US Department
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Federal Railroad Administration

Research Results

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Pilot for Rail Passenger Cab Cars

SUMMARY

The results of this Federal Railroad Administration (FRA)-funded Small Business Innovative Research (SBIR) project indicate that cab car-led trains are no more likely to derail than passenger locomotive-led trains, when involved in grade crossing accidents. The performance of cab cars in comparison to passenger locomotives, in grade crossing accidents, became of interest to the railroad industry partly due to the Glendale, CA incident. In Glendale, a parked jeep was intentionally placed on the railroad tracks, resulting in the derailment of a Metrolink train. This event and similar past incidents fueled the debate on whether cab car-led passenger trains are more prone to derailment than locomotive-led passenger trains when involved in grade crossing collisions. The SBIR research focused on cab car and locomotive pilots, also known as snowplows, which function to prevent obstacles from interfering in the operation of the railcar trucks. Pilots are installed on railcars to clear the tracks of small obstacles, which generally weigh much less than 10,000 pound mass (lbm) such as shopping carts, tree branches, etc. Examples of a cab car and a locomotive pilot are depicted in Figures 1 and 2, respectively. Reports of past grade crossing accidents involving cab car- and locomotive-led passenger trains were reviewed to understand the damages sustained by the pilots, and in the case of derailments, the cause. The Massachusetts Bay Transportation Authority (MBTA) maintenance facility was visited to review the design of pilots installed on cab cars and passenger locomotives. Drawings, photographs, and measurements were taken of the pilots and their supporting structures. This information was used to create finite element models of the pilot's structure. The finite element model results were used in collision dynamics models to analyze and predict how much the pilots would crush in various collision scenarios. Also investigated was the potential for the lead vehicle (cab car and locomotive) to derail, resulting from the pilot striking a heavy object in the grade crossing. The collision dynamics analyses results indicate that for a pilot to crush less than 1 ft and not promote train derailment, the pilot must be designed to withstand a force of 1,000,000 pound force (lbf). The ability of the underframe to support such a load was not evaluated as part of this study.

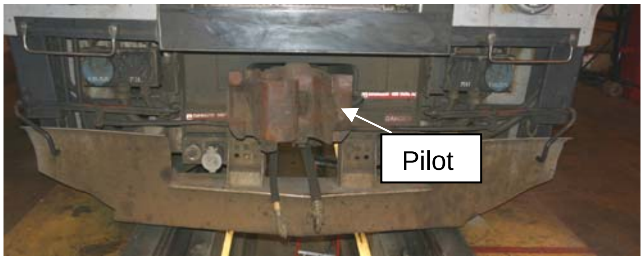

Figure 1: Front view of a cab car pilot

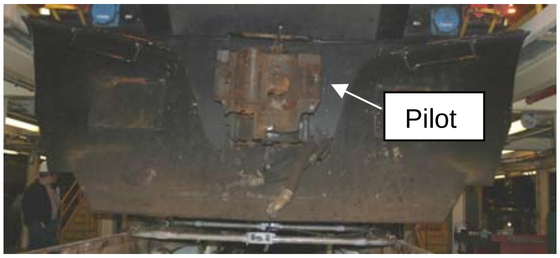

Figure 2: Front view of a locomotive pilot

BACKGROUND

The FRA funds safety-related research on passenger rail equipment. The goals of this research program were two-fold: determine if alternative cab car pilots could reduce the likelihood of a derailment under prescribed conditions, and to investigate the potential for cab car-led passenger trains to derail in grade crossing accidents compared to locomotive-led passenger trains. A review of accident reports involving passenger trains and road vehicles at grade crossings was performed to understand the damage sustained by the rail vehicle, and in the case of derailments, the cause. Accident reports from the past 18 years were reviewed. Also investigated was the grade crossing accident that occurred on October 23, 2006, in Franklin, MA. The accident involved a cab car–led passenger train and a low-bed trailer, which had a rock crusher on its bed. The cab car pilot struck the trailer, causing the rock crusher to collide with the underframe of the cab car. The cab car derailed. The pilot-to-carbody attachment bolts failed and the pilot was forced under the front end of the cab car. This accident scenario was used in computer model simulations to investigate the performance of cab car and locomotive pilots. Locomotive pilots are stiffer than the cab car pilots. However, neither the locomotive nor the cab car pilot was designed with the intent to clear the tracks of heavy objects, such as objects weighing more than 10,000 lbm.

