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RESEARCH RESULTS

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Prototype Design and Test of a Collision Protection System for Cab Car Engineers

SUMMARY

Advancements in the design of rail cars can potentially prevent the structural collapse of space occupied by a cab car engineer during a train collision. With adequate survival space maintained, the next crashworthiness objective is to minimize the consequences of any resulting secondary impact between the engineer and the control stand. A conceptual Engineer Protection System (EPS) has been developed to meet these design objectives and requirements, using finite element analyses and component-level tests [1]. The system was fabricated and dynamically tested using an instrumented Hybrid III 95th percentile male anthropomorphic test device (ATD).

The prototype EPS consists of an airbag system and a deformable knee bolster system. It was installed into a baseline cab console, or desk, which has features and geometry similar to many console designs. The performance of this prototype EPS was evaluated under simulated collision conditions representing a moderately severe frontal train collision (see still frame from test video in Figure 1).

The test highlighted the ability of the EPS to protect a cab car engineer under the specified collision conditions, meeting all prescribed performance criteria, including ATD compartmentalization and limits on the head, chest, neck, and femur injury criteria. The system functions without requiring input from the engineer, without restraining him or her, and without impeding egress, while adding minimally to cost or weight of the car.

The prototype design could be used to retrofit existing cab consoles, or it could be integrated into new cab console designs.

Figure 1. ATD and Airbag Kinematics during Sled Test

BACKGROUND

In rail-to-rail vehicle collisions, the cab or locomotive engineer is in a vulnerable position at the leading end of the train. In direct impact scenarios with a conventional cab car leading, the control cab often suffers the most deformation damage given that there is little energy-absorbing structure between the control cab and the front of the car. As cars with increased crashworthiness performance are developed, there is significant potential for preserving more occupant space for the engineer. In particular, full-scale impact tests have demonstrated that the space occupied by the engineer can be preserved at closing speeds up to 30 mph [2]. When sufficient survival space is preserved, the next imperative is to protect the engineer from the forces associated with secondary impacts and extreme rapid deceleration. Secondary impacts occur part of the interior. Given the hard surfaces and protruding knobs and controls in a cab, even a low speed collision can result in large, concentrated forces causing blunt force injuries to the engineer.

Current cab designs have interior crashworthy features. The clean-cab concept from the 1970s removed sharp edges and protruding objects from the cab. Although this is an improvement for very low-speed collisions, a more rigorous occupant protection system is necessary for higher-speed collisions.

A conceptual design has been developed for an EPS to protect a cab engineer in a moderate-to-severe train collision. The collision scenario was based on test data from a single multilevel car impacting a rigid wall at 36 mph [3] (represented by the EPS test pulse, shown in Figure 2). This system included a large, passenger automobile-style airbag with a standard inflator and a knee bolster that features off-the-shelf crushable honeycomb material and deformable support brackets.

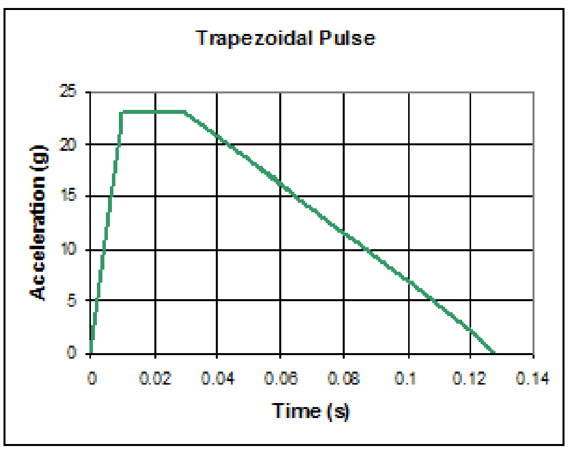

Figure 2. Crash Pulse Applied to Sled

OBJECTIVES

The primary objective of this research was to develop a system to protect engineers during secondary impact with the control desk.

The scope of the effort was as follows:

- Design and fabricate an EPS to meet the performance requirements,
- Design and fabricate a baseline cab console to which the EPS components will be installed,
- Evaluate the design performance using computer model(s) and component tests,
- Conduct a sled test to verify EPS performance, and
- Compare the test performance of the EPS with the analysis predictions.

The EPS was designed to compartmentalize a 95^{th} percentile ATD and limit the measured injury criteria for the ATD's head, chest, neck, and femurs. Maximum allowable injury values (consistent with requirements for rail passenger seats and tables) are defined below in Table 1. In addition, the EPS must not require action from the engineer to trigger the system. Seatbelts or other systems that must be disengaged before the operator can flee the cab must not be incorporated into the design. The EPS must not impede egress of the engineer following an accident.

