Quantifying the effect on safety of a correctly fitted windscreen

The windscreen is an essential part of the vehicle structure, and although not one of the most obvious car safety features, the presence of a correctly fitted windscreen has links to the overall safety of the vehicle with respect to secondary safety (the safety provided in a crash) and the role of the windscreen in supporting airbag inflation and preventing occupant ejection and roof crush in rollover accidents.

A previous TRL study identified that over 35% of windscreens that had been previously replaced in the Republic of Ireland were judged to exhibit some type of quality or safety issue (McCarthy, 2012). Following on from this finding, the aim of this project was to examine this issue further to quantify the extent to which a correctly fitted windscreen affects the level of safety provided to car occupants.

The study reviewed published evidence on windscreens and safety and carried out two full-scale FMVSS 212 crash tests, using Ford Focus C-Max vehicles, to compare the biomechanical injury values measured by the Hybrid III dummies in crashes with a correctly replaced windscreen an improperly replaced, unbonded windscreen.

A correctly fitted, bonded windscreen is important to safety for several reasons:

Occupant ejection

Previous TRL research highlighted that a well-bonded windscreen that remains in place during an impact has dual benefits of reducing the risk of occupant ejection and providing support for the passenger airbag during inflation. The risk of serious or fatal injury has been shown to be increased between 3 and 40 times for ejected occupants compared to being retained inside the vehicle. For an occupant not wearing a seatbelt, a European airbag is unlikely to restrain the occupant, and in this case, the windscreen is important in reducing the risk of ejection from the vehicle

Rollover accidents

In a rollover accident the protection of the occupant compartment, and particularly the roof, is critical to safety. TRL research has shown that in such accidents, the displacement of the roof towards the occupant may be increased by up to 30% if a windscreen is not present.

Torsional and structural stiffness

A windscreen also affects the torsional stiffness of a vehicle, which is important to its handling characteristics. Previous work by TRL found that in a full-scale vehicle torsion test, the presence of a windscreen contributed approximately 34% of a passenger car's stiffness (Phillips and McGrath, 2000). Therefore, a correctly-fitted and bonded windscreen contributes to the stiffness of the vehicle and this may affect the handling characteristics of the vehicle. The magnitude of the safety effect of this is difficult to judge, but deviations from the 'design performance' should be avoided.

Airbag inflation and FMVSS 212 tests

TRL reviewed high-speed video from more than twenty full scale crash tests and this found that windscreen contact by the passenger airbag is a consistent feature, but that the extent of contact varies between models. TRL consider that supporting airbag inflation is important to ensure that the restraint system provides the intended level of protection by the airbag being in the correct (design) position.

In this project, two FMVSS 212 tests (with a test speed of 48km/h into a rigid barrier) were carried out by TRL, one with a correctly replaced windscreen and one with an improperly replaced, unbonded windscreen. In both tests, the dummies were belted, and the seatbelt was the primary restraint acting to arrest the forward motion of the occupant before any hard structures were contacted. The airbag also provided some arresting support for the head and thorax and also reduced the risk of any hard contacts. In the first test, the windscreen was retained in the vehicle; in the second test, the windscreen was entirely displaced. Therefore, in the case where the windscreen was displaced, the occupants are at increased risk of ejection, especially if a rollover accident occurs. In this situation, the lack of a windscreen also means that the occupants are more vulnerable to injury from roof crush.

These tests also showed that the displaced windscreen influenced the position of the passenger airbag. In the test with the unbonded windscreen, the passenger airbag inflates outside the confines of the vehicle and the airbag was therefore positioned further forward (i.e. closer to the front of the vehicle) when the dummy first strikes the airbag. Compared with the test with the correctly replaced windscreen, the dummy contacted lower down on the airbag (95mm lower in the test with the unbonded windscreen). This resulted in a marginally greater Head Injury Criterion (HIC) value (262.9 vs. 274.9) and slightly lower chest compression (26.05mm vs. 25.49mm) in the unbonded test. In both cases, the dummy values represented very low injury risks. The small difference between the tests may at least partly be because the unbonded windscreen test was slightly more severe. Peak head acceleration and chest loading occurred earlier in the impact in the test with the unbonded windscreen. At greater impact speeds, this may be more of an issue for those more vulnerable to injury, such as older occupants.

In both tests, the seat belts provided effective occupant restraint and this meant that the difference in measured injury risk between these two tests was negligible and were considered in the range of variation that might be expected of repeated tests. However, while the measured injury risks for the average occupant in this vehicle and at this test speed and for this impact configuration were largely unaffected by a displaced windscreen, there is insufficient evidence to say whether this is true in the case that any one of these aspects are varied. For example, the risk of injury is known to vary with a range of other factors and some occupant characteristics (e.g. age, height, weight etc.) may be disproportionately affected by smaller changes in biomechanical values recorded by the dummies. Moreover, the consequences of windscreen displacement may be more significant in more severe crashes, in different collisions types, or for different types of occupant, where the effects of different occupant kinematics could result in unstable airbag contacts and increased injury outcome.

Accident data

Accident data was examined to assess how frequently the windscreen is displaced. This found that windscreen displacement for accidents in Great Britain as a result of the impact forces is a relatively unusual event, occurring on less than 2% of accident involved vehicles. This percentage is also consistent with the views of TRL's accident team who have experience of many hundreds of accidents in Great Britain.

In 2011 there were 839 fatalities in cars in Great Britain (DfT, 2012). If a value for the average car occupancy is assumed and that the accident involves one or two cars, an initial estimate of the GB target population can be made. This is the number of fatalities

associated with windscreen displacement and not the number of fatalities caused by windscreen displacement. Applying the 1.7% estimate for vehicles which involved displaced windscreens to the estimates for 839 - 1,678 vehicles and 1.58 occupants per vehicle (DfT, 2011), results in an estimate that between 8 and 17 fatally injured occupants per year might have been travelling in vehicles that experienced a windscreen displacement; of these, passengers (front and rear seat passengers) account for between 8 and 17 fatalities. However, this parameter may be under-recorded and there is no national accident data that records this information.

In areas which have been found to have a higher rate of poor quality windscreen replacements, displacement of the windscreen in accidents might be expected to be more frequent. TRL's previous study in the Republic of Ireland found that over 14% (14.3%, 95% confidence interval: 11.4% to 17.2%) of windscreens that had been previously replaced were judged to exhibit safety issues rated as having 'high' or 'medium' risks. In this case, the number of casualties in vehicles with windscreen displacement in the Republic of Ireland might be greater than in Great Britain.