Rollover Roof Crush and Occupant Protection Testing

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Static Tests: *SAE J374, FMVSS 216 and M216*

This type of test was developed by General Motors in the late 1960s. It was turned into a Society of Automotive Engineers (SAE) Recommended Practice (J374). NHTSA proposed a more stringent version of the test in 1971 but it was written to conform with the SAE test when it was issued as a final rule. In 2001, the Center for Injury Research developed a two-sided version of the test at the original pitch angle of 10º, which is a much more stringent test.

Test Procedure: A platen is pressed against a vehicle roof at specified roll and pitch angles until a specified force is achieved. The test may be repeated on the second side of the roof. FMVSS 216 tests only one side at 25º roll and 5º pitch. The test is continued until the resistance reaches 1.5 times the unloaded vehicle weight. If this occurs before 5 inches of crush, the vehicle passes. In 2005, the agency proposed to raise the minimum force to 2.5 times the unloaded vehicle weight, and in 2008 it proposed two-sided testing. The angle of the platen in FMVSS 216 permits the B pillar to absorb an unrealistic portion of the load.

Deficiencies: This test does not accurately emulate the forces of a rollover on a vehicle roof. The platen is applied at too shallow a pitch angle so that it does not realistically load the A-pillar. FMVSS 216 is applied only to one side of the roof, though injury-causing rollovers typically cause more injury to the far side occupant. In fact, it is the far side of the roof that is subject to the greatest force in a rollover. Both sides must be tested because they perform differently.

The proposed upgrades to FMVSS 216 do not address the standard's critical deficiencies. M216 is an improvement in that it applies the force at a more realistic 10º pitch angle and a more realistic 40º roll angle on the second side. As a consequence, a roof can provide only about half the resistance in the M216 test as in the FMVSS 216 test. A static test cannot properly demonstrate a vehicle's rollover occupant protection capability.

Dynamic Tests

Inverted Drop Test – SAE J996. This test was used by auto companies in the 1960s but SAE later dropped it because it was being used against the industry in product liability cases.

Test Procedure: The vehicle is turned upside down with the 25º roll and 5º pitch orientation. It is typically dropped from about 12 inches onto a flat, horizontal surface. There are no generally agreed upon criteria for passing or failing this test.

Deficiencies: This test applies a dynamic force but the test conditions are not typical of rollovers. The pitch angle is too shallow and the typical drop height is unrealistically high. The procedure does not emulate the dynamic effects of vehicle geometry and of its rolling motion.

Dolly Rollover Test –FMVSS 208. This test is defined in FMVSS 208 and in 1971 was expected to be made into a federal minimum standard. However, it has remained optional. Although manufacturers still use this test, none certifies vehicle compliance with the standard.

Test Procedure: The vehicle is rolled laterally off the inclined ramp of a dolly moving at 30 miles per hour. A vehicle typically rolls two to four times. A vehicle will pass the test if no part of an unrestrained dummy in the vehicle is ejected.

Problems: After the vehicle initially hits the ground, its motion is uncontrolled and is likely to roll differently in each test.

Controlled Rollover Impact System (CRIS). This test was developed by the auto industry for defense of litigation. It has been used primarily to demonstrate that a dummy will sustain neck forces that are the same in a vehicle with a roll cage installed as in a production vehicle.

Test Procedure: vehicle is mounted on a spit at the back of a moving tractor-trailer. It is rolled as the truck drives along a flat surface at a given speed and is dropped so that it lands on its roof while rolling. After release and initial impact, the vehicle continues to roll to rest.

Deficiencies: This test equipment is very expensive and the test is expensive to run. Since the test is run with the vehicle's wheels and tires in their full extended position, the vehicle is dropped from an unrealistic drop height. The other test conditions used thus far have also been highly unrealistic in that the initial impact is with the initially trailing side of the roof right over the seated occupant. The height and impact point ensure a high load on the dummy's head.

Jordan Rollover System (JRS). This test was developed and operated by the Center for Injury Research. It provides the most realistic and highly controlled test of a vehicle's rollover occupant protection performance. The JRS is the *only* rollover test device that has demonstrated a high degree of repeatability; its cost is minimal.

Test Procedure: In the test, the vehicle is mounted on an axis that permits it to roll and be dropped. As the vehicle is rotated, a roadway segment is run underneath and the vehicle is dropped so that its roof strikes the road as it would in an actual rollover. The vehicle is then lifted by the spit so that it will sustain no further damage. Subsequent rolls can be conducted by resetting and running the JRS test a second time. Unlike tests used by the National Highway Traffic Safety Administration (NHTSA) to test roof crush resistance, the JRS allows two sequential roof-to-ground contacts.

Deficiencies: This test has demonstrated few deficiencies other than the fact that to date neither NHTSA nor the auto industry has used it.

Why is Dynamic Rollover Testing Critical?

A safety test should emulate the key conditions of the crashes it is intended to demonstrate. In the case of rollovers, there are a number of factors that are involved:

- A vehicle's geometry will determine how its various parts will strike the ground in a rollover. In particular, the forces on a square roofed vehicle will be substantially greater than on a more rounded vehicle.
- The forces on the near (initially leading) side of the vehicle tend to be more vertical while the forces on the far side tend to be at a greater roll angle.
- Only a dynamic test can show the rollover performance of restraints: safety belts, interior padding, and window curtain air bags.
- Only a dynamic test can accurately show whether occupant ejection portals – structural failures in roofs, broken windows, sun roofs and doors – will fail, leaving opportunities for ejection.

The recent tests conducted on the JRS show that even vehicles with very good performance under FMVSS 216 show roof structure failures when tested dynamically. These problems also show up in rollovers that have been documented in the National Accident Sampling System.

Dynamic testing is used for frontal and side impact occupant protection performance. It provides a complete picture of a vehicle's safety that includes crash energy management, structural integrity, safety belts, air bags, and interior padding. The same comprehensive approach should used for rollover occupant protection. The Jordan Rollover System shows the power of dynamic rollover testing in demonstrating vehicle performance.