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FINITE ELEMENT ANALYSIS OF APTA PASSENGER RAIL 8G STRUCTURAL SEAT TEST

SUMMARY

The Federal Railroad Administration (FRA) sponsored researchers at the Volpe Center to perform finite element analyses (FEA) of 8g dynamic crash tests with a commuter rail 2-passenger seat design and Hybrid-III family anthropomorphic test devices (ATDs). The simulations analyzed (1) residual (i.e., survival) space during the crash test, (2) compartmentalization during the crash test, and (3) egress space after the crash test in structural integrity seat tests with two 95th percentile male (H3-95M) ATDs impacting a row of seats and thereby reducing the residual and egress space for either a H3-95M ATD or a 5th percentile female (H3-5F) ATD in a wall seat, as depicted in Figure 1.

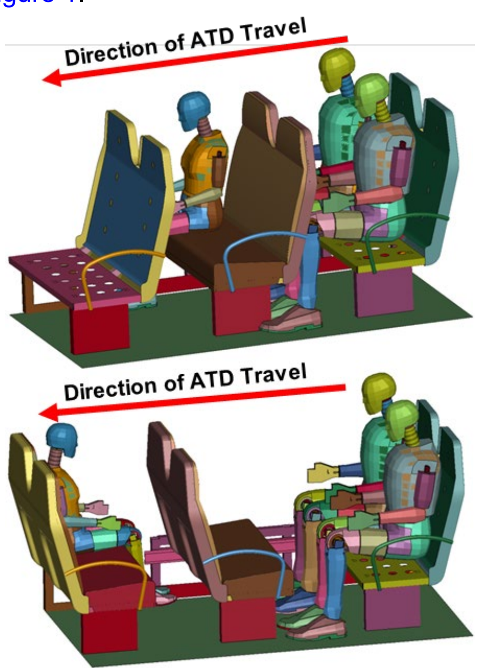

Figure 1. Residual and Egress Space FE Model of Forward-facing Row-to-Row (Top) and Open Bay (Bottom) Sled Tests

The researchers modified the forward-facing structural integrity test setups from the American Public Transportation Association (APTA) seat standard (APTA PR-CS-S-016-99, Rev. 3 [1]) to consider the residual and egress space for an occupant (either a H3-95M or H3-5F) in an adjacent wall seat. The researchers conducted this study to (1) address part of the National Transportation Safety Board's recommendation R-19-015 on the compartmentalization of occupant sizes outside of the currently used range and (2) address questions from interior equipment manufacturers and test labs on the evaluation of egress space in the APTA seat standard.

For the particular commuter rail 2-passenger seat design analyzed, the simulation results indicate that occupants in row-to-row seats have sufficient residual and egress space; however, occupants seated adjacent to open bay seats may not have sufficient residual space because the forward-facing H3-95M ATDs were not compartmentalized.

BACKGROUND

Passenger seats in U.S. commuter rail trains are subject to the safety requirements described in the APTA seat standard. This standard requires seats to undergo an 8g sled test with instrumented ATDs to evaluate seat integrity, human injury performance, and occupant compartmentalization. The standard requires three sled tests with ATDs:

1. Forward-facing human injury test with instrumented H3-50M ATDs – **modeled in a companion research result** [2]
2. Rear-facing human injury test with instrumented H3-50M ATDs

3. Forward-facing structural integrity test with H3-95M ATDs – **modeled in this work**

The standard also requires static strength tests for seat components, lateral and vertical seat attachment tests, and flame and smoke emission tests.

The APTA seat standard requirements state that (1) the ATDs shall be compartmentalized, and (2) after testing, the seats shall not be deformed to such an extent that they present an impediment to emergency egress. However, there are no defined minimum requirements for post-test measurements of egress space. In some cases, a test lab technician has physically moved into and out of the seat row to demonstrate that there is sufficient emergency egress space. The APTA seat standard does not currently have requirements on residual space. GM/RT 2100, Issue 6 [3] is a safety standard in the UK that includes residual space requirements for a rear facing seat; however, the researchers were not able to find quantified residual or egress space requirements in a forward-facing configuration.

OBJECTIVES

The objective of this research was to evaluate (1) residual (i.e., survival) space, (2) compartmentalization, and (3) egress space in the APTA seat standard structural integrity seat test.

