DEVELOPMENT OF A SLED SIDE IMPACT TEST FOR CHILD RESTRAINT SYSTEMS

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ABSTRACT

Currently the majority of Child Restraint Systems (CRS) in the UK are approved to ECE Regulation 44 Amendment 03. This focuses on the crash performance of the CRS under frontal and rear impacts and does not include a sled side impact test.

Although standards from Australia and New Zealand have for some time contained such a test, they do not include an element reproducing the effects of intrusion. Intrusion is a major factor in serious and fatal injuries to children in CRS. This paper describes a research programme conducted to develop a simple side impact test which attempts to reproduce the effects of side structure intrusion on a CRS installed in a car on the struck side. A hinged door was mounted on the Middlesex University test sled, which, when opened contacted a CRS restrained on the ECE R 44 test seat mounted laterally on the sled. The door was opened under impact conditions when it struck an auxiliary impactor at the beginning of the sled deceleration phase. The chest and head response of ATDs restrained in current and prototype CRS was measured. These were compared with full car side impacts conducted at TRL. The results suggested that the peak response of the ATD was representative of the car/barrier impacts but the energy input to the CRS as a function of time needs more development.

INTRODUCTION

Analysis of accidents in which child occupants of vehicles were killed or seriously injured indicates that side impact incidents are potentially more serious in terms of occupant outcome than the more common frontal incident [1]. Adult belt retained CRS, widely sold and used in the UK, are presently all approved to the European standard ECE R44, currently to amendment 03. This standard, although comprehensive and exacting in most respects, does not incorporate a dynamic evaluation of CRS in a side impact scenario. It is only in certain antipodean countries that CRS are evaluated in such an impact type [2]. However even these tests do not reflect fully the dynamic effects observed during actual lateral car to car impacts, as they do not include the effects of the intruding structure.

OBJECTIVE

The objective of the work conducted in this study was to ascertain the practicability of developing a simple and reproducible side impact test with intruding side structure. The input to the child occupant is representative of that seen during typical vehicle to vehicle perpendicular side impact collisions. It is intended that the test be capable of being conducted on a single sled as described below, which is of a type used widely by organisations involved in the CRS industry in the UK. The research is being performed as a contribution to the development of an international standard for the side impact testing of child restraints through ISO.

DYNAMIC TEST FACILITY

Testing was conducted at the dynamic test facility of Middlesex University's Road Safety Engineering Laboratory*.

The dynamic impact test rig consists of a 'bungee' propelled, rail mounted sled which is decelerated by, in this instance the appropriate ECE R44 polyurethane deceleration tubes and olives. The facility was designed to be particularly suitable for routine dynamic testing of adult and child restraints and has been described in detail elsewhere [3]. Manikin head/chest (tri-axial) and sled (uni-axial) accelerations were routinely recorded and in addition, where appropriate, belt forces and loads imparted by a restraint system upon its fixings. Kinematic motion of both manikin and sled throughout the event were recorded using high speed video equipment. Standard data processing techniques were employed during the analysis.

IMPACT DIRECTION AND SEVERITY

ISO has concluded, from a review of accidents, that it would be appropriate for a test procedure to be developed

*Impact sled now located at TRL.

that would represent a perpendicular car side impact of 50kph [1]. It was hence determined that the sled based test should represent the important conditions of such an impact, with the possibility for child occupant on either the struck or non struck sides. The basic parameters to which the sled test needed to conform were established by a series of full scale vehicle tests employing six vehicles in the average mass range described in [1], being struck by a trolley with a deformable front structure of mass 950kg similar to the struck vehicles.

The resulting post impact plastic deformation of the struck vehicles was established in the area of the rear seated child occupant by measurement, which showed a characteristic side impact deformation. The profile of the interior intrusion was found to be minimal at the 'C' pillar, and maximum near the 'B' pillar / front edge of the rear seat cushion, the surface of the rear door inner panel / trim remaining basically flat. The rear door essentially folded in around the rear door rebate in the latch area, (Figure 1). If the front seating position were to be simulated, the intrusion effect would be reversed, with again peak intrusion at the 'B' pillar, and minimal intrusion at the 'A' pillar.