OBJECTIVES

The research objectives were to investigate the differences in derailment potential between cab car and locomotive led trains when they strike heavy objects at grade crossings. Energy-absorption design concepts to improve the crashworthiness of pilots were studied.

METHODS

Various cab cars and passenger locomotives, along with the cab car involved in the Franklin, MA incident, were inspected during a site visit to the MBTA facility in Somerville, MA. The information obtained from MBTA was used to develop finite element models of the cab car and locomotive pilots. Figure 3 shows an example of the finite element model in which the pilot has been attached to a pre-existing cab car finite element model. The models were developed to review the baseline performance of the pilots and to evaluate concepts for improving their design. The performance of the pilot is dependent on the mass of the object in its path. To achieve low deformation of the pilot, thus minimizing penetration under the trucks, the pilot and its support structure must resist high forces.

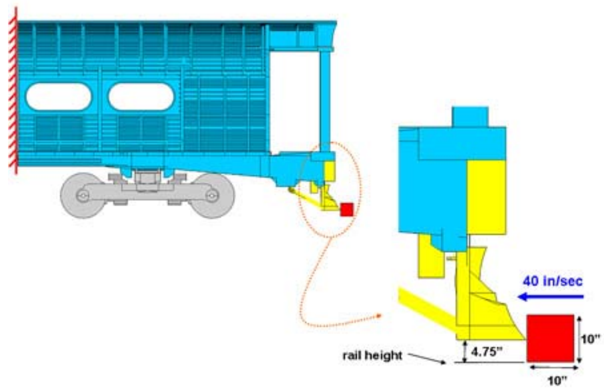

Figure 3: Finite element model of the cab car with pilot attached

In the models, the back end of both the cab car and locomotive were constrained against all motion. For baseline analysis, the collision obstacle was modeled as a 10-in high by 10-in thick by 160-in wide block. The obstacle was fixed against lateral and vertical movement, as well as rotation. The obstacle was allowed to move longitudinally into the pilot at a relatively slow speed (40 inches per second [in/s] to generate a quasi-static force-crush response for the pilot. Computer simulations were performed to investigate the effect of the weight of the obstacle on the crush of the pilot structure and the lead vehicle derailment factor (L/V). Previous studies have suggested that derailment occurs when the railcar's L/V factor is greater than 0.6.

Once the force-crush analyses were completed, the results were used to evaluate the collision dynamics performance of cab cars and locomotives in grade crossing collisions with heavy objects. The Franklin, MA incident scenario described earlier was used for the collision dynamics analyses. The collision dynamics model was comprised of five passenger cars and one lead vehicle (locomotive or cab car), with a pilot attached, interacting with a low-bed trailer. The low-bed trailer was aligned perpendicular to the tracks. Simulations were run for cab car- and locomotive-led trains with varied parameters, such as obstacle mass, impact speed and pilot strength. In the simulations, the center of mass of the obstacle was offset from the center of the rail by 5 ft. Table 1 below summarizes the simulations that were performed.

Cab Car Simulation	Obstacle Mass (lbm)	Impact Speed (mph)	Pilot Strength
1	5,000-25,000	30	Baseline
3	10,000-20,000	10-60	Baseline
5	5,000-25,000	30	2,000,000
7	5,000-25,000	30	2,000,000
Locomotive Simulation	Obstacle Mass (lbm)	Impact Speed (mph)	Pilot Strength
2	5,000-25,000	30	Baseline
4	10,000; 20,000	10-60	Baseline
6	5,000-25,000	30	1,000,000
8	5,000-25,000	30	2,000,000

Table 1: Collision dynamics simulations used to investigate the performance of the pilot

Simulation sets 3 and 4 were run to investigate the effect that impact speed has on the crush of the pilot structure and derailment factor for the baseline pilot. The simulation sets showing pilot strengths of 1,000,000 lbf and 2,000,000 lbf were evaluated to understand the effect that strengthening the pilots could have on its performance.