METHODS

Volpe researchers created an LS-DYNA FE model of a 2-person commuter rail seat as described in a separate research result [2]. The previous work used detailed (i.e., refined mesh) versions of the Hybrid-III ATDs necessary to calculate injury criteria. In this study, the researchers used fast (i.e., coarse mesh) versions of publicly available ATD models: (1) H3-5F, released on July 2, 2012; and (2) H3-95M, released on September 27, 2013.

Figure 2 shows the FE model of the forward-facing seat structural integrity test with three rows of 2-passenger seats and two H3-95M ATDs seated in the first row (i.e., launch seats). The researchers seated a third ATD in an adjacent wall-side seat to load the third row of seats and used this occupant for analysis of residual and egress space. The researchers used either a H3-95M or H3-5F ATD to bound the possible deformation of the third row of seats and the required residual and egress space. The red dashed lines and arrows indicate the pre-impact egress space, as defined in the APTA seat standard. The researchers removed the seat-back and seat-bottom foam cushions when they were not directly impacted or required for spatial analysis to improve the simulation stability and reduce runtime.

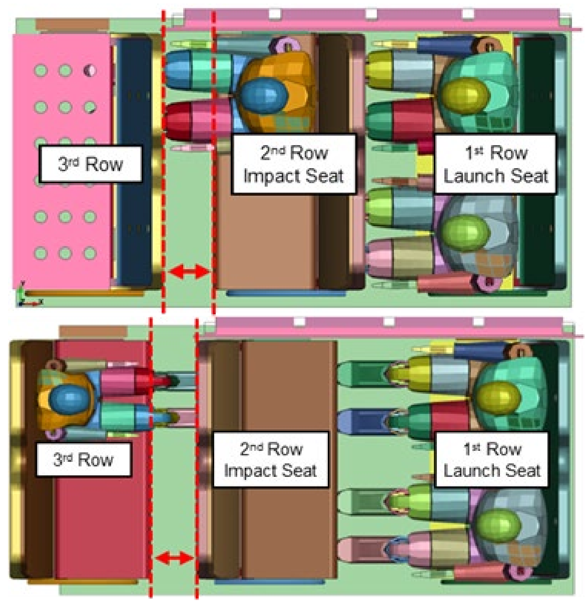

Figure 2. Top Views of Row-to-row (Top) and Open Bay (Bottom) FE Models with Egress Space Annotated

RESULTS

The results presented here focus on residual space, compartmentalization, and egress space in an APTA seat standard forward-facing structural integrity test.

Figure 3 shows the ending egress space for the H3-5F and H3-95M ATDs in row-to-row (R2R) and open bay (OB) configurations. The ATDs seated adjacent to open bay seats had significantly less egress space as measured per the APTA definition, but the researchers qualitatively note there appeared to be space for egress post-impact and the definition in the standard could be improved.

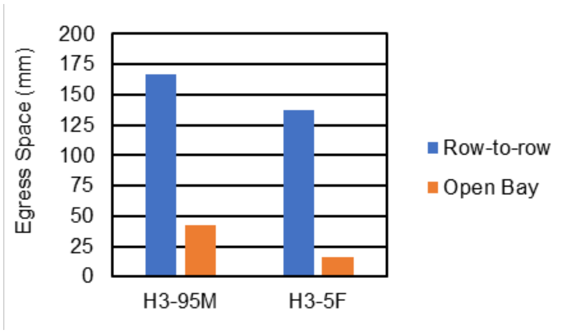

Figure 3. Egress Space in Impact Seat Row from Forward-facing APTA Seat Test Simulations

Figure 4 shows a side view snapshot of the R2R FE models at the time point of minimum residual space with the H3-95M at 325 ms, and Figure 5 similarly shows the H3-5F at 275 ms. At the end of the simulations, the researchers measured egress space of 167 mm (6.57 inches) for the H3-95M ATD and 137 mm (5.39 inches) for the H3-5F ATD. The researchers also determined the ATDs were all compartmentalized and that they were not pinched between two rows of seats, meaning that there was some remaining residual space. The researchers qualitatively noted that the H3-95M ATD appeared to have less residual space and would likely have more difficulty egressing.