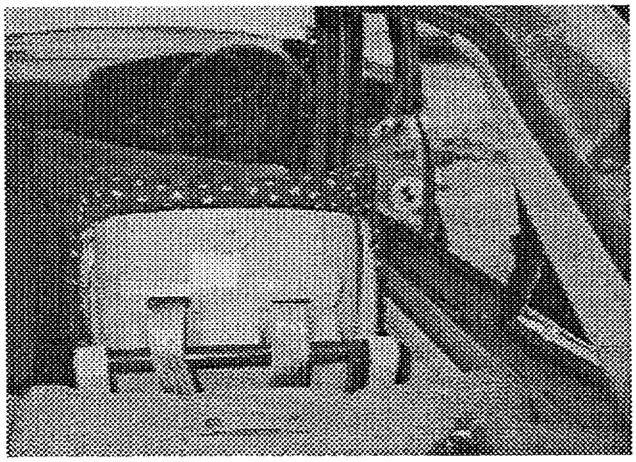

Figure 1 Deformation of vehicle side structure

In addition to accelerations experienced by the manikin at the head and chest, the lateral accelerations of the vehicle shell at the non struck 'B' pillar, and both the CRS and intruding door or side structure were recorded.

The following figures detail the derived angular velocity of the intruding rear door surface or side structure during the events, in addition to the lateral linear acceleration of the struck (initially stationary) target vehicles.

Based upon this range of data from the six test vehicles, corridors were established for both intrusion panel angular velocity and linear lateral acceleration of the struck vehicle against time. These corridors formed the foundation of the rig test requirements.

SLED TEST SET UP

The standard ECE R44 test seat was mounted longitudinally on the sled.

An intrusion panel was hinged on a structure at the front of the test seat (the hinges being perpendicular to the test seat cushion) which when fully 'open' latched into position (at 17.5°). The hinge line of the panel was in a position similar to the door rebate of the vehicle 'C' pillar with respect to the occupant.

Although it is not possible to reproduce totally the complex interactions of a full scale side impact on a single sled, this methodology attempts to generate the important separate dynamics of the intruding structure and the chassis acceleration in a standardised test for child restraints. The test sled with seat and anchors reproduces the dynamics of the undeformed struck car structure, while the intruding 'door' structure reproduces the dynamic intrusion.

Reproducing the events observed in the vehicle tests requires two basic tasks; firstly rapidly accelerating the intruding door structure into the seated occupant at an angular velocity commensurate with the data given in Figure 2, and secondly accelerating the seat bench from under the occupant in line with the lateral acceleration characteristics seen in the vehicles as seen in Figure 3.

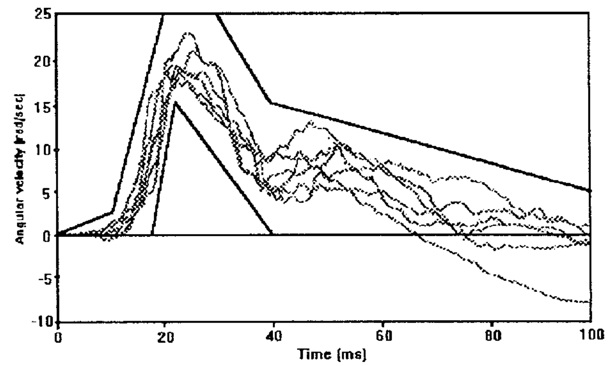

Figure 2 Angular velocity of a hinged plane simulating the vehicle side structure intrusion calculated from full scale impact tests

The timing of these two events is critical to reproduce the scenario of events seen in the vehicle tests.

With regard to manikin response, other factors must be considered, particularly stiffness of structures, seat and other contacting surfaces.

