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Impact Test of a Diesel Multiple Unit Fuel Tank

SUMMARY

On June 28, 2016, the Federal Railroad Administration's (FRA) Office of Research, Development and Technology performed a dynamic impact test of a fuel tank from a Diesel Multiple Unit (DMU) rail vehicle with support from the Department of Transportation's John A. Volpe National Transportation System Center. The test was performed at the Transportation Technology Center (TTC) in Pueblo, CO. An impact vehicle weighing approximately 14,000 pounds and equipped with a 12-inch by 12-inch impactor head, struck the bottom surface of a DMU fuel tank mounted vertically on an impact wall. The test setup is shown in Figure 1.



Figure 1. Test Setup: Fuel Tank Mounted on Crash Wall and Impact Vehicle

The impact was centered on two baffles within the fuel tank. The target impact speed was 11.5 mph, and the actual impact occurred at

11.1 mph. The test resulted in a maximum indentation of approximately 8 inches, and buckling of several internal baffles. Figure 2 shows the fuel tank after the test. Following the test, the tank was cut open to inspect the damage to the internal structure. This examination revealed that the buckling behavior of the baffles was isolated to the baffles immediately adjacent the impact location, each one buckling as the tank deformed inward.



Figure 2. Post-Test Fuel Tank

This test is part of an FRA research program investigating puncture resistance of passenger locomotive fuel tanks. The objective of this research program is to establish the baseline puncture resistance of current locomotive fuel tanks under dynamic impact conditions and to develop performance requirements for an appropriate level of puncture resistance in alternative fuel tank designs, such as DMU fuel tanks.



BACKGROUND

Between October 2013 and August 2014, FRA conducted a series of “baseline tests” to measure the puncture resistance of retired passenger locomotive fuel tanks. These tests demonstrated that the test setup could simulate a blunt impact to the bottom of a fuel tank and collected measurements of the force required to deform the tank.

Currently, Title 49 Code of Federal Regulations (CFR) Part 238, Appendix D contains three load cases and a material design requirement addressing structural strength of locomotive fuel tanks. While these requirements have worked well to prevent gross loss of fuel tank integrity during derailments when the weight of a heavy locomotive rests on the fuel tank, localized puncture is another area of concern being investigated in this research program. Specifically, this research is focused on the design features necessary to provide protection to the occupants (passengers and crew) of DMU equipment. DMU equipment is a general term referring to a passenger-carrying rail vehicle powered by an onboard diesel engine, as opposed to a passenger car that is hauled by a separate locomotive. The current CFR requirements for fuel tank strength are applicable to all locomotives, including freight locomotives, passenger locomotives, and DMUs. DMUs have several differences that may require additional or separate requirements from conventional passenger locomotives. For example, DMU equipment is typically much lighter than both freight and passenger locomotives. One additional, significant difference is that DMU equipment carries passengers. The presence of more people on a

DMU requires careful consideration of the risks posed by a diesel fuel tank onboard the vehicle.

OBJECTIVES

The objective of this test was to strike the bottom surface of a DMU fuel tank, centered on two baffles and measure the force-versus-displacement behavior of the tank. The target impact speed was 11.5 mph. Based on pre-test finite element analysis (FEA), this impact speed was not expected to result in puncture of the tank.

METHODS

FRA purchased three new fuel tanks from a DMU manufacturer in operation in the US. The manufacturer provided technical drawings, material specifications and mounting hardware.

Pre-test finite element (FE) models were constructed using the engineering drawings and the mounting hardware information. FEA was used to predict the behavior of the tank during the test. The FE model of the tank is shown in Figure 3. Following the test, the tank was cut open to inspect and document the interior baffle performance. Material coupons were cut and sent for material testing. Prior to the test, the FE model used minimum properties provided by the manufacturer. The post-test model will be updated with actual material properties based on the material testing.

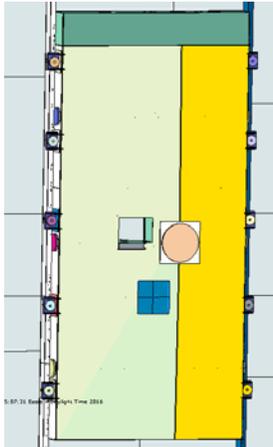


Figure 3. DMU Tank Finite Element Model Exterior

The primary result of this test was the force-versus-displacement behavior, derived from accelerometer data measured on the impact cart. Four sets of tri-axial accelerometers were installed on the cart. Accelerometers were placed on stiff structural members of the test vehicle, such as the side sills of the cart. The instrumentation is summarized in Table 1.

