Optimising Driving Cab Design For Driver Protection In A Collision (T190)

Introduction

This research has sought to explore the boundaries of what improvements to driver protection are practicable with a view to improving standards. It responds to recommendation 54 of Lord Cullen’s report into the collision at Ladbrooke Grove in 1999: “current standards of crashworthiness should be reviewed …. to ensure that there are adequate measures for the protection of drivers…”.

Cab occupants have accounted for approximately one quarter of all fatalities in train accidents. Fatal and serious injuries principally occur in end-on collisions, with almost two thirds of fatalities occurring at collision speeds below 60km/h, the design speed for current British crashworthiness requirements. Modern crashworthiness standards do not as yet mandate features for protecting drivers from severe collision damage.

The recent introduction of the Train Protection Warning System (TPWS) onto the UK rail network is expected to significantly reduce the number of future fatalities arising from collisions due to signals passed at danger (SPADs) and collisions with buffer stops. However this still leaves a residual risk of collision and the ability of the cab to protect drivers in such eventualities has therefore been considered.

A substantial amount of research work was undertaken in Great Britain in the 1990s, as part of the BR Crashworthiness Development Programme, and more recently in Europe and the USA, to address this subject. Despite this, a number of gaps still exist in the industry’s knowledge base, and these are covered by this project.

The project comprises of tasks, which are covered by separate reports as follows:

- A Review of Past Work.
- Investigation into Improved Driver Protection Measures.
- Modelling of Combined Safety Measures.
- Assessment of Feasibility, Costs and Benefits.
- Report on Sled Tests with Airbag and Knee Bolster.
- Report on Consultations and Recommendations.

Approach

A range of safety measures was investigated with the objective of providing better protection to drivers in predominantly frontal collisions. These included:

- Burst-through bulkheads,
- Airbags,
- Knee bolsters,
- Seat belts,
- Sliding seats,
- Measures for improving egress.

Finite Element (FE) modelling techniques were used, combined with physical testing using crash test dummies, to consider the possible injury mechanisms for drivers in a variety of cab types and the potential merits of installing the above protection measures. An example FE model and sled tests are shown in Figure 2 demonstrating the
effectiveness of a combined airbag and knee bolster system in preventing injuries from longitudinal impacts against a typical cab console.

Drivers and vehicle manufacturers were consulted to discuss the feasibility of incorporating safety features into modern cabs.

Findings

The safest course of action is for the driver to vacate the cab to a safer place within the vehicle once he has taken all available actions to mitigate a collision, however there are those cases where the driver does not have sufficient notice to do this. In such cases the cab design should protect the driver as far as possible.

The principal findings with respect to driver protection are:

a) Design requirements

Modern drivers’ cabs currently incorporate no specific interior driver protection measures. Recent accidents have shown that relatively low speed collisions can give rise to the driver sustaining serious or fatal injuries. This research demonstrates that drivers can be successfully protected in frontal collisions up to closing speeds of 80 km/h. Three features need to be incorporated together to provide such protection:

(i) Prevent loss of survival space.

This can be achieved by minimising loss of survival space by using a combination (but not necessarily all) of increased front-end energy absorption, burst through bulkhead, sliding seat and greater cab space although this would be within the constraints imposed by the UK loading gauge.

(ii) Secondary impact protection.

The research has shown that injurious impacts against the console can be prevented by providing the driver with passive devices such as a knee bolster and a seatbelt (with strengthened seat) working together with an airbag.

(iii) Improved emergency egress.

An unobstructed path to a place of safety is required, facilitated by pushback or swivelling seats, careful console design and burst through doors. Training for
emergency egress should be included as part of driver training programmes.

(b) Driver Response:
Despite improvements to cab safety (i) and (ii), above, the safest course of action for a driver is usually to evacuate the cab to a safer place within the vehicle once the brakes have been applied (iii).

(c) Feasibility:
There are no technical or operational problems foreseen at present to prevent the fitment of driver protection measures in terms of design, engineering, maintenance or driver acceptance, though retrofit for i) and iii) would be prohibitively more difficult than at new-build. The only exception is seatbelts; following consultation drivers want to see more evidence that they will improve secondary impact protection without hindering egress, which is seen to be the prime mitigation to avoiding injury.

(d) Viability:
The viability of incorporating the various safety improvements was assessed, in terms of their potential effectiveness and economic viability for retrofit, where significant modifications may be necessary, and also for fitment on new vehicles where they can be designed into the cab. Taking account of the introduction of TPWS the following conclusions have been drawn:

- **New-build vehicles:** Airbags and knee bolsters with a burst-through cab wall were found to be marginally viable, in combination with measures for facilitating driver egress. Seatbelts were found to be viable but required further development for rail use and drivers have expressed concern that they would hinder egress (b. above).

- **Retrofit:** The incorporation of a sliding seat and burst-through cab wall in conjunction with a seatbelt and knee bolster was found not to be viable. Seatbelts with strengthened seats and improved egress were considered to be marginally viable but, as with new-build, would require further development for rail use.

The viability of the safety measures in general is less than in previous studies conducted in the 1990s. This is due to the anticipated reduction in collisions on UK railways following the introduction of TPWS.

- **Overall** the economic case for these measures is not strong and therefore wider industry consensus is required.

During the course of the investigation, several secondary recommendations were made, giving best practice methods for design of driver protection systems from lessons learned and findings from this research programme.

- Systems need to be cab specific, particularly knee bolsters and airbags as cab design can vary significantly between cabs. Studies should be carried out to ascertain how each system would function with a range of occupant sizes.

- Future generic cab designs would minimise the number of different protection systems to be designed and associated costs. This is inline with the European Drivers’ Desk project that seeks to develop a generic ergonomic desk design.

- Driver protection system designs should consider the whole train’s mass and energy absorption characteristics. This is a practical means of deriving the acceleration pulse and size of survival space.

- During collision, accelerations are seldom purely longitudinal and designs should allow for modest lateral and vertical accelerations concurrent with the longitudinal pulse. The driver lifting can have significant consequences on injury mechanisms.

- Seat, footstep and console geometry should ensure a predictable trajectory
across the spectrum of likely occupants and sizes.

- Contact stiffness values, friction coefficients and precise dimensions (vehicle and driver) should be faithfully reproduced in models, as results were sensitive to such parameters. Static tests are a useful way of obtaining realistic contact stiffness and friction data for modelling.

- Modelling predictions of survivability need to be supported by sensitivity studies to explore the presence of “cliff edge” effects, which may invalidate proposed safety benefits under some conditions. For instance a knee may or may not slide into consoles depending on small changes in starting position or friction values.

- If sled testing is carried out without protection measures, test dummies may become damaged or see over-ranging on their instrumentation. Above such limits as may be imposed to minimise this, non-instrumented ballast dummies can be of use in validating trajectories from computer modelling.

**Next Steps**

The findings of this work are to be discussed with stakeholders to establish how they can best be implemented including consideration of incorporation into future standards.

Since this work was commissioned there have been two significant accidents where drivers have not been killed through loss of survival space or collision with the cab interior but through ingress of debris. Stakeholders have requested further work to investigate this and to see whether additional protection can be afforded to the driver.

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