most Forward Head Position in Test Series 1

In the following results of the other test series will be presented in two ways using only the most important figure K7 which represents the minimum head to instrument panel distance in the tests. K7 will be given as an average figure from the test carried out in each series. Firstly influence of the different seating position as explained earlier will be demonstrated per driving manoeuvre and subsequently influence of the different driving manoeuvres per seating position will be shown.

INFLUENCE OF SEATING POSITIONS

The diagrams below show that for each driving manoeuvre the seating position is extremely influent how close a belted passenger can get to the instrument panel. Especially postures quite frequently observed on long journeys when the passengers turn around to talk to rear seat passengers or the shoulder belt had slipped off the shoulder (seating positions 3 and 5) proved to be risky in terms of the front passenger getting close to the instrument panel. The same applies to a possible kind of misuse of the seat belt (position 4).

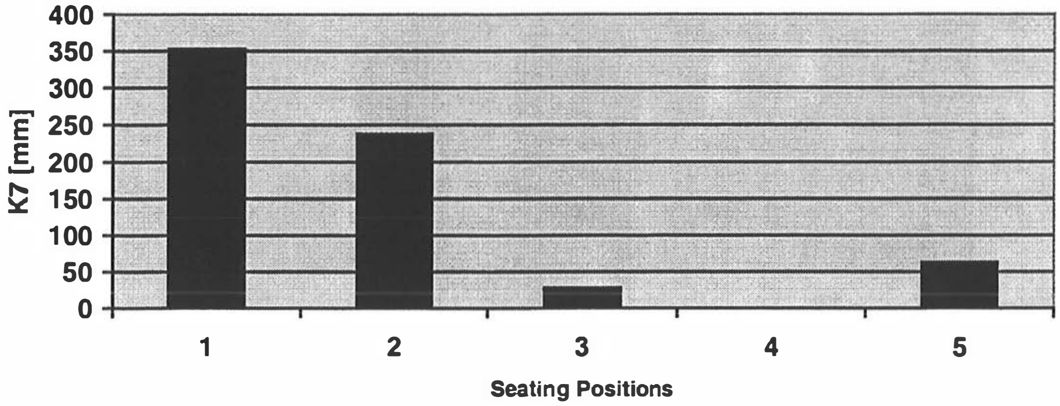

