L7 CLASS ELECTRIC VEHICLE FRONTAL CRASH PERFORMANCE STUDY

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1 Abstract

This study investigates the performance of a L7 class electric vehicle (EV) in frontal crash tests, as there are no mandatory safety requirements for this vehicle class. Two virtual crash test scenarios were simulated using ANSYS LS-DYNA software, featuring two different crash protection systems: a stationary prevention system and a replicable concept bumper. The results show that the replicable bumper provides significant benefits, particularly in low-speed impact collisions with a deformable barrier, which can be repaired without compromising the main structure, highlighting the importance of considering these types of collisions for future safety standards.

***KEYWORDS** L7 class EV Crash, RCAR bumper, L7 front replaceable bumper crash performance, frontal crash virtual test with ANSYS LS-DYNA

2 Introduction

As cities become increasingly crowded, there is a growing need for small, environmentally friendly cargo vehicles, and electric vehicles (EVs) are gaining popularity. The L7 class of vehicles, with their options for electric motors, are particularly suitable for this purpose.
The Anadolu Isuzu design is an L7 class vehicle and can accommodate one driver and one passenger. While there is no defined collision scenario for this type of vehicle, it's essential to consider passenger safety against collisions. However, since these types of accidents are becoming more frequent, regulations will likely be updated in the future. Due to the low top speed of these vehicles, impact scenarios are thought to be at low speeds as well. For the rigid wall test, an impact velocity of 20 km/h was chosen. However, when examining commercial vehicles, another low-speed test called "RCAR" (URL 1) was found, which involves impacting a deformable barrier at a speed of 10 km/h. Both scenarios were compared with a stationary bumper that is welded to the chassis and a replaceable bumper with a bolted connection to the chassis.
Both models, with the same weight and under the same conditions, were subjected to virtual crash tests using ANSYS LS-DYNA. The replaceable bumper was evaluated through simulation, with various designs and materials being examined. The study compared both models and suggested a design for the replaceable bumper, which was evaluated during the development process.

3 Methodolgy

A finite element model was created for crash simulations, which closely matched the original manufactured model. The materials and connections of the parts were properly defined. The seats and battery boxes were modeled as rigid due to the focus on the vehicle's behavior in these collision scenarios. The vehicle can be divided into three main parts: the cabin and chassis, which are connected with welded profiles; the cargo carrier, which is an optional add-on attached with bolts and varies depending on customer choice. Two collision scenarios were simulated: a high-velocity impact into a rigid wall at 20 km/h and an impact into a deformable structure defined by RCAR specifications. The results of both collisions were compared in terms of cabin contraction and chassis plastic deformation for various vehicle options.

3.1 Finite Element Model of Vehicle

The finite element model of the vehicle consists of 857256 elements and 878724 nodes.

