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APPLICATION OF ALTERNATIVE CRITERIA AND PROCEDURES TO PASSENGER RAILCARS

SUMMARY

Occupied volume integrity (OVI) refers to a passenger railcar's ability to preserve space for passengers and crew during an accident. The Federal Railroad Administration's (FRA) Office of Research and Development (R&D) is sponsoring research investigating OVI. The results of a series of tests have been published in an FRA Report [1]. This research forms the basis for establishing alternative OVI evaluation procedures. The alternative procedures permit an analysis to be validated with data from an elastic test. The validated analysis may then be used to extrapolate the behavior of the subject car under destructive load conditions, without conducting companion destructive testing.

The previous tests used Budd Pioneer passenger cars that had been fitted with crash energy management (CEM) systems. The CEM systems on these cars altered the path of collision loads through the occupied volumes. For the test, evaluation loads were placed along the collision load path. The results of this previous program indicate an analysis that has been validated with elastic test data is capable of then extrapolating the carbody's behavior under destructive loading conditions. The results of the destructive analysis were reasonably descriptive of the results of actual destructive tests that were performed on the carbodies.

Currently, an FRA-sponsored research program is underway to expand upon the results of the previous program. This research program will subject a CEM-equipped Budd M1 passenger railcar to a program of testing and analysis as if an OVI waiver were being sought according to established procedures [2].

The testing portion of this program includes an elastic test as well as a crippling test. The elastic test is intended to provide data to validate a model. The validated model will then be used to simulate loading of the car up to its crippling load. A second test loads the car to the point of crippling. An M1 car is shown in Figure 1 in the testing frame.



Figure 1. M1 Car in Testing Frame

The outcomes of this program will include documentation of the results of the 800-kip test and analysis, as well as discussion of the data necessary to achieve model validation. The results will include the information expected in an actual application for a waiver.

BACKGROUND

OVI is a measure of a passenger railcar's ability to preserve space for passengers and crew during an accident. The current requirement for longitudinal strength (see 49 CFR 238.203) requires a carbody structure to experience no permanent deformation when an 800,000-pound load is placed on the car's line of draft.



FRA’s Railroad Safety Advisory Committee (RSAC) Engineering Task Force (ETF) has adopted a set of alternative criteria and procedures for demonstrating crashworthiness in alternatively designed vehicles [2]. These criteria and procedures introduce the concept of using the crippling load of the carbody as a performance-based measure of OVI. Evaluation of the crippling load is intended to ensure an equivalent level of safety between an alternatively designed car and one compliant with the 800-kip load requirement. The ETF’s three conditions for evaluating OVI are shown in Table 1. For any condition, the load is to be applied to the car along its collision load path.

Table 1. ETF OVI Options

Load Magnitude	Pass-fail Criteria
800,000 pounds	Without permanent deformation
1 million pounds	Without exceeding 5% plastic strain OR vehicle shortening of 1% over any 15 feet
1.2 million pounds	Without crippling

Previous OVI research sponsored by FRA has demonstrated the technical basis for the ETF’s elastic validation testing and destructive analysis methodology [1]. This prior research program used CEM-equipped Budd Pioneer cars in a series of quasi-static tests and analyses. These tests followed the ETF’s methodology of using an elastic test to validate a finite element (FE) model, then using that FE model to simulate loading up to crippling.

The presence of CEM structures on these cars permitted evaluation loads to be introduced into the occupied volumes of the cars at a location other than the line of draft. Because the occupant volume was originally constructed to meet the conventional 800-kip buff strength requirement, application of the ETF’s methodology would provide data on the OVI capacity of a conventionally designed car.

The results of this prior research indicate that if an analysis program is performed properly, a model that has been validated using elastic test data that describe the behavior of the car up to its crippling load. This prior research has also demonstrated that the crippling load of a conventionally designed passenger railcar is approximately 1.2 million pounds.