RESULTS

The baseline pilot strength analyses, as shown in Table 1, indicate that the cab car and locomotive pilots absorb a considerable amount of energy prior to failure.

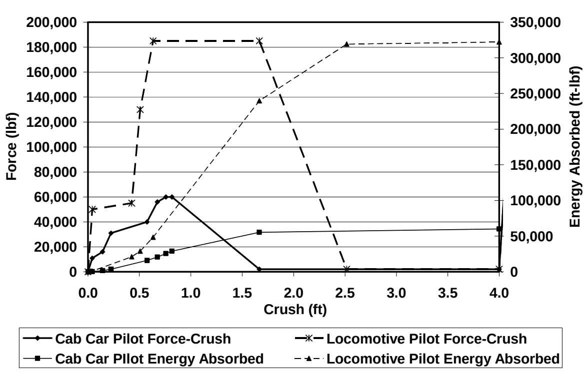

Figure 4: Baseline pilots force-crush and energy absorption curves

The cab car pilot absorbs 30,000 ft-lbf of energy, at only 0.82 ft of crush, while the locomotive pilot absorbs 240,000 ft-lbf of energy (see Figure 4). The results of the collision dynamics models were used to predict the crush behavior of the pilots. For the cab car simulation, set 1, the pilot and its supporting structure were predicted to crush more than 4ft. This suggests that the pilot would not have prevented the objects of specified masses shown in Table 1 from being lodged under the underframe nor from possibly interacting with the truck. The locomotive simulations, set 2, exhibited similar results, but only when the object’s mass was 15,000 lbm or more. Figure 5 summarizes the results from simulation sets 1 and 2.

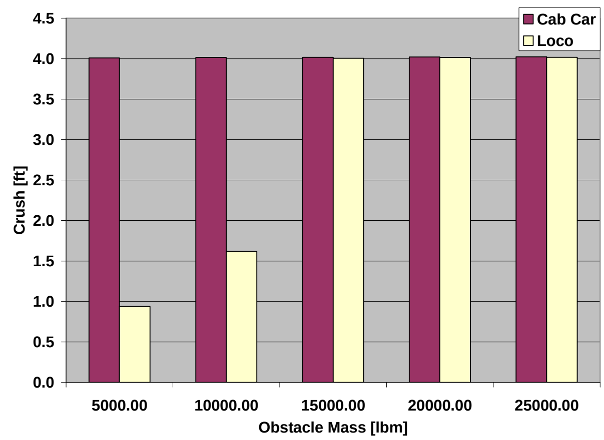

Figure 5: Baseline pilot crush in a 30 mph collision with the prescribed obstacle.

The L/V ratio was calculated for the lead vehicle (cab car or locomotive). None of the L/V values exceeded 0.6, indicating that derailment will not occur while the pilot is being crushed. In simulation set 3, the cab car pilot was predicted to crush more than 4 ft for impact speeds of 20 mph and greater, For obstacles of mass 10,000 lbm and speeds of 10 mph, the cab car pilot crushes less than 1 ft. The locomotive pilot crush was less than that of the cab car pilot for obstacle mass of 10,000 lbm, at speeds of 40 mph or more. When impacting a mass of 20,000 lbm at speeds of 30 mph or more, the locomotive pilot crushes the same amount as the cab car, as shown in Figure 6 Simulation sets 5, 6, 7, 8, were run to investigate the behavior of stronger pilots. The peak strength of the pilots was increased to 1,000,000 lbf and 2,000,000 lbf. For an idealized pilot with a peak strength of 1M lbf and a crush distance of 18 in, the energy absorbed was predicted to be 1,500.000 ft-lb, as can be seen in Figure 7.

