



Improving the design of seats and tables, and evaluating restraints to minimise passenger injuries (T201) - Review of Two-Point Passenger Restraints

Introduction

Investigations into seven recent accidents within the UK (research project T310) have highlighted the importance of containing passengers within a vehicle during the dynamic phase of an accident.

During the course of these accidents a number of passengers were ejected from vehicles some of whom received fatal injuries.

Keeping a passenger within the vehicle, can be achieved by:

- Improved glazing integrity
- Passenger restraints (seat belts)

A separate project (T424) managed by RSSB is considering the role of bodyside glazing in an accident scenario.

The work reported in this research brief considers the effect of fitting two-point passenger restraints (lap belts) to rail vehicles. Work on three-point (lap and diagonal) restraints is in progress.



Aims

The aim of the research was to understand the implications of fitting two-point passenger restraints to seats in rail vehicles and the potential net benefit (or disadvantage) in terms of passenger safety.

The research was undertaken by AEA Technology Rail (AEAT) and aimed to:

- Test and compare the predicted injury levels of restrained and unrestrained seated passengers.
- Review, understand and comment on the suitability of two-point restraints for use by children (approximately 3-14 years old).
- Investigate previous accidents as a basis for reviewing the effect of loss of survival space or structural intrusion on restrained/unrestrained passengers.

Scope

The scope of work was as follows:

1. Literature Review

A review of current literature including the aerospace, automotive and bus and coach industries was undertaken.

2. Positioning Paper

AEAT authored a paper to formalise the test parameters and test protocols. This 'positioning paper' was used as a point of discussion and formed the basis of the testing programme.

3. Workshop

A workshop was held at the Transport Research Laboratory (TRL) to perform a peer review of the positioning paper.

The workshop comprised experts with experience in road, air and construction industries in addition to rail. It validated the proposal, the rationale used and supported the proposed testing conditions and boundary cases.



4. Computer Modelling

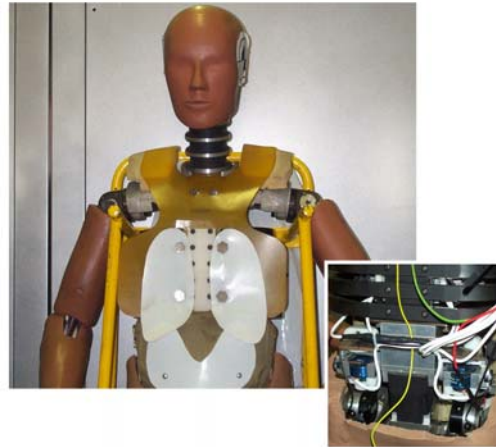
A computer model of the seat to be used in the subsequent tests had been developed using LS Dyna[®] software, allowing the dynamic performance of the seat under crash conditions to be evaluated. The universally recognised MADYMO[®] software representing the human body was used in conjunction with this in order to assess passenger movement and injuries under accident conditions. This combination permitted an investigation of a wide range of scenarios in order to highlight the most significant cases for full testing and evaluation. The software used a facet body model of the 50th percentile Hybrid III crash test dummy (Anthropomorphic Test Dummy - ATD) and a multi-body version of the seat to carry out these studies.

The 50th percentile refers to the human stature below which 50% of the population (male or female) lies. Other percentiles are *pro rata* and represent smaller or larger percentages of the population.

5. Testing

A suite of full-scale tests based on the positioning paper was carried out using the HyGe rig at TRL with a deceleration pulse as defined in the Association of Train Operating Companies (ATOC) Standard, AV/ST9001. A wide range of ATDs were used (5th to 95th percentile), representative of the UK adult population, including the Hybrid III RS ATD, developed in a previous phase of research for RSSB. This particular ATD is more representative of the human body in the lumbar region.

The results of these tests have been analysed and reported in terms of predicted passenger injury levels.



