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REPEATABLE DYNAMIC ROLLOVER ROOF TEST FIXTURE

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ABSTRACT

Experimental rollover tests have been criticized for their poor emulation of actual rollovers and for their lack of repeatability. We have designed and built a test fixture that overcomes both of these criticisms. The fixture holds a passenger compartment, weighted to match the inertia characteristics of a complete vehicle, or a complete vehicle at the appropriate pitch and yaw. The compartment is then rotated about its principal (longitudinal) axis through an arc that mimics the rolling motion of an entire vehicle. At the appropriate roll angle and falling velocity, the roof strikes a moving patch of concrete. The compartment is controlled throughout the sequence and is suspended after the impact, so that a sequence of impacts can be individually studied in separate tests. Initial tests have shown that we can achieve repeatable impacts. Test variables include pitch, yaw, roll rate and vehicle center of gravity motion (both lateral and vertical velocity). This test device addresses the various shortcomings of previous rollover tests, fixtures and the various static and drop tests of vehicles conducted to determine rollover performance.

INTRODUCTION

One-third of all light vehicle fatalities and severe injuries occur in rollovers. A majority of these injuries and fatalities result directly or indirectly from the failure of the occupant compartment to prevent intrusion allowing ejection and causing injurious contacts. Roof strength is currently governed by a completely ineffective standard that quasi-statically tests only one side of the roof structure (Kahane, 1989 and Friedman and Nash, 2003).

A new set of roof strength tests, including a new dynamic test procedure, is needed for several reasons. (1) NHTSA must upgrade the existing quasi-static Federal Motor Vehicle Safety Standard, FMVSS, 216 to ensure adequate roof strength to protect occupants in multiple rollovers. (2) NHTSA needs to address the contribution of the windshield to roof strength. (3) NHTSA must address the effects of friction between the ground and the vehicle roof. (4) Any new regulatory or consumer information tests must be repeatable. (5) NHTSA must have a means of evaluating rollover injury and ejection potential including alternative systems such as window curtain air bags and safety belt pretensioners.

DESCRIPTION OF THE FIXTURE

We have designed, built and tested a fixture that can be used to evaluate the performance of a roof and of a vehicle's rollover occupant protection system under highly controlled, dynamic conditions. Those conditions have been generally specified by analysis of the catastrophic injury impacts of the Malibu series of experiments (Orlowski, et al., 1985, Bahling, et al., 1990 and Friedman and Nash, 2001). The device can combine well-defined vertical, lateral and roll impact conditions with vehicle rotation in a single impact.

Tests with this device will be less expensive than dolly rollover or CRIS tests, but will be more representative of real world rollover conditions, repeatable and objective. The device can be used for vehicle and safety systems development, for consumer information testing and for regulatory purposes.

The device, shown in Figure 1, holds the ends of either a body-in-white or a complete vehicle between two arms that permit it to be rotated about its longitudinal axis. The control arms and their mounting points on the vehicle can adjust the pitch and yaw angles of the vehicle at the time of the roof impact.

The impact surface moves horizontally, along tracks, below the suspended vehicle. An energy source similar to that used in an impact sled propels it. In the test sequence, the vehicle is positioned in the control arms at the appropriate pitch and yaw angles. It can be rotated at up to about 1 revolution per second.

The rotation is coordinated with the release of the control arms in which it is suspended and with the propulsion of the road plate (the impact surface) so that the vehicle body strikes the road plate at a specified roll angle. After the vehicle is released, only its lateral motion continues to be controlled by the control arms except that the vehicle's vertical motion is halted before it strikes the tracks along which the impact surface moves.

The test may be designed to permit impacts with both sides of the roof in a single test. The road plate is moving at a speed of up to about 20 mph (32 km/hr) and will move out from under the vehicle after the impact or impacts. Note that the inertial frame of reference for this test moves at the speed of the impact surface at the time of the initial roof contact.

After the vehicle impact, it will be suspended by the control arms as its rotation ceases without further vehicle impacts. Using a weighted body-in-white permits tests with production structures at substantially increased rollover strength to weight ratios.

If it is desired, a second impact can be staged on the same vehicle. The impact surface is returned to its initial position, the arms are raised, and the parameters are adjusted appropriately. The test with altered impact parameters can then be repeated.

Instrumentation and cameras can record the results of the test. Test dummies can be used to assess and measure the total performance of the rollover occupant protection system, or a simpler test setup can be used to measure the dynamic roof crush and intrusion.

Figure 1: Dynamic rollover test device.

TEST RESULTS

The initial tests utilized a 1987 Chevrolet S-10 Blazer buck held at 10° of yaw and 10° of pitch. The vehicle weight was reduced to 2000 pounds and the roof was strengthened by wood cross bracing under its front corners. The vehicle was rotated at 188 degrees per second and dropped from a height of 4 inches. The leading roof rail contacted the concrete near the front edge. Because of its rebound there was no second contact with the trailing side roof rail. The initial test was instrumented with tri-axial accelerometers under the roof corners and was observed using normal and high speed video cameras. The vehicle did not have test dummies.

An important parameter of the vehicle is the Strength to Weight Ratio, which is a measure of the vehicles roof strength to the weight of the car (Friedman and Nash, 2001). By altering the weight of the buck, the strength to weight ratio can be modified to allow simulation of a production vehicle and a vehicle with either a strengthened or weakened roof.

In this case, the first test was weighted to approximate 60 percent of the weight of the vehicle. Particularly with the internal bracing, this test approximated the response of a reinforced roof. Despite the bracing and the reduced vehicle weight, the roof deformed approximately 3 inches in the impact and the windshield broke.

CONCLUSIONS

Initial testing indicates that the fixture is robust and performs as it was designed to perform. The results were realistic and repeatable, and provide an excellent means for evaluating vehicle rollover performance. We expect that the device will have a wide range of automotive safety applications including regulatory testing, consumer information testing, vehicle and component development testing and research. This fixture is an improvement in its representativeness, repeatability and low cost over existing rollover testing methods.

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