

Heavy Truck Stability with a Trailing Axle Tire Blowout

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ABSTRACT

Trailing axles, otherwise known as tag axles, are utilized in many states to allow heavy duty dump trucks and cement trucks to maximize their capacity. The trailing axle is an additional axle mounted on an arm on the rear of the truck that can be raised and lowered. When lowered, the axle extends the overall wheelbase of the vehicle and increases the total number of axles, thereby allowing for additional load to be carried without exceeding load-restriction regulations.

There are multiple manufactures of trailing axles that utilize different suspension designs. One design uses an articulating axle that is mounted to the framework that lowers it. In this study, the sensitivity of this design to tire blowout on one of the trailing axle tires is studied. Testing was conducted that involved initiating a sudden air-loss event by creating a hole in the sidewall of the tire. The handling response of the vehicle was documented with on-board instrumentation and on-board and off-board video.

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INTRODUCTION

Federal bridge laws specify the maximum load that any set of axles on a motor vehicle can legally carry on the Interstate Highway System [http://www.ops.fhwa.dot.gov/freight/sw/brdgcalt/calc_page.htm]. Compliance with the law is calculated using the following formula:

$$W = 500 \left[\frac{LN}{N-1} + 12N + 36 \right] \quad (1)$$

W = the overall gross weight on any group of two or more consecutive axles to the nearest 500 pounds.

L = the distance in feet between the outer axles of any group of two or more consecutive axles.

N = the number of axles in the group under consideration.

Vehicles equipped with additional axles can carry a greater payload and still abide by these guidelines by distributing their weight along the length of the vehicle. Pusher axles, axles located between the steer and drive axles that can be lowered when needed for additional capacity, are an example of this. Another technique that is used to increase payload is the addition of a load-bearing trailing axle that rotates down from the rear of a truck when additional capacity is needed. Trailing axles (TA) both distribute the weight to an additional axle and provide a significantly larger wheelbase over which the load is distributed. There are multiple designs of trailing axles. One version consists of a

solid axle that moves vertically relative to the lowering arm with a four-bar linkage. In this design the trailing axle remains horizontal relative to the truck chassis, other than roll motion allowed through compliance in the mechanism's frame and bushings. Another design has an articulating axle that pivots about a pin joint at the center of the axle, allowing for roll or relative vertical motion of each wheel. Jounce motion of the axle is achieved through vertical movement of the entire axle mounting frame that raises and lowers the trunion assembly the axle is mounted to. This is the type of trailing axle design that was the subject of this research, and an example of which is shown in Figure 1. With both designs, the trailing axle wheels are mounted to a kingpin that allows the wheels the freedom to steer. Because of the caster angle of the kingpin, the tires typically follow the path of the axle without generating significant side force. There are also steering spring-damper assemblies mounted between the axle and hub to assist with alignment of the tires and damping of shimmy-type oscillations. The left and right wheels are connected with a tie rod, linking the amount of steering at the trailing arm wheels.



Figure 1. Articulated design trailing axle.

LITERATURE REVIEW

Statistical analyses of heavy truck accidents concluded that crashes due to tire blowouts are a rare event. [Bareket, Dunlap] The analyses found that steer (front) tire blowouts are more likely to result in an accident than drive or trailer (rear) tire blowouts. In the case of steer-tire blowouts, a significant relationship was also observed between the side of the vehicle on which the blowout occurred and the direction the vehicle departed from its intended path of travel after the event. Blowouts to the left steer tire typically lead to the vehicle traveling toward the left lane and resulted in more multi-vehicle accidents, whereas vehicles with right steer tire blowouts were more likely to depart the road and result in a single-vehicle accident. [Bareket, Dunlap]

In 2007, the National Transportation Safety Board conducted a series of seven tire blowout tests and eight delaminations as part of an investigation of a motorcoach accident that occurred in 2006. The purpose of the testing was to determine the effect of a front axle tire delamination and blowout on a driver's ability to control a motorcoach during a tire failure. The tests were conducted at speeds of 50 mph or greater. The study found that in most trials, the steering torque required to maintain driving in the travel lane was nominal. The test drivers stated that controlling the vehicle during the testing was "no problem." [Sind]