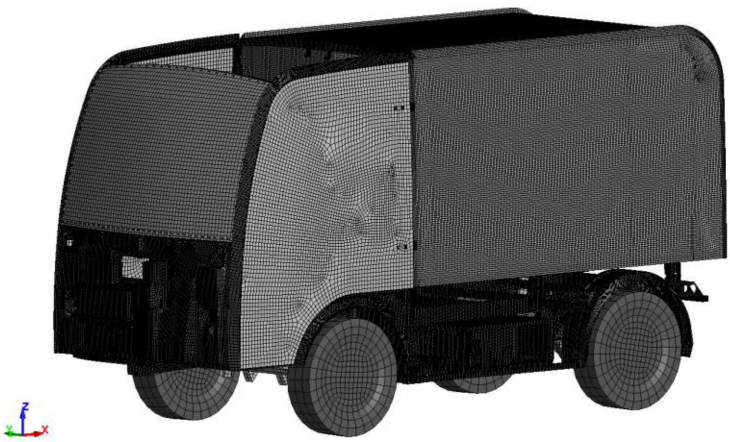

Fig.1: Finite element model of the BIG-e vehicle model

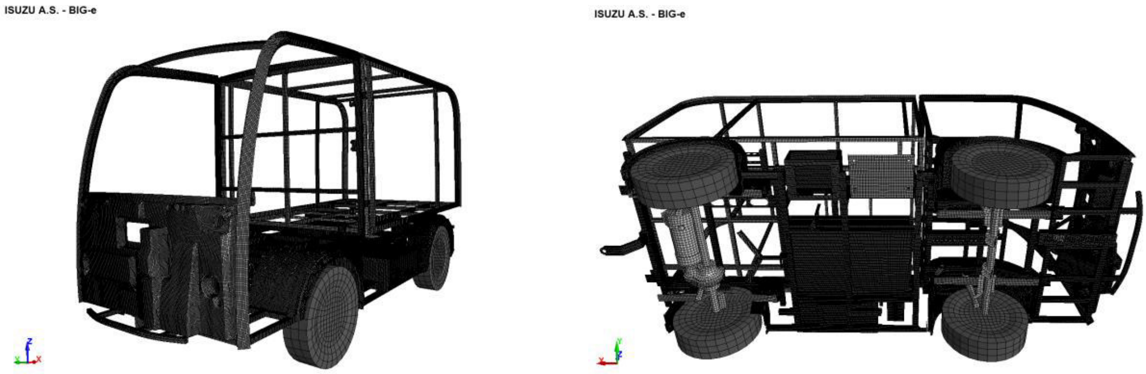

Fig.2: Finite element model of the BIG-e vehicle model

Fig.3: Material assignment plot of the BIG-e vehicle model

The finite element model was created with a range of materials assigned to various components, including S235 and S355 to profiles, as well as FRP and glass for added realism. The metallic parts were modeled using the MAT_098-Simplified Johnson-Cook material model. Tires were defined with elastic properties and air pressure. The seats and battery box were modeled as rigid bodies with proper weight definitions. The mesh size varied, with 5 mm used in stress-relevant areas and 10 mm in non-stress areas. A time step of 5e-7 seconds was used, along with proper element quality criteria. The model was built in the LS-DYNA software using the MPa, N, mm, s, and ton unit system.

3.2 Deformable Barrier

Deformable barrier is prepared by LSTSC according to the RCAR test procedures. The RCAR Bumper Test encourages vehicle manufacturers to produce effective bumper systems that feature tall energy absorbing beams and crash boxes, that
are fitted at common heights and can effectively protect the vehicle in low-speed crashes.

- In the opinion of RCAR, good vehicle bumper beams should:
- be fitted to both the front and rear of vehicles
- be replaceable without cutting / welding
- incorporate a beam height exceeding 100 mm
- be positioned to fully engage with the front and rear bumper barriers
- be torsion-resistant to carry eccentric loads without twisting
- absorb energy and restrict damage to the bumper system only
- be attached to the body via energy absorbing structures that are inexpensive to repair or replace
- be stable during impacts to prevent underride and override.
- prevent damage to structural, welded or bonded and other expensive parts
- extend laterally to protect the corners of the vehicle.