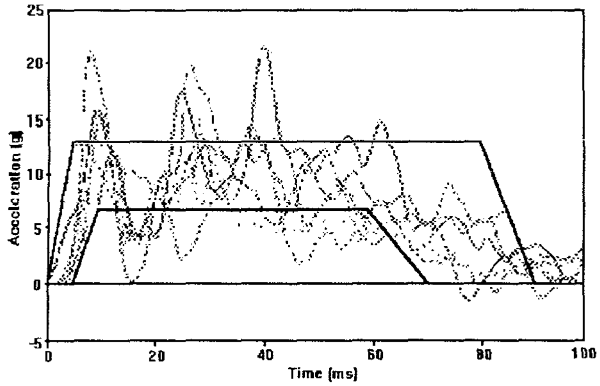

Figure 3 Lateral acceleration of target vehicle

Lateral acceleration of the sled from under the occupant can be achieved relatively simply by employing deceleration of the sled. The impact velocity of the sled was 25kph (6.9m/s), thus reproducing the post impact velocity of the target vehicle when impacted by a vehicle of similar mass travelling at 50kph.

It proved more difficult to achieve an angular velocity of the intrusion panel of at least 15 rad/sec relative to the sled. To open (and latch) the intrusion panel, a separate impactor with stiff rubber spring on its end was employed. The problem with a set-up of this type is that the deceleration of the sled over approximately 0.5m predominately takes place after the contact between intrusion panel and its impactor. Unfortunately the maximum linear travel of the panel is considerably less than 0.5m. This means that after impact with the panel, the impactor must be moved away to prevent the panel from being ripped off.

Initially a simple mechanical lever system affixed to the head of the sled was employed to push the impactor away. Results of those initial tests were reported in [1]. The system proved sufficient to demonstrate the principles, but the angular velocity of the intrusion panel was insufficient.

The second series of tests employed an alternative intrusion panel impactor. Instead of being affixed to the head of the sled, the impactor incorporating a stiff rubber spring at its contact end, was free to 'fly clear' after impact with the panel (see figure 4). A design of this type gave the benefit of allowing the impactor to strike the centre area of the panel - a situation that was effectively impossible with the previous mechanical design. By striking at the calculated point of percussion it was found possible to increase the angular velocity of the panel without overloading the hinges. The characteristics of the initial spring stiffness and the door panel and impactor masses were established by mathematical modelling to realise the desired panel acceleration and angular velocity.

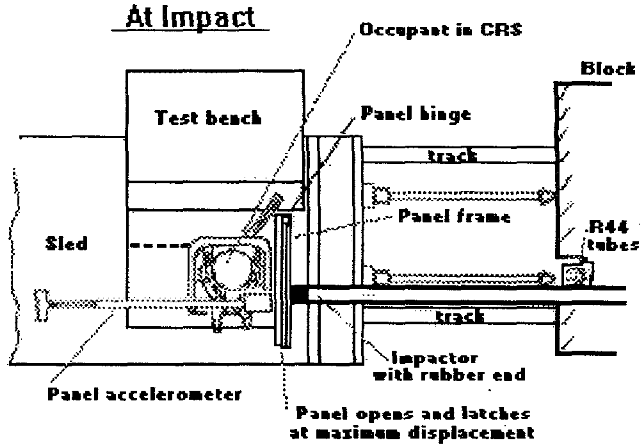

Figure 4 Final test set up (plan view)

PARAMETERS EVALUATED

In addition to the above mentioned parameters, manikin head, chest and CRS lateral accelerations were measured to allow comparison with the vehicle test results. The manikin employed in the comparative tests was a TNO P3, whilst in addition, a TNO P¾, was used in later CRS assessments [4].

DESCRIPTION OF CRS EVALUATED

For the comparative tests purposes, similar CRS were used in the sled and vehicle evaluations. At a later stage a range of alternative production belt retained and prototype CRS employing rigid fixings were evaluated. These later CRS were all based on the same moulded production types to facilitate comparison.