Table 1. Maximum Allowable Injury Values

Injury Criterion	Limiting Value
HIC_{15}	<700
N_{ij}	<1.0
Neck tension	<937 lbf (4,170 N)
Neck compression	<899 lbf (4,000 N)
Chest deceleration	<60g over a 3ms clip
Axial femur loads	<2,250 lbf (10,000 N)

METHODS

The prototype EPS was comprised of three elements:

- The baseline cab console, which simulated the dimensions of the composite cab;
- The knee bolster system which was composed of a honeycomb structure and deformable brackets (Figure 3); and
- The airbag system which was composed of a cushion or bag, and corresponding inflator (Figure 4).

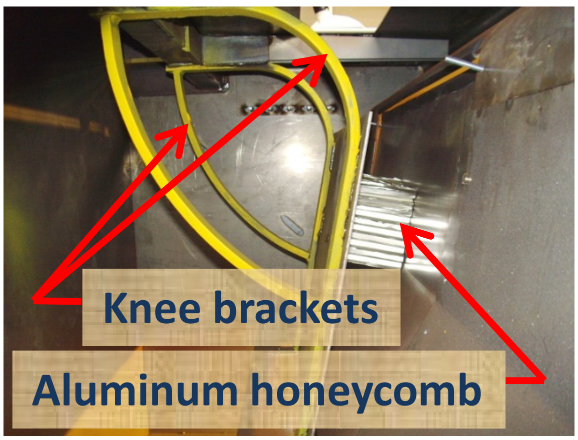

Figure 3. Knee Bolster Installation

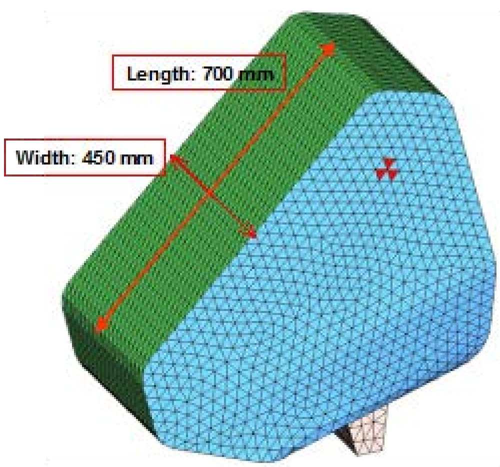

Figure 4. Airbag Schematic

Sled testing was conducted to validate the performance of the prototype EPS under the prescribed collision conditions. The baseline cab console with integrated knee bolster and airbag system was rigidly fastened to the HYGE™ test sled, as was an engineer's seat. The 95th percentile ATD was positioned in the seat facing the cab console. The test sled was accelerated backwards, simulating a frontal collision.

RESULTS

The measured injury indices from the test are outlined below (Table 2). The EPS was effective in protecting the engineer and keeping all injury indices within limits, while also maintaining effective compartmentalization.

Table 2. Injury Indices

Injury Parameter	Index Limit	Test
HIC_{15}	700	144
Chest 3ms (G)	60	32
Femur Left (N)	10,000	8,426
Femur Right (N)	10,000	8,996
Neck Tension (N)	4,170	1,951
Neck Compression (N)	4,000	1,200
N_{te}	1.0	0.58
N_{tf}	1.0	0.29
N_{ce}	1.0	0.33
N_{cf}	1.0	0.32

The computer simulations captured the ATD kinematics, forces, moments, and injury indices with sufficient fidelity to serve as an effective tool for designing similar protection systems. Most differences observed between the simulations and the test data would likely fall within the expected range of statistical variations in design, manufacturing, and ATD setup, thereby adding confidence to the development effort.

CONCLUSIONS

Performance of a prototype EPS for cab car engineers, consisting of an airbag system and a deformable knee bolster, was successfully demonstrated under simulated collision conditions using a dynamic sled test. The test highlighted the ability of the EPS to protect a cab car engineer in a moderate-to-severe train collision, meeting all performance requirements including compartmentalization of the ATD, and limiting injuries to the head, neck, chest, and femurs. The system functions without requiring input from the engineer, without restraining him or her, and without impeding egress, while adding minimally to cost (approximately $3,000) and weight (approximately 30 lbm) of the car.

The project demonstrated the feasibility of a secondary impact protection system that can effectively protect engineers under moderate-to-severe collision conditions, using modern occupant protection concepts and technologies. A final report describing the sled testing in detail will be published.

FUTURE ACTION

Additional research may be conducted to simplify the design and improve the cost-effectiveness from material and manufacturing perspectives. Further analyses may be conducted to verify the system performance using a range of occupant sizes and initial positions, as well as different crash pulses. Additional research is needed to develop and tune an airbag trigger system with threshold values and associated time delays, which are specific to rail car design.

There are plans to use these research results to develop an American Public Transportation Association recommended practice for crashworthy cab car design.

REFERENCES

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KEYWORDS

Crashworthiness, cab console, secondary impact protection, airbags, energy absorption, crushable knee bolster, sled testing, crash energy management, injury criteria, finite element analysis