C6 Limit Performance and Controllability Testing of Vehicles Towing Loaded Tow Dollies

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After attending this presentation, attendees will gain an understanding of combination vehicle dynamics.

This presentation will impact the forensic science community by addressing tow vehicle dynamics related to weight ratios.

There are not many standardized tests that have been developed for vehicle limit handling. There are of course braking tests and some limit performance turning testing for single unit vehicles. For trailers or vehicles towing another, there is even less. For trailer towing there are tests that evaluate the damping. In the damping test, a very small short steering disturbance is introduced and the sway is observed. The growth or decay of the amplitude is measured. There is no standard test to evaluate the control- lability of a combination once the sway starts. There are a class of towed vehicles that have no brakes and are designed allow a vehicle to be towed behind a tow vehicle. There are no standardized tests for this combination.

Over the last ten years a series of tests have been performed to investi- gate the controllability of combination vehicles that consist of a vehicle towing another vehicle on a tow dolly.

Tow dollies were originally designed to be used behind vehicles like large moving trucks and motor homes. The weight ratio between the tow vehicle and what was being towed was relatively large and usually at least two to one. Some rental companies have allowed rental of dollies to small vehicles where the resultant weight ratio is closer to one to one or even worse. Since the tow dolly is frequently un-braked, this can create potential controllability problems. The following issues were investigated:

1. Stopping distance increases, since the towed portion of the combination is un-braked.
2. Braking can cause jackknifing, due to the saturation of the rear tires on the tow vehicle
3. Loss of directional control due to sway can occur due to the saturation of the rear tires during trailer oscillations.

Since the tow vehicle is the only one with brakes, the retarding force on the combination is limited. For a 2:1 ratio compared to a 1:1 ratio the stopping distance is 67% compared to 50% of the stopping distance of the tow vehicle alone.

If the vehicle combination is in a turn, the braking forces transmitted through the trailer hitch have a lateral component. This lateral component can and does easily cause jackknifing.

Sometimes the combination with the un-braked tow dolly will jack- knife under straight line braking.

If the vehicle is placed into a small turn the lateral forces will be generated on the tow vehicle.

Trailers sway for a number of reasons including wind gusts, road disturbances, driver input, etc. Once the sway starts, the ability of the combination to resist the sway depends on the reserve friction available on the tow vehicle, particularly in the rear. The saturation of the tires in the rear of the tow vehicle can result in either jackknifing or the entire combination may yaw out of control.

Jackknifing or out of control combinations can lead to rollovers and other types of accidents.

Testing of various vehicle combinations have been conducted dating back ten years. Combinations included:

- Small SUV towing small passenger car
- Pickup towing sedan
- Station Wagon towing sedan
- Medium sized SUV towing sedan
- Small Pickup towing sedan

Instrumented tests were performed for each of the combinations. The control inputs and the dynamic output were measured. Typical continuous measurements were made of:

- Steering wheel angle
- Brake pedal force
- Speed
- Throttle position
- Accelerations of tow vehicle and towed vehicle
- Rotation rates of tow vehicle and towed vehicle
- Video cameras documented each maneuver The vehicle was tested in the following

ways:

- Straight line braking
- Braking in a turn
- Reverse steer

The tow vehicle was also tested without the tow dolly attached.

In each case, the testing was also performed with a van type truck both with and without the towed vehicle on the tow dolly. The comparison of weight ratios between the tow vehicles and the van type truck increased the ratio

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of the tow vehicle to towed vehicle from close to 1:1 to closer to 2:1.

As might be expected, there was no control problems with the higher weight ratio combinations, even with higher control inputs.

Straight Line Braking: Straight line braking consisted simply of driving the combination to test speed and applying the brakes at maximum. The stopping distance or the deceleration was observed.

As predicted, the stopping distance increased and the deceleration rate decreased with a lower weight ratio. In other words a small vehicle cannot stop as readily, while towing a vehicle on an un-braked tow dolly, as a larger vehicle. While this result may not be surprising, sometimes the combination would jackknife without any turning input from the tow vehicle. In the jack- knifing cases the instability of the combination manifested itself that was further confirmed in the braking in a turn test.

Braking in a Turn: The Braking in a Turn test involved steering a slight amount, 90 to 180 degrees on the tow vehicle steering wheel, and then braking.

The tow vehicle with the towed vehicle attached experienced severe loss of control as demonstrated by extreme jackknifing in the braking in a turn test at speeds as low as 15 to 20 mph.

The tire friction forces of the tow vehicle, particularly for the rear axle, were almost saturated from braking alone. When the additional lateral forces were applied to turn and stop the towed vehicle, the friction limit at the tire road interface was exceeded and jackknifing occurred.

Reverse steer: The reverse steer is designed to start the towed portion of the vehicle to sway. The sway was intentionally induced in order to evaluate the ability of the combination to be controlled. The vehicle is steered one way, the steering wheel brought back to zero, steered the other way, and then brought back to zero. This turning sequence could result in an approximate lane change under some circumstances. There will be swaying of the towed portion of the combination.

The combination with a weight ratio of tow vehicle to towed vehicle of 1:1 loses control at much lower input levels than the combination with weight ratios of closer to 2:1.

The loss of control occurs in one of two ways. Both limit performance configurations result from the exceeding the friction force capacity of the rear tires of the tow vehicle. In the limit, the vehicle combination can jack- knife or swing out of control in a sweeping yawing motion with the vehicles almost aligned.

These series of three tests have been successful in quantifying the controllability and limit performance levels for tow vehicles towing other vehicles with a tow dolly. One obvious conclusion is that the weight ratio needs to be closer to 2:1 than 1:1.

Tow Dolly Testing, Limit Handling Performance, Controllability

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