INITIAL COMPARATIVE TESTING

Having defined the door velocity profile and the sled deceleration, the mass and moment of inertia of the door were modified until close proximity of the results to the vehicle tests was obtained.

Figures 5 and 6 below show the initial comparative sled tests compared to the corridor defined by the full scale vehicle tests. It will be noted that in comparison with figure 2, the intrusion panel angular velocity traces only just reach the required minimum value. It will also be noted that the angular velocity of the door falls more rapidly than in the vehicle tests. Furthermore, the linear acceleration of the sled does not rise quite as rapidly as in the vehicle tests. Figure 7 shows the tabulated peak manikin response data obtained for the comparative tests.

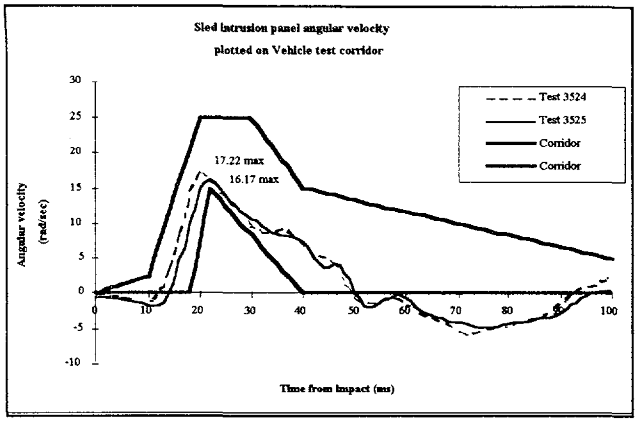

Figure 5 Angular velocity of intrusion panel

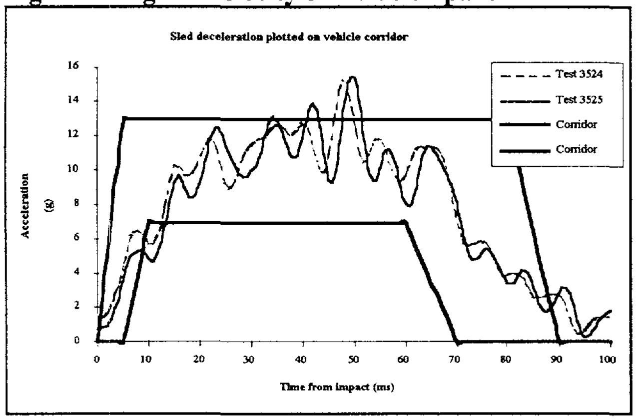

Figure 6 Linear sled acceleration

Figure 7 Manikin response in comparative tests

	Resultant 3ms chest acceleration [peak accel] (g)	Resultant 3ms head acceleration [peak accel] (g)	Lateral CRS acceleration [peak] (g)
Full scale vehicle test	56 [67]	42 [45]	118
Test 3524	65 [69]	61 [75]	103
Test 3525	66 [82]	61 [107]	85

It can be seen that the chest response in the sled tests is similar to that seen in the vehicle test whilst the head response is somewhat higher. This higher result is considered to be attributable to the higher position of the top of the hinged intrusion panel in the test in comparison with that in the particular model of vehicle used in the baseline test.

Even though the results have not been found to duplicate completely the vehicle test results, it was decided to proceed with an evaluation of a number of child restraint systems, both conventional and prototype, in direct comparison to the New Zealand side impact test NZS 5411, which it should be noted is conducted at a slightly higher velocity change of 32kph (8.9m/s).