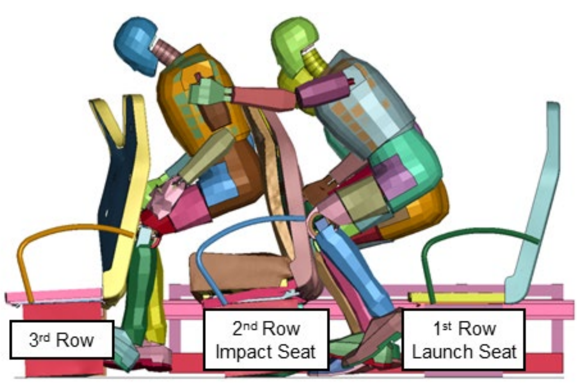

Figure 4. Row-to-row FE Model for H3-95M

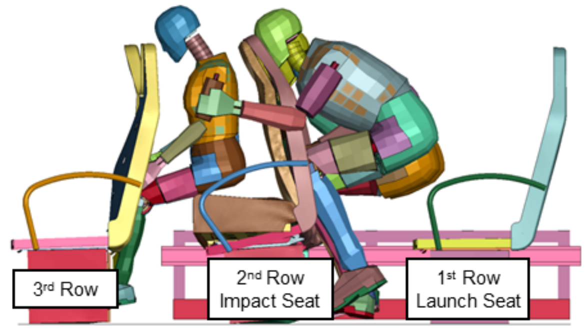

Figure 5. Row-to-row FE Model for H3-5F

Figure 6 shows a side view snapshot of the OB FE models at the time point of minimum egress space (320 ms) with the H3-95M, and Figure 7 similarly shows the H3-5F. At the end of the simulations, the researchers measured egress space of 42 mm (1.7 inches) for the H3-95M ATD and 16 mm (0.64 inches) for the H3-5F ATD. The researchers also determined the two H3-95M ATDs seated in the open bay seats were not compartmentalized, and in both cases, the H3-95M and H3-5F ATDs in the adjacent seats were impacted by the OB ATDs. Additionally, the knees of the rear-facing H3-95M contacted the 2nd row impact seatback.

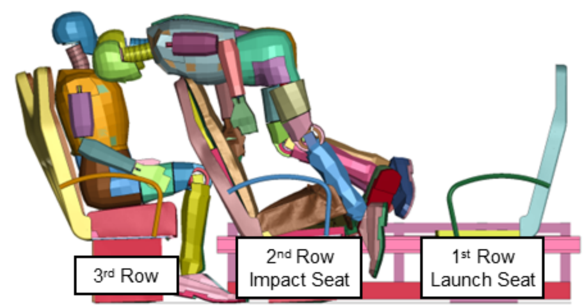

Figure 6. Open Bay FE Model for H3-95M

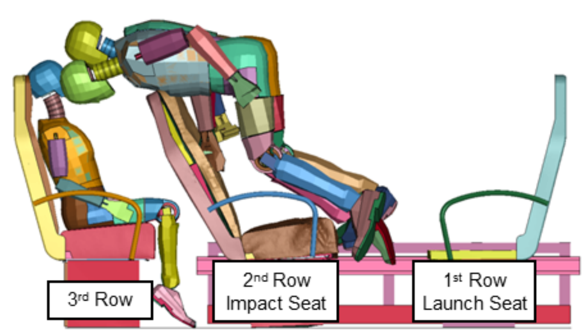

Figure 7. Open Bay FE Model for H3-5F

CONCLUSIONS

The analysis presented here indicates that residual and egress space were preserved in the R2R seating configuration for the APTA seat standard structural integrity test. In the OB seating configuration, the forward-facing ATDs were not compartmentalized and impacted the adjacent ATDs, which would result in a test failure.

FUTURE ACTION

Further research could improve the definitions of residual space measured during the sled tests and egress space measured after the sled tests in the APTA seat standard. Physical sled tests would be helpful to demonstrate the suitability of the new definitions for the APTA working group.

REFERENCES

[1] American Public Transportation Association (March, 2021). APTA PR-CS-S-016-99, Rev. 3 - Standard for Passenger Seats in Passenger Railcars. Washington, D.C.

[2] Federal Railroad Administration (2023). Finite Element Analysis of APTA Passenger Rail 8G Injury Seat Test (Report No. RR 23-07). FRA.

[3] Rail Safety Standards Board (May 2021). GM/RT 2100, Issue 6.1: Rail Vehicle Structures and Passive Safety.

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KEYWORDS

Crashworthiness, dynamic sled testing, ATDs, rail passenger safety, secondary impacts, finite element analysis

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