Volvo Trucks view on Truck Rollover Accidents

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INTRODUCTION

Rollover is the most common heavy truck accident type. Experiencing a rollover is like being inside a washing machine. The outcome for the occupants is dependant on the road and surrounding topography, the speed, and the actual energy absorbed by the cab structure. Even if the total energy generally is high, the absorbed energy by the cab is considerably often low enough, due to e.g. superstructure effect, to be in range where realistic countermeasures by e.g. a suitable BIW design are possible. Obviously, even if the 3-piont seat belt has its drawbacks in rollover accidents, it still adds greatly to a successful outcome.

Volvo is since 1969 investigating truck accidents on the scene. The goal for the Accident Research Team, ART, is to establish statistics, understanding why accidents happen and analyse how they occur.

Since 1959 Volvo performs vehicle tests according to the Swedish Impact Test rule, which mainly provides cab strength, which simulates rollovers. If the cab intrusion is low enough to provide survivable space the design of the cab interior is of utmost importance. Therefore the interior of Volvo cabs is checked using the FMVSS 201 test procedure.

To reach further in the occupant protection for rollovers, it’s possible to improve the test methods and introduce more sophisticated rollover protection systems. To be able to design such systems it’s important to understand vehicle and occupant kinematics.

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1 Volvo Accident Research Team, Statistics and observations

Approximately 45% of the accidents surveyed included a rollover event. The two accident types most likely to include rollover were both single vehicle accidents. Important cab BIW areas to consider in the design are the upper part of the A-pillar and the roof structure.

| 1. Truck single Driving off road | 35% | Single vehicle accident, first event driving off road, in most cases followed by a rollover or a collision. | Rural roads and highways. | 65 kph average = 67 kph in 50% of accidents | Driver inattention or Driver fatigue. |
| 2. Truck single Rollover on road | 12% | Single vehicle accident, first event instability, rollover or sliding. | Rollovers occur on highway exits/entries in rural as well as urban areas or curves on rural roads. | 52 kph average = 57 kph in 50% of accidents | Driver inattention. Misjudgement of speed. Unstable combination. Load displacement. Slippery road. |

Table 1. Rollover statistics according to ART.

Conclusions regarding driver injuries and cab deformations:
To protect the occupants it’s most essential to keep him in position during the entire sequence, i.e. using the seat belt. The strong cab structure provides survival space and the ‘friendly’ interior protects him from injuries at an interior impact.

• The occupant is often injured due to not wearing the seatbelt. If unbelted, he is thrown around in the cab and sometimes ejected out of the cab, completely or partly.

• During the years, average seatbelt usage is less than 10% in the sample. (It is however improving; seat belt usage at present is approximately 35% in Sweden.) The ART analysis of the effect of the seatbelt is clear; in at least 60% of the accidents there is an injury reducing effect if wearing the seatbelt.

• Even if belted there is a risk of injuries in a nearside rollover. The upper body parts might impact the hard ground or be partly ejected through the side window opening. An active curtain that covers the side window or a belt system that keeps the occupant tighter to the seat might reduce the risk for injuries of head, chest and upper extremities.

• There is a deformation of upper A-pillar in ~ 40% of all accidents in sample. This is mainly as a result of impact against ground, earthen bank, guardrail, rock, tree, etc. after a rollover.

Figure 1: Longitudinal cab deformation of upper A-pillar.
Single truck accident, driving off road (type 1 accident), followed by a right hand side rollover (far side) and a collision of the roof structure against the earthen bank.

2 Present Volvo rollover protection

Since 1959 Volvo performs the Swedish Impact Test, which mainly provides cab strength for rollovers. The test consists of the following three sub-tests:

1. Static loading of the roof up to 147 kN.
2. Pendulum front impact on one of the A-pillars. Impact energy 29.4 kJ.
3. Pendulum rear impact on the rear wall. Impact energy 29.4 kJ.

It is Volvo’s opinion is that the Swedish Impact Test simulates a rollover accident and in this context the front pendulum impact is the most significant part of the test. Rear impact has a low significance according to ART statistics. It should be pointed out that this test does not cover frontal accidents.

As a part of crash safety effort Volvo performs head impact tests on interior. The impact areas for interior parts are tested that are likely to be hit by the drivers/passengers head in a crash/rollover situation. In general the following impact areas are identified: Roof and side panels, A and B-pillars, Dashboard, Seats and Steering wheel. Tests are performed according to the test method FMVSS201.
3 Proposed Rollover test

It’s Volvo Trucks position that the Swedish Impact Test gives an increased protection for the occupants in rollover accidents. However, in order to reach a global regulation we are strongly committed in groups discussing alternative, globally acceptable, test. It that context it should be understood that it’s both quite difficult to combine both rollover and frontal accident in one single test.