Figure 10: K7 During Straight Braking on Even Surface

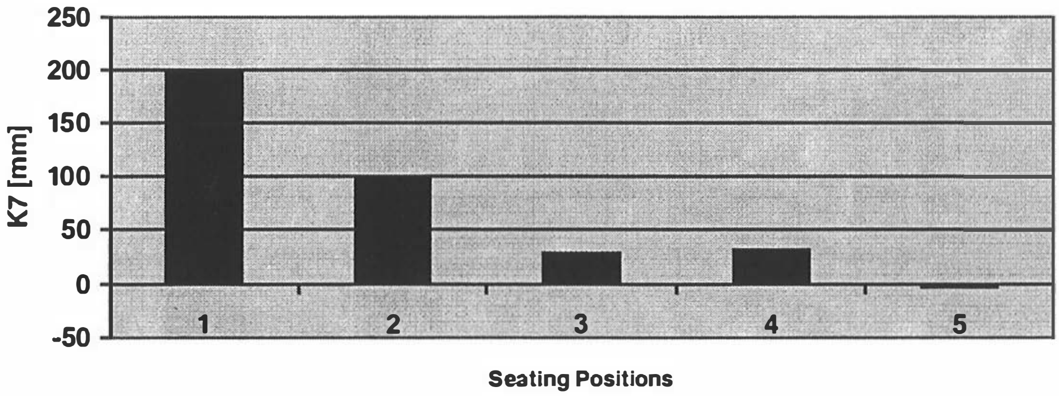

Figure 11: K7 During Braking plus Deviation on Even Surface

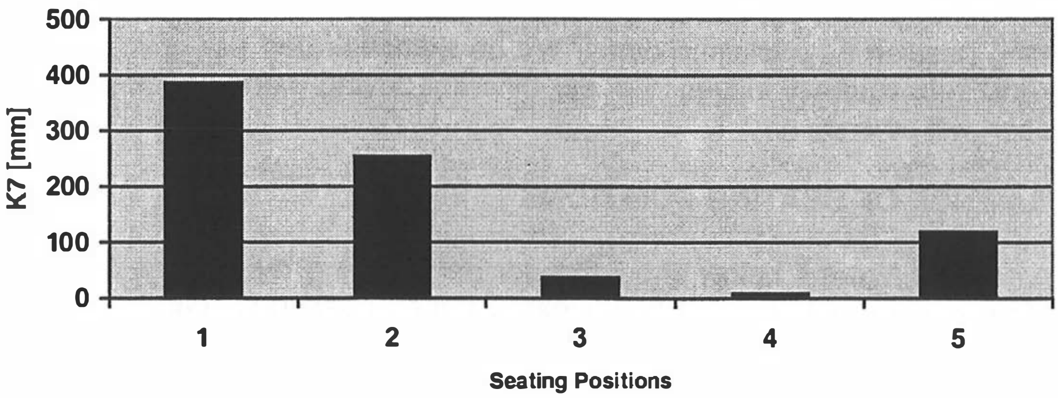

Figure 12: K7 During Straight Braking on Rough Road

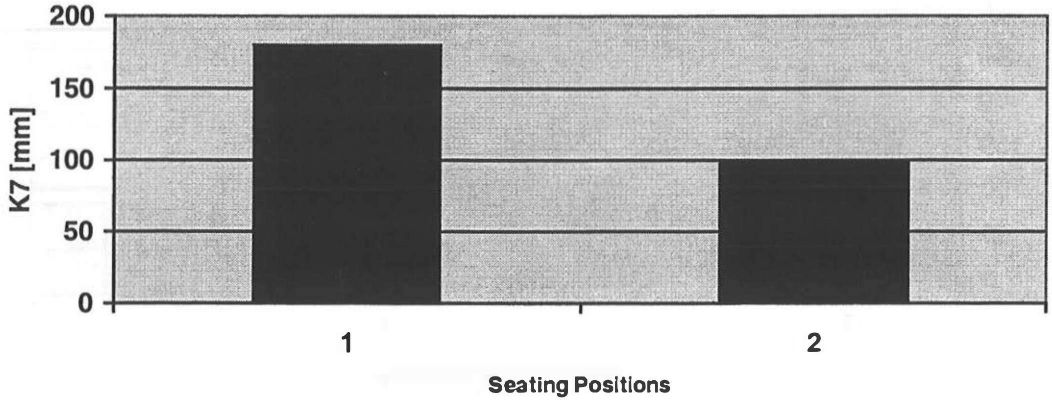

Figure 13: K7 During Braking plus Deviation on Rough Road

Notes:
- Negative figures are due to the fact that K7 is a calculated value; they actually mean contact to the instrument panel;
- The last driving manoeuvre was carried out only for two seating positions as the three others were judged to be too dangerous.

INFLUENCE OF DRIVING MANOEUVRES

The figures 14 and 15 show that a front passenger normally seated with and without slack in the seat belt system gets closer to the instrument panel if the emergency braking is accompanied by a deviation manoeuvre. Influence of the road surface seems to be marginal.

In case of incorrectly worn seat belts or other than standard seating positions there is independently from the driving manoeuvre a risk for a front passenger to get very close to the instrument panel.