The drivers also reported that they were unable to feel a slow loss of tire pressure to levels less than half of the recommended inflation pressure. The steering torque measurements supported these observations in that the levels were on the order of nominal driving conditions. This observation was attributed to the power steering capability of the vehicle and lead to the hypothesis that drivers would be unaware if a tire on their vehicle was underinflated, even if it had been properly inflated at the time of the pre-trip inspection. [Sind]

CASE STUDY ACCIDENT

The subject trailing axle research was initiated as a result of a single vehicle rollover crash that the authors of this paper investigated. The subject vehicle was a seven-axle dump truck, including three airlift pusher axles and a trailing axle. It was carrying a payload of approximately 50,000 lbs of dirt, creating a total weight of approximately 79,500 lbs. The crash occurred on a straight, two-lane rural highway, with a 2-way striped centerline, and a posted speed limit of 65 mph. The vehicle was traveling on a level section of the highway when it lost control and rolled over for a reason unspecified by the police accident report. One hypothesis was that the rollover occurred as a result of a tire blowout. The tire in question was the right tire of the trailing axle. The purpose of the authors' investigation was to determine the cause of the loss-of-control leading to the rollover, and the involvement, if any, of the trailing axle tire deflation.



Figure 2. Police photograph of tire marks looking upstream from the location the vehicle departed from the roadway.

As part of the investigation, the subject vehicle and exemplar vehicles were inspected, and testing was performed with an exemplar vehicle. Review of the police scene photographs showed that the vehicle suddenly veered left and traveled across the lane of opposing traffic and went partially off the opposite side of the roadway, as shown in [Figure 2](#). Tire marks were observed from both trailing axle wheels and gouge marks were created by the right side trailing axle wheel. Pieces of the right side trailing axle tire were dispersed in the travel lane prior to the vehicle crossing into the opposing lane. The left side trailing axle tire created a tire mark starting well before the truck crossed the centerline. Based on the tire marks, the driver must have input a steer to the right as the vehicle was crossing the oncoming lane of traffic. The vehicle yawed clockwise well past 90 degrees to the direction of initial travel and rolled driver side leading nearly one full revolution, coming to rest with the trailing

axle against a tree located adjacent to the roadway (as depicted in [Figure 3](#)).



Figure 3. Police photographs of accident vehicle at its rest position.

TESTING

A series of tire deflation stability tests were conducted to evaluate the potential for loss of control due to a tire air out. The testing was conducted on a two-mile oval asphalt track with an adjacent 10-acre skid pad. The blowout events were conducted on the portion of the track adjacent to the skid pad so that the driver had additional space to maneuver the vehicle if necessary. The test vehicle was an exemplar 7-axle dump truck equipped with an articulating-type trailing axle, and was configured identically to the accident vehicle. These tests were designed to evaluate the effect deflation of the right rear trailing axle tire had on the stability of the truck.

The test vehicle was instrumented with: (1) a MicroSat R20 GPS system to evaluate position and velocity, (2) a Crossbow inertial measurement unit (IMU) to evaluate

acceleration and angular rates, (3) a steering wheel torque sensor, (4) a potentiometer to measure the steering wheel angle, (5) a potentiometer to measure the trailing axle steer angle, and (6) a throttle position sensor. The vehicle was ballasted with 50,000 lb of dirt in the bed of the dump truck to replicate the vehicle load at the time of the incident. The steering limiting adjustment (stop bolts) on the trailing axle were confirmed to be at the same position as the accident vehicle. A photograph of the test vehicle is shown in [Figure 4](#).



Figure 4. Test Vehicle: Heavy Duty Dump Truck with Trailing Axle.

The testing was documented with still photographs, four on-board real-time cameras, and one off-board real-time camera. One on-board real-time camera was located in the cab and documented the driver's actions throughout the testing. The remaining on-board cameras were mounted to the rear of the vehicle and captured the response of the trailing axle, as depicted in [Figure 5](#). The off-board camera was located in a chase vehicle that was driven behind the test vehicle for each test.



Figure 5. Deflated right TA tire and steering left TA tire.