OBJECTIVES

The objective of the current research program is to develop additional guidance on performing the tests and analyses necessary to demonstrate OVI using alternative procedures. The product of this research effort is intended to be a “mock waiver” containing the type of information that would be submitted in an actual application of the ETF’s OVI procedures. This program will use a combination of elastic testing, FE analysis, and destructive testing to quantify and document the OVI performance of the M1 car. Through careful monitoring of the modeling efforts, this program seeks to establish that different approaches to performing an FE analysis can result in a model that adequately captures the deformation behavior of the vehicle up to its crippling load.

The results of this program will help establish the level of detail needed in a model for successful demonstration of OVI. The results may also indicate that the OVI procedures currently in place need to be revised to ensure that application of an elastic test and elastic analysis can result in a model capable of making a successful prediction of the crippling behavior of the car. Finally, performing a crippling test on a vehicle type other than that used in the previous research may increase confidence in the ETF’s recommended criteria of a minimum crippling load of 1.2 million pounds.



METHODS

The passenger car chosen for this research program is a Budd M1 car. The particular car being tested has had a CEM system installed on both of its ends. This CEM system shifts the collision load path away from the line of draft and into the occupied volume via two floor-level and two roof-level energy absorbers. All test loads will be introduced into the car at these locations.

The current research plan calls for an 800-kip elastic test to be performed the week of March 11, 2013, at Transportation Technology Center (TTC) in Pueblo, CO. This test will load the M1 car, up to a total applied load of 800,000 pounds, at its floor-level energy absorbers. The M1 car selected for this testing program is shown in Figure 2.

The purpose of this test is to nondestructively load the occupant volume of the car in order to generate data to be used in model validation. The data to be collected includes longitudinal shortening, vertical deformation of the underframe, and strain data throughout the carbody structure.



Figure 2. M1 Car Intended for Use in Testing

The data collected in the 800-kip test will be used to validate the FE models. Two independent FE models of the M1 car are currently being developed. The ETF's report

includes validation thresholds for comparing test results and model calculations. These thresholds will be applied during this research to validate the FE models. A model may require adjustments to boundary conditions, mesh size, material properties, or other aspects in order to achieve successful validation within the indicated thresholds.

Following successful validation, the FE models will be used to simulate loading up to crippling. The current test plan places the crippling load simultaneously at the floor-level and roof-level energy absorber supports. The total load will be increased until the overall maximum ("crippling") load has been reached. This test is planned for the summer of 2013 at TTC. The strain and displacement results from the FE model will be compared with the results of the crippling test to verify that a model validated with elastic data is capable of capturing the behavior up to crippling.

FE models of the M1 car to be tested will be developed as part of this program. Material samples have been cut from several areas of a second car of the same design, and tensile strength testing has been performed. While a model represents a physical car, the choice of mesh size, element type, and other features representing the carbody may vary. Sound engineering judgment must be applied when making these choices and when approximating certain details in a computer model that represent the vehicle being tested.

RESULTS

An expected outcome of this research program is additional information about the types of assumptions that will yield a satisfactory model when simulating crippling of a carbody. The research may also result in additional recommendations for incorporation into the ETF's procedures. These recommendations would help guide the development of a model that is capable of successfully simulating the behavior of a railcar loaded up to crippling.



The final product of this research program will be a report written as if an OVI waiver were being sought for the tested car. This “mock waiver” is intended to serve as a guideline for other entities demonstrating OVI using a combination of testing and analysis. The “mock waiver” report will present the information that is needed to successfully validate an OVI FE model using elastic testing. This report will serve as a template describing instrumentation placement and the types of detailed results that would need to be provided to FRA in a waiver submission. It will also encourage a consistent approach to preparing documentation intended to demonstrate that a design satisfies an OVI requirement.

REFERENCES

- [1] Carolan, M., Perlman, B., and Tyrell, D. “Alternative Occupied Volume Integrity (OVI) Tests and Analyses.” U.S. Department of Transportation, DOT/FRA/ORD-13/46.
- [2] Carolan, M., Jacobsen, K., Llana, P., Severson, K., Perlman, B., and Tyrell, D. (eds). “Technical Criteria and Procedures for Evaluating the Crashworthiness and Occupant Protection Performance of Alternatively Designed Passenger Rail Equipment for Use in Tier I Service.” U.S. Department of Transportation, DOT/FRA/ORD-11/22. October, 2011.

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