Table 1. Instrumentation Summary

Instrumentation	Channel Count
Accelerometers	12
Speed Sensors	2
Total Data Channels	14
Digital Video	5 Cameras

RESULTS

Figures 4 and 5 show comparisons of the test results to the pre-test FEA. The tank plastically deformed by approximately 8 inches and did not puncture. The damage was focused in the area immediately around the impact and caused the

tank to hinge forward from the wall rotating about the attachment points.

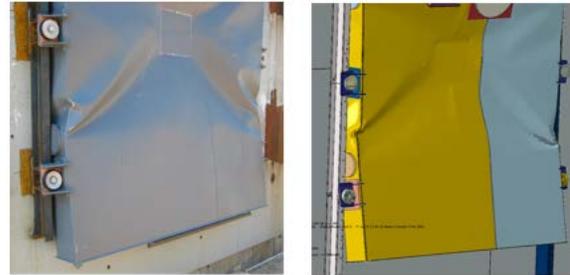


Figure 4. Oblique View of Lower Portion of Tank: Photos of Test Result (left) and Pre-Test FEA (right)

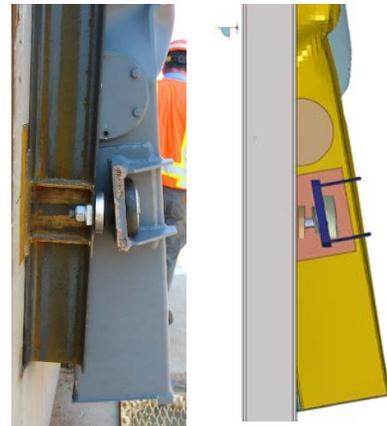


Figure 5. Side View: Photos of Test Result (left) and Pre-Test FEA (right)

Accelerometers mounted on the cart were used to calculate the force-displacement data. Figure 6 shows a plot of the average force-displacement measurement from the test as well as the average force-displacement response calculated from the post-test model. Both the test and FEA results have been filtered using a CFC60 filter. The results show excellent agreement between the pre-test model and test results.

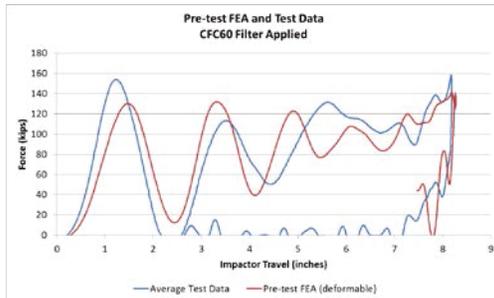


Figure 6. Force-Displacement Behaviors from Test and FEA

CONCLUSION

A blunt impact test of a DMU fuel tank was performed on June 28, 2016, by FRA's Office of Research, Development and Technology at TTC. The impact occurred at 11.1 mph, which resulted in damage but no puncture of the tank. Post-test examination of the tank revealed the baffle deformation behavior. The pre-test FE results are in excellent agreement with the test results. This test shows that a DMU tank can sustain an 11-mph dynamic impact with a rigid indenter.

FUTURE ACTION

Future tests are planned within this research program during 2018 and 2019. The lessons learned during testing supports the FE modeling of impact conditions beyond what was tested. Additional tests to investigate the puncture resistance of fuel tanks during sideswipe or raking collisions are also planned.

The FE model will be updated based on material characterization measurements. The next effort on evaluating DMU fuel tank performance under dynamic loads is focused on a raking collision. The FEA will be developed to better understand this loading condition on fuel tank integrity. From this information, a test setup will be developed to evaluate fuel tank performance. The results from these dynamic tests will be compared to fuel tank performance under the existing strength-based CFR requirements.

ACKNOWLEDGEMENTS

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KEYWORDS

Fuel tanks, finite element modeling, FE, diesel multiple unit, DMU, impact testing, puncture resistance, finite element analysis, FEA, passenger locomotive

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