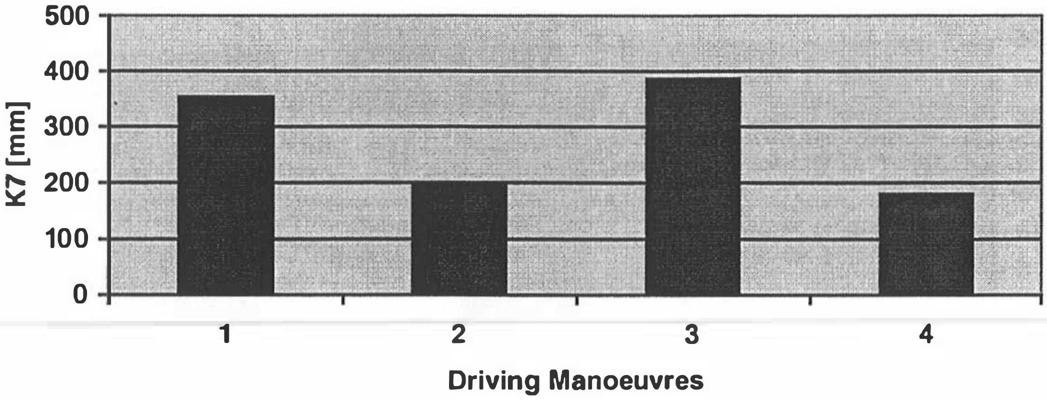

Figure 14: Standard Seating Position

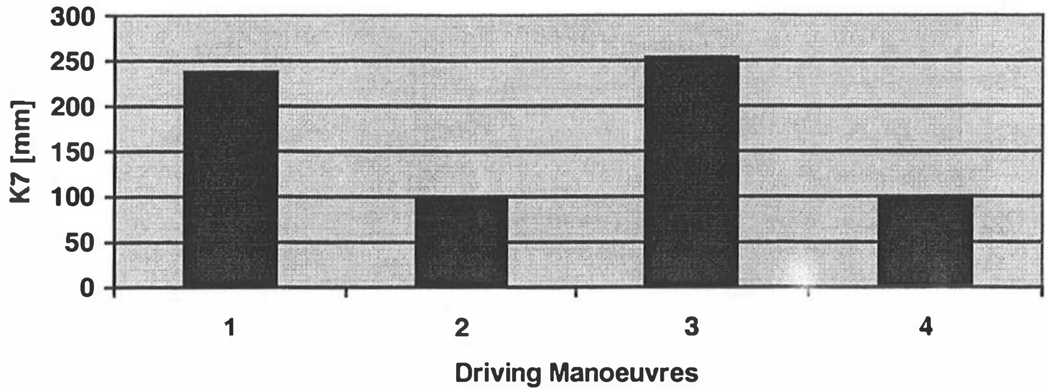

Figure 15: Standard Seating Position Plus 80 mm Belt Slack

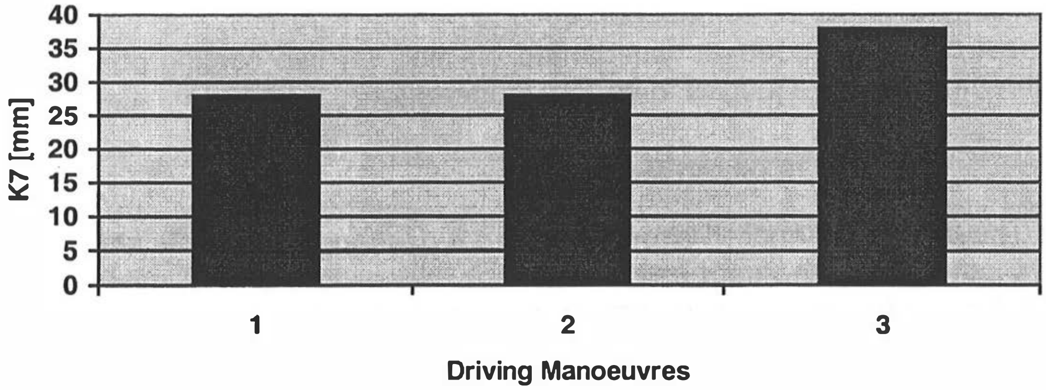

Figure 16: Passenger Turned to the Rear

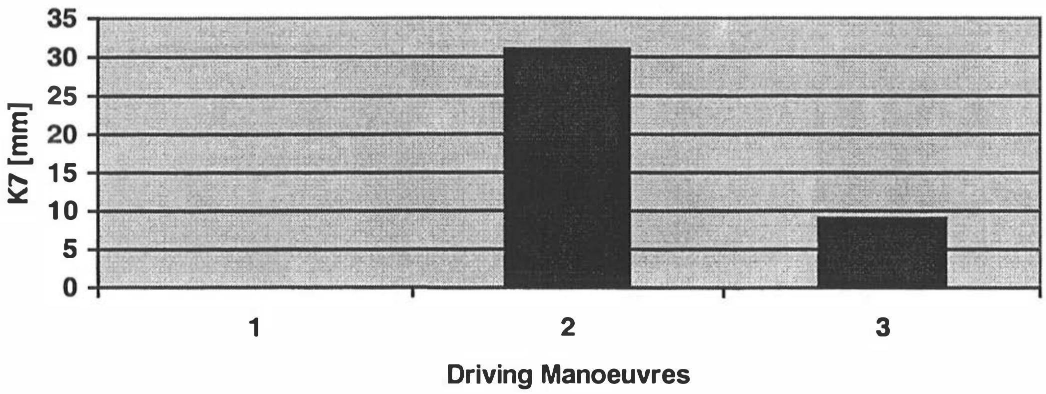

Figure 17: Misuse: Diagonal Belt under Shoulder

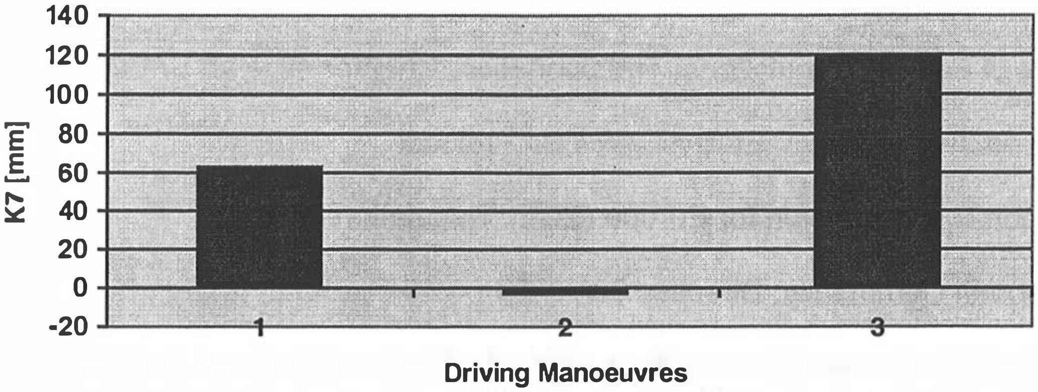

Figure 18: Diagonal Belt Slipped off Shoulder

SUMMARY

Although this study does show only tendencies and a volunteer after experiencing a couple of test does show defence reactions, it demonstrates that emergency braking is extremely influent for the posture of a belted front passenger.

An average adult passenger (comparable to a 50th percentile dummy) seated normally with the seat in mid and lowest position, seat back angle about 25°, and correctly belted in any of the performed tests the passenger does not get very close to the instrument panel during straight emergency braking manoeuvres. In case there is a combined braking and deviation manoeuvre it was observed that this passenger could slip out of the seat belt which gets him very close to the instrument panel. For a normally seated average passenger the influence of the road surface was found to be marginal.

Front passengers in postures other than standard seating positions are exposed to the risk of getting very close to the instrument panel even in straight emergency braking. A combined deviation manoeuvre increases the risk.

Similar observation was made in cases when the seat belt and especially the diagonal belt could not develop its full restrain abilities. This can easily occur due to slack in the seat belt system or careless use of the seat belt.

As stated earlier this study can only show tendencies but it could initiate more detailed studies on this subject and results should be considered for the design of new passenger airbag systems.

Furthermore it shows that only correctly worn seat belts can offer the best protection in combination with an airbag system.

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