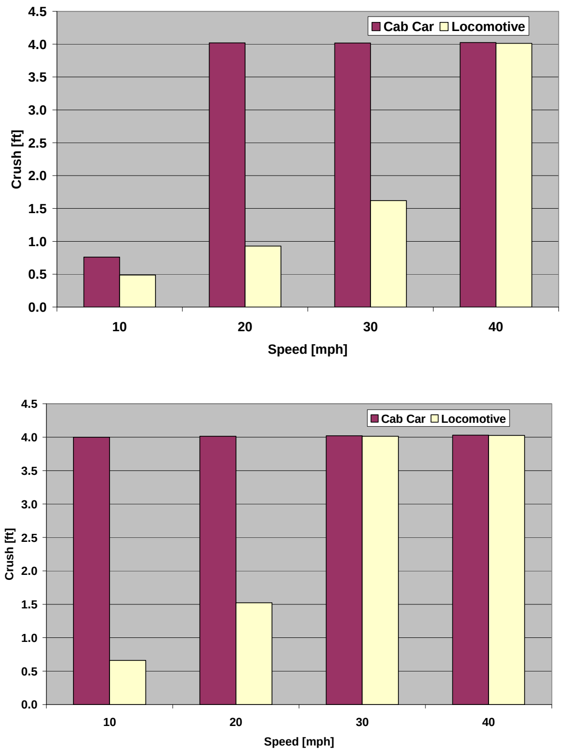

Figure 6: Crush vs. Speed for the pilots impacting a: A) 10,000 lbm object B) 20,000 lbm object

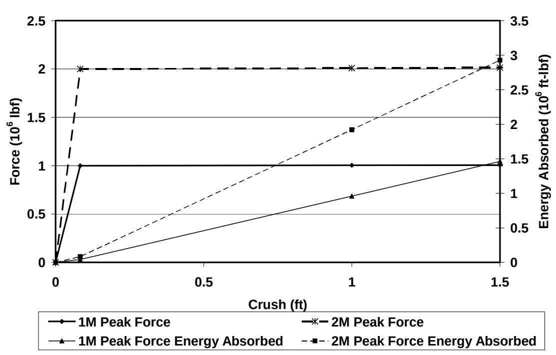

Figure 7: Force-crush and energy absorption curves for idealized pilot (1,000,000 lbf strength)

The derailment potential for the cab car- and locomotive-led passenger train L/V ratio was investigated for the stronger idealized pilot. The predicted derailment potential for a strengthened cab car pilot (1M lbf) interacting with a 25,000 lbm object suggests that the cab car would derail while the locomotive would not. Note that the predicted L/V factor for the cab car simulation exceeds the limit by only 3 percent. It should be made clear that a pilot designed to develop strengths as high as those theorized in simulation sets 5–8 would require significant modification to the underframe of the vehicle.

CONCLUSIONS

The focus of this SBIR research was to investigate the crush behavior of passenger locomotive and cab car pilots and how such behaviors influence the derailment potential of the lead vehicle. Collision dynamics simulations, centered around the 2006 Franklin, MA derailment scenario, were run for each lead vehicle type in conjunction with a range of collision speeds and obstacle masses. Results from the baseline pilot simulations indicate that the pilots, for either cab cars or locomotives, would crush more than 4 ft. This suggests that in order to keep heavy objects from intruding a great distance below the underframe, stronger pilots would be needed for use, in both cab cars and passenger locomotives. To limit the intrusion distance under the underframe when the cab car strikes an obstacle of mass 25,000 lbm or more, the cab car pilot would need to be 10 times stronger than the current design. When the pilots of the cab car and passenger locomotive were hypothetically strengthened to 1,000,000 lbf and 2,000,000 lbf, neither the cab car-led nor passenger locomotive-led train was predicted to derail after impacting an offset object weighing 20,000 lbm or less.

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