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Research Results

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Train-to-Train Impact Test of Crash Energy Management Passenger Rail Equipment

SUMMARY

On March 23, 2006, a full-scale test was conducted on a passenger rail train retrofitted with newly developed cab and coach car crush zone designs. This test was conducted as part of a larger testing program to establish the degree of enhanced performance of alternative design strategies for passenger rail crashworthiness. The alternative design strategy is referred to as Crash Energy Management (CEM), where the collision energy is absorbed in defined unoccupied locations throughout the train in a controlled progressive manner. By controlling the deformations at critical locations, the CEM train is able to protect against two very dangerous modes of deformation: override and large scale lateral buckling.

Figure 1 includes frames from high-speed movies recorded at the train-to-train test of existing equipment and the train-to-train test of CEM equipment. In the train-to-train test of existing equipment at a closing speed of 30 mph, the colliding cab car crushed by approximately 22 feet. No crush was imparted to any of the trailing equipment. Due to the crippling of the cab car structure, the cab car overrode the conventional locomotive. The space for the operator's seat and for approximately 47 passenger seats was lost. During the train-to-train test of CEM equipment, at a closing speed of 31 mph, the front of the cab car crushed by approximately 3 feet, and the crush propagated back to all of the unoccupied ends of the trailing passenger cars. The controlled deformation of the cab car prevented override. All of the crew and passenger space was preserved.

Figure 1. Frames from Train-to-Train Test Movies of Conventional and CEM Equipment

BACKGROUND

The Federal Railroad Administration (FRA) has been conducting research on passenger rail equipment crashworthiness to develop technical information needed to promulgate passenger rail equipment safety regulations. The principal focus of passenger rail equipment crashworthiness research has been the development of structural crashworthiness and interior occupant protection strategies.

Six tests have been conducted to measure the crashworthiness performance of existing equipment and the performance of equipment incorporating CEM features. The collision scenario addressed by these tests is a cab car-led passenger train colliding with a conventional locomotive-led passenger train. The tests conducted for each equipment type include:

1. Single-car impact into a fixed barrier
2. Two coupled car impact into a fixed barrier
3. Cab car-led train collision with standing conventional locomotive-led train

The results from the single and two-car full-scale impact tests show that the CEM design has superior crashworthiness performance over conventional equipment. In the single car test of conventional equipment, the car crushed by approximately 6 feet, intruding into the occupied area, and lifted by about 9 inches, raising the wheels of the lead truck off the rails [1]. Under the same single-car test conditions, the CEM trailer car crushed about 3 feet, preserving the occupied area, and its wheels remained on the rails [2]. In the two-car test of conventional equipment, the conventional car again crushed by approximately 6 feet and lifted about 9 inches as it crushed; in addition, the coupled cars sawtooth-buckled, and the trucks immediately adjacent to the coupled connection derailed [3]. In the two-car test of CEM equipment, the cars preserved the occupant areas and remained in-line, with all of the wheels on the rails [4]. In the train-to-train test of conventional equipment, the colliding cab car crushed by 22 feet and overrode the locomotive [5]. The space for the operator's seat and for approximately 47 passenger seats was lost. In the train-to-train test of CEM equipment, the front of the cab car crushed by approximately 3 feet, and override was prevented [6]. Structural crush was pushed back to all of the trailer car crush zones, and all of the crew and passenger space was preserved.

TRAIN-TO-TRAIN TEST DESCRIPTION

In this test, a moving cab car-led train impacted a standing locomotive-led train. The locomotive-led train included two hopper cars, ballasted such that both trains weigh nearly the same. The cab car-led train includes four coach cars and a trailing locomotive. The impact occurred on tangent track, with the cab car-led train initially traveling at 30.8 mph.

CEM end structures were installed at each end of each passenger car. Figure 2 shows the FRA prototype cab end crush zone design that was developed as part of the research. The cab car crush zone includes four key elements:

1. A deformable anti-climber arrangement
2. A push-back coupler mechanism
3. An integrated end frame, which incorporates an operator compartment
4. Roof and primary energy absorbing elements

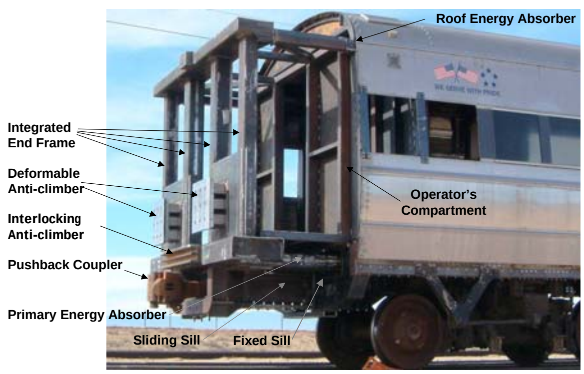

Figure 2. Cab Car Crush Zone

A similar design was developed for non-cab end crush zones. The non-cab end design does not include the deformable anti-climber or incorporate the operator's compartment.

Figure 3 shows results from the train-to-train tests of conventional and CEM equipment. In the train-to-train test of existing equipment, the colliding cab car crushed by approximately 22 feet. No crush was imparted to any of the trailing equipment. Due to the crippling of the cab car structure, the cab car overrode the conventional locomotive. The space for the operator's seat and for approximately 47 passenger seats was lost. During the test of CEM equipment, all of the operator and passenger space was preserved, override and lateral buckling of both the impacting and coupled equipment was prevented, and the train remained on the tracks. Overall, the energy of the collision was successfully managed.

Figure 3. Photographs of Crush Distribution in Train-to-Train Tests of Conventional and CEM Equipment

CONCLUSIONS

In the train-to-train test of conventional equipment, the space for approximately 47 passengers and the operator was destroyed. Under the same impact conditions, the CEM equipment preserved the space for all of the occupants.

CEM features can be progressively added to existing equipment to improve crashworthiness incrementally. A conventional cab car-led train of single level equipment with end vestibules can protect all of the occupants in a collision with a locomotive-led train of the same weight for closing speeds up to approximately 15 mph. Changing from a conventional cab car to a CEM cab car, such as the cab car used in the test, increases the closing speed to 25 mph. Further modifying the trailer cars to include push-back couplers (with conventional carbody structures) increases this closing speed to 28 mph. The highest level of crashworthiness is provided by CEM cab and trailer cars, which can protect all of the occupants for closing speeds up to 38 mph in this scenario.

Further work is needed to evaluate the use of CEM features on locomotives. While the current CEM cab car design accommodates for the features of conventional locomotives, the robustness of a CEM system would be enhanced at the train level by including features, such as push-back couplers and deformable anti-climbers, on conventional locomotives.

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