Volvo opinion is that a rollover test should include impact on the upper part of the A-pillar and roof structure. Added to this a static roof load test is also needed. In that perspective we see the following alternative procedure, which could possibly replace the Swedish test:

1 Impact using a flat pendulum, according to figure below.
2 Roof load using a flat load surface. (Not shown.)
4 Full scale rollover tests

Volvo Trucks has conducted two types of full-scale rollover tests. Accelerating the truck to approx. 80 km/h and then driving the far side wheels over a ramp initiated the rollover. A Hybrid III 50th percentile dummy occupied the driver’s seat. In order to know more about which events occur in a nearside rollover, and in which order, the dummy movement were studied.

![Figure 6: Full-scale ramp test.](image)

The second type of full-scale test replicated rollover negotiating a roundabout. The truck was accelerated at a constant radius from rest until it rolled over. Also in this test the dummy movement were studied.

![Figure 7: Full scale curve test.](image)
5 Rollover simulations

Since physical tests are expensive MADYMO simulations are used to perform in-depth study of the occupant kinematics. Results from physical tests are used for correlation reasons. The Rollover Model’s motion is described by the x, y and z acceleration pulses, and the rotational displacement signal.

![Figure 8: MADYMO model of cab interior and driver occupant.](image)

Occupant movement in the MADYMO model was compared to that in the rollover tests by observation. Below MADYMO kinematics from three rollover cases will be described:

1. Near side rollover, belted driver.
2. Far side rollover, belted driver.
3. Far side rollover, Un-belted driver

5.1 Near side, Belted

In the simulation, the shoulder belt provided little restraint. It was noticed that the occupant was moving upwards relative to the seat, causing the seat to reach the top of its travel during the rollover event. The dummy impacted the door panel and side window earlier than was seen in the test. After impact with the door, the dummy rebounded and moved inboard. The inboard movement was then reversed by the lap belt, resulting in another impact with the door. The 3-point seatbelt provides vertical (pre-impact) and longitudinal (post-impact) restraint.

![Figure 9: Screen-shots showing kinematics for near -side, belted occupant.](image)
5.2 Far side, Belted

The dummy’s head was seen to approach, but not strike, the roof panel in the belted, far side rollover simulation due to the upward motion caused by cab-ground impact. The upper body comes loose of the chest belt allowing it to swing freely and thereby risk to impact the head to the dashboard.

![Figure 10: Screen-shots showing kinematics for far side, belted occupant.](image)

5.3 Far side, Unbelted

The dummy moves freely towards the roof. The first impact, which also is the most critical, is head hitting the roof. Consecutive hits are toward the far side of the cab interior. This sequence shows the characteristic “washing machine” effect an un-belted occupant may experience. Obviously, if parts of the dummy are exposed to cab openings, the dummy will be ejected.

![Figure 11: Screen-shots showing kinematics for far side, unbelted occupant.](image)

N.B: There is no dummy fully suitable for truck rollover accidents. Also, damage criteria for rollover specific head/neck injuries needs still to be verified to biomechanical data.
6 Discussion

General Rollover
Demands on cab BIW rollover strength should include impact on the upper part of the A-pillar and roof structure. Added to this a static roof load test is also needed. Cab interior should fulfil head impact demands.

For occupants, in rollover accidents, injury is caused by contact with cab interior surfaces or objects. Therefore, injury will be reduced if the occupant is restrained from contacting any surfaces or objects during the rollover event. That is, the occupant must be restrained securely to the seat.

Nearside Rollover
The main injury-causing event in nearside rollover is the high deceleration experienced by the occupant when they land on the door, side window or the ground. Properties of the interior surfaces on the driver’s side must be made softer and/or deploying structures as inflatable curtain airbags or inflatable tubular structures (ITS) should be used.

Far Side Rollover
The 3-point seatbelt is highly important in reducing occupant movement and injury in far side rollover. An extra device could be needed to reduce the ineffectiveness of the shoulder belt in this crash situation. Specifically, inboard rotation and forward lean of the torso must be limited in order to reduce load on the lumbar spine. A complete system, which satisfies both of these requirements, the 3+2-point seatbelt with Active Side Support, has already been proposed by Autoliv.