	New Zealand test (8.9m/s impact)				Intrusion panel test (6.9m/s impact)			
	Test No	Chest resultant	Head resultant	head excursion	Test No	Chest resultant	Head resultant	lateral accel
CRS type		g	g	mm		g	g	g
Forward facing P3 manikin								
Conventional framed CRS					3524	65	61	103
L & D retained					3525	66	61	85
Conventional molded plastic CRS, L & D retained	3176	40	44	454	3535	52	46	85
Prototype CRS. Two rigid lower fixings + top tether	3198	26	35	320	3568	39*	30*	105*
Prototype CRS. Two lower straps + top tether	3177	32	35	527	3537	53	42	91
Rear facing P3/4 manikin								
Rigid molded plastic CRS, L & D retained	3239	31	39	600	3542	80	110	100
Molded polystyrene CRS, L & D retained					3541	105	107	108
Prototype CRS. Two rigid lower fixings + top tether	3237	27	25	387	3549	64	86	90
Prototype CRS. Two lower straps + top tether	3250	42	45	552	3554	66	85	103

* Door failed to latch. Results not comparable to other tests.

Figure 8 Intrusion panel tests vs non intrusion panel tests (ECE R44 03 belt anchor positions)

CRS EVALUATIONS

Figure 8 compares side impact tests, with intruding structure, with tests conducted to the existing side impact procedures without side structure.

The following observations can be made from the above results. Firstly with respect to the intruding structure test, it is evident that the size, mass and particularly the rigidity of attachment of the CRS is significant. The concern is particularly evident with the larger CRS employing rigid attachments, where insufficient energy is available to move or deform the seat sufficiently, a situation not evident in the vehicle tests. It can be seen that, although conducted at a lower velocity than the existing sled based side impact test, the effect of the manikin and CRS striking the intruded structure does, as expected, produce an increase in occupant deceleration levels. However, when reviewing the forward facing 15kg occupant, the increases are not large when compared with the lateral CRS acceleration levels. This can be attributed to the head and chest being in close proximity to the hinge about which the intruding panel rotates, and hence seeing contact at a much lower velocity, reflecting reality for the rear seat situation. The situation can be seen to be reversed when considering rear facing infants whose head is in close proximity to the vehicle 'B' pillar. In these cases, the head and chest acceleration levels, particularly in the case of less rigidly retained CRS are much higher. The lightest conventionally retained CRS demonstrates the highest levels of acceleration. It must at this point be noted that the manikins employed for these tests are relatively stiff, and have a limited neck structure. This effect has been observed in some full scale vehicle impacts performed in the EuroNCAP test programme[5].

This represents the impact conditions for a child restraint seated in the rear seating position of the vehicle. To represent the front seating position, the door should be hinged at the front edge to duplicate the intrusion pattern for the front seat. The relative effects on the rear and forward facing child restraints would then be expected to be reversed.

SUMMARY

It is apparent that the angular velocity of the intruding structure, although reaching the prescribed levels, is still low, and drops off rapidly. If Figures 2 and 5 are compared, it is apparent that a shortfall in kinetic energy exists in comparison to the full scale vehicle tests, particularly later in the intrusion panel travel.

Apart from modifications to the test to impart more energy to the intrusion panel later in the event, the remaining parameters that can affect impact severity and hence occupant response are panel mass and stiffness. These parameters need to be tuned to obtain the optimum desired CRS and manikin response levels equivalent to the full scale vehicle tests.

CONCLUSION

The concept of an intruding panel side impact test does offer potential advantages over current performance evaluations for existing CRS retained by adult belts in rear seating positions. However the test, as presently proposed, does not seem to impart sufficient energy to evaluate adequately the very rigidly retained CRS proposed in the near future (ISOFIX) .

This test procedure will, however, offer an opportunity to assess more realistically the lateral impact performance of CRS, particularly rear facing infant carriers in the rear of vehicles where the child's head is positioned in close proximity to the area of maximum potential intrusion in a side impact. A modification to the test arrangements would be necessary to evaluate the performance in the front seating position.

The preliminary sled test findings relating to rear facing infant carriers detailed here, supported by observations made during the recent EuroNCAP tests, indicated a significant potential risk of head and chest injury in a side impact when positioned on the struck side in rear seating positions.

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