Hybrid III RS ATD and Lumbar Region

6. Accident Analysis

Previous major accidents have been evaluated to understand the link between passenger injury and train interior features or structural intrusion.

7. Discussion

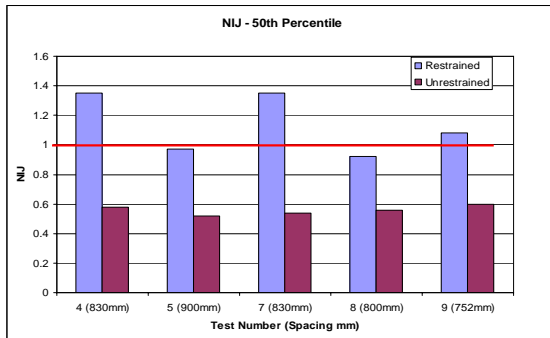
The effects of factors that it has not been possible to physically test are discussed. This included the suitability of restraints for children and the effect of vehicle rollover.

Findings

1. In analysing the tests it was recognised that the two most vital parameters were the predicted neck injury (NIJ) and head injury criteria (HIC). These are universally recognised criteria for determining injury levels and are derived from a combination of parameters representing injury severity.

For a 50th percentile ATD:

- Predicted neck injury (NIJ) was higher for the restrained occupant. In some cases the NIJ was above the accepted tolerable limit.



**NIJ for 50th Percentile ATD
(NIJ = 1 is the accepted tolerable limit)**

- For the 50th percentile ATD the HIC was relatively low.

For the 95th percentile ATD:

- NIJ was worse for the restrained passenger.
- HIC was relatively low in all cases.



95th Percentile Neck Bending

For the 5th percentile ATD:

It is believed that the limits of the ATD were reached during this testing. Images taken from the videos indicate significant neck bending for the restrained occupant.

- The levels of HIC are significant for the restrained occupant.



5th Percentile Neck Bending
(note: seat flexes to cushion impact)

2. Accident analysis shows that fatalities predominantly arise from either ejection or loss of survival space due to structural intrusion. A comparison was therefore drawn between:

- Passengers who had been fatally ejected and who may have survived if they had been wearing two-point restraints.
- Passengers who were internally thrown clear of areas suffering major structural collapse and who would not have survived if they had been restrained in their seats by a two-point restraint.

This suggested that for every life that may have been saved by a two-point restraint, several lives would have been lost due to major structural collapse.

- Two-point restraints are not suitable for restraining children below 12 years unless accompanied with a booster seat or other suitable device because of the potential danger to vital organs.
- There is a serious risk of entrapment for persons restrained in their seats when an unrestrained person impacts the rear of the seat. The seat back deforms under this impact into the spine of the restrained occupant causing injury.



Typical Seat Deformation due to Unrestrained Passenger Knee Intrusion



Knee intrusion into the back of the seat from the unrestrained occupant is a significant problem.

5. The limits of current standard ATDs have been highlighted in this research. The increased flexibility of the lower spine of the Hybrid III RS better represents the human spine and is therefore better suited for two-point restraint testing.

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Conclusions

- There is no overall net safety benefit associated with the fitting of two-point passenger restraints to trains. Two-point passenger restraints should therefore not be fitted to rail vehicles.
- Fitting two-point restraints would, in the majority of situations, increase passenger injuries in a crash situation.
- Predicted passenger injury outcomes for the restrained passenger are higher than for the un-restrained passenger in the majority of cases tested.
- Using crashworthy seat design to constrain passengers offers better overall protection than installing two-point restraints.

Next Steps

It is necessary to conduct further work into other methods of passenger containment.

- RSSB is conducting work into the role of bodyside windows – T424 ‘Requirements for train windows on passenger rail vehicles’.
- RSSB is continuing the evaluation of seatbelts with an appraisal of three-point passenger restraints (lap and diagonal).

The results of these projects should be read in conjunction with this work.