Analysis of Variability in Heavy Truck Braking Systems

BACKGROUND

The Federal Motor Carrier Safety Administration (FMCSA) is interested in ongoing explorations of truck platooning, an automation application in which two or more commercial motor vehicles (CMV) use adaptive cruise control and other technologies to travel in close formation behind one another. A key parameter in determining the position of each truck in a platoon is its stopping distance. To minimize the chance of collisions within the platoon during a braking event, the vehicle with the shortest stopping distance should be placed at the rear of the platoon, and the vehicle with the longest stopping distance should be placed at the front of the platoon. But stopping distances vary even under ideal conditions. This variability is relevant to platooning technologies. Further, truck tractor braking system performance is a key element of a tractor-trailer's overall braking performance, which is relevant to other safety-related topics.

PURPOSE

This study analyzed stopping distances for trucks of varying weight, length, and brake type to produce findings relevant to safe truck platooning. It provides a starting point for further research and a rough baseline for how much braking performance varies between configurations and for individual trucks. The full system brake performance data examined in this study differs from "normal" platoon operations braking performance, but these data can still inform platooning research because rare edge-case emergency situations may require full system brake performance from trucks operating in a platoon. Because platooning capitalizes on the reduced drag associated with close following distances, truck sequencing and following distances must account for variability in stopping distance performance, particularly the effect of brake type.

Accordingly, the information examined here is useful in staging future research into platoon configurations, including truck sequencing. Figure 1, for example, shows average stopping distances for different brake types across the sample population.

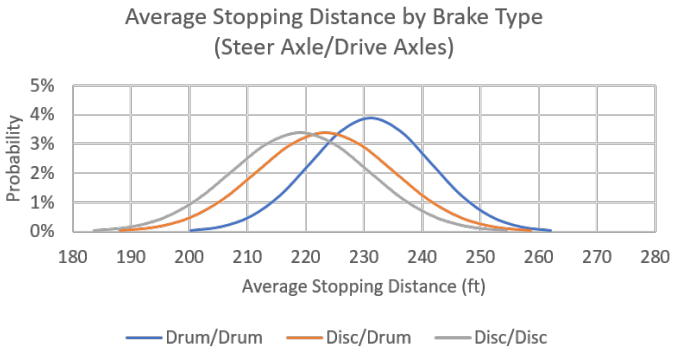

Figure 1. Chart. Probability distribution of stopping distances for various truck tractor brake types derived from test data parameters.

The study also measured stopping distance variability for each category—that is, the probable range of stopping distances for a truck in a given configuration. This information is useful in evaluating minimum safe following distances. Figure 2 shows stopping distance variability for the same categories as Figure 1.

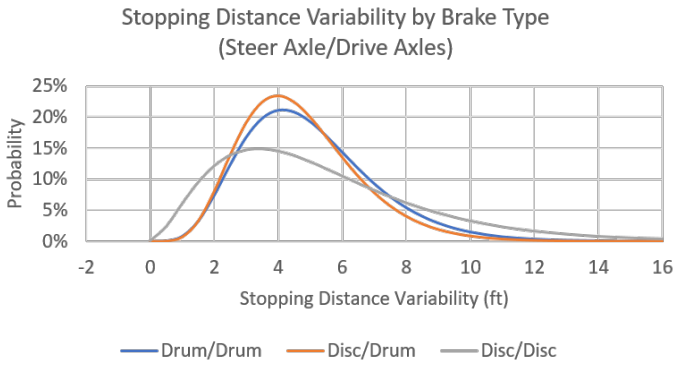

Figure 2. Chart. Probability distribution of stopping distance variability for various truck tractor brake types derived from test data parameters.

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METHOD

The study used previously collected data describing more than 800 vehicle tests. These tests used unbraked trailers (as shown in Figure 3) and tractors with a variety of brake configurations under controlled conditions. Researchers sorted tests into categories based on truck characteristics and applied statistical methods to ascertain stopping distance and stopping distance variability values.

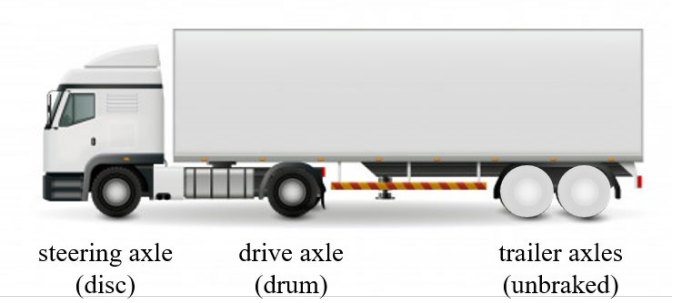

Figure 3. Picture. CMV with disc/drum brakes and an unbraked trailer.

SELECTED FINDINGS

Stopping Distance

Several of the examined parameters affected tractor stopping distance. First, the average stopping distance for disc/disc brakes was shorter than either drum/drum or disc/drum brakes. Second, tractors with a gross vehicle weight rating (GVWR) of 45,000–50,000 lbs had shorter stopping distances than any other examined weight category, but these data did not support any further statements regarding links between GVWR and stopping distance. Third, the 151–200-in. wheelbase category of vehicles had the longest average stopping distance. Finally, tractors with the 6S6M (six sensors and six braking modulators per braked wheel) anti-lock braking system (ABS) had stopping distances shorter than either the 4S4M or the 6S4M.

Stopping Distance Variability

Brake type did not have a statistically significant effect on stopping distance variability. Weight did have a significant effect; the 50,000–55,000 lb GVWR range had more variability than both the next lower (45,000–50,000 lb) and next higher (55,000–60,000 lb) ranges. Vehicles with a 251–300-in. wheelbase had a lower stopping distance variability than those with a 151–200-in. wheelbase. The 6S6M ABS had a lower stopping distance variability than the 4S4M ABS.

The stopping distance variability was used to calculate a stopping distance range for an individual vehicle's 60-mi/hr full-system stopping distances. These ranges were calculated for both two standard deviations (95.4 percent of observations) and three standard deviations (99.7 percent of observations).

These ranges are centered on an individual vehicle's average full-system 60-mi/hr stop under the conditions specified in FMVSS 121 (one tractor and unbraked control trailer loaded to the tractor gross vehicle weight). As such, these results cannot be applied directly to variability for a standard over-the-road tractor-trailer combination.

The practical implication of these numbers is that the distance needed for a tractor-trailer combination to come to rest can vary by tens of feet even under test conditions. The degree to which this holds true for actual over-the-road configurations is still to be determined.

POTENTIAL NEXT STEPS

Because these tests used unbraked trailers and only examined full stops, their applicability to truck platooning is limited. They do, however, provide a starting point for more realistic tests. The study found that stopping distance and stopping distance variability can vary considerably, and the results reinforce the importance of ensuring that trucks in operation be properly maintained to maximize the predictability of their braking performance.

Further testing might account for similar parameters but incorporate more realistic conditions. For example, future tests might use braked trailers or set up scenarios more reflective of normal platoon operation.

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