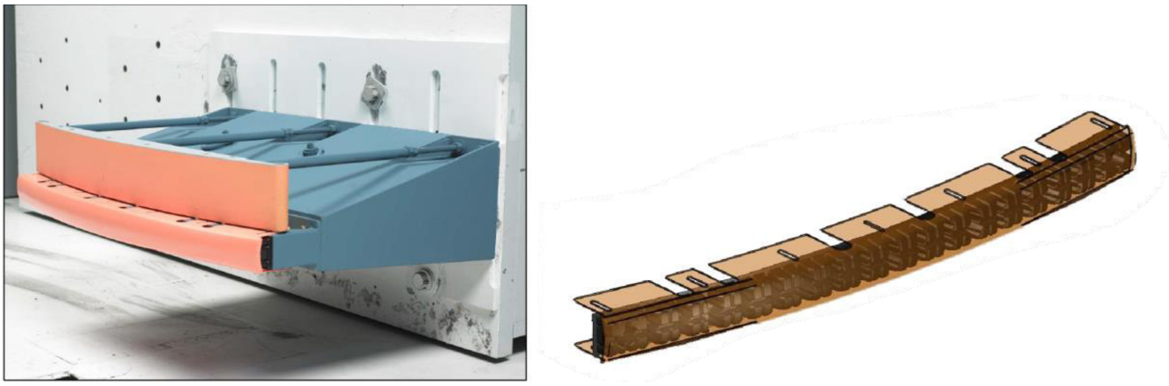

Fig.4: The RCAR test procedure deformable bumper CAD model

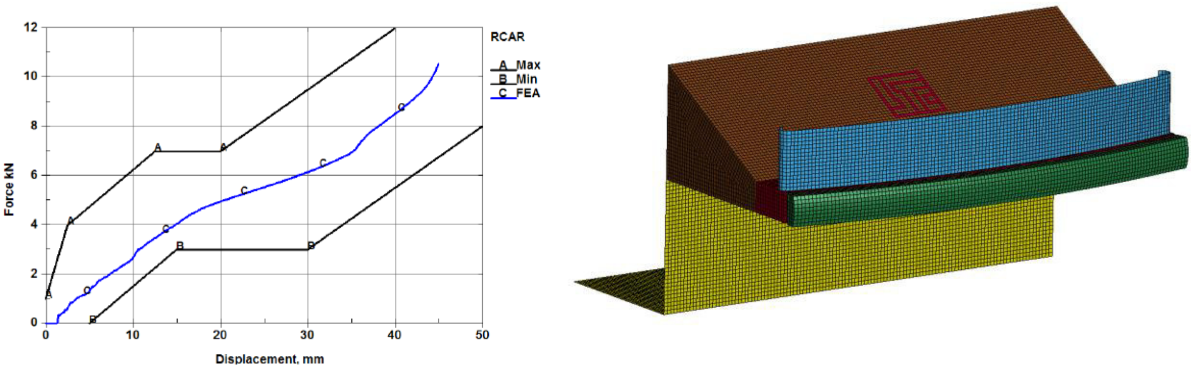

Fig.5: The RCAR test energy absorber force deflection corridors and FEA model

Relevant bumper engagement is < 75 mm. Insurance claims data indicate that rear bumpers are often under ridden by the striking vehicle when vehicles of similar type collide due to the influence of dynamic vertical dive of vehicles during braking. Due to this the front and rear bumper tests are undertaken at differing heights.
Insurance data also show that rear bumpers are overridden when struck by high ride height vehicles (SUVs, pickup trucks). In markets where such vehicles are common the rear test may be conducted at the higher mounting position to prevent override. The impact velocity shall be 10.0 km/h ± 0.5 km/h. The FEA model of the RCAR test bumper has 36848 elements and 35729 nodes.

3.3 Replaceable Bumper Model

The replaceable bumper model consists of three distinct parts. The front side is designed using roll-formed high-strength dual-phase steel, while the crash box side features a rectangular tubular structure made of mild steel, with triggers formed using mild steel and flash plates manufactured from high-strength steel, connected via bolts. The profile has a height of 25mm and a width of 825mm.

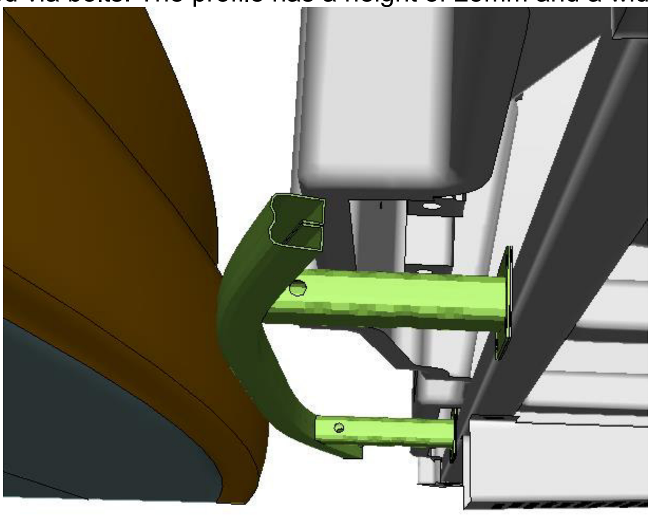

Fig.6: Replaceable bumper mathematical model presentation

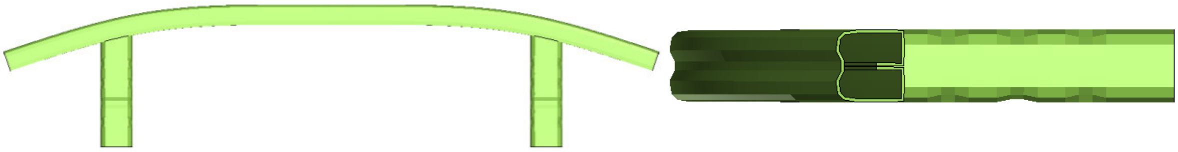

Fig.7: Replaceable bumper mathematical model presentation (top and side views)

3.3.1 Template “Heading 3“

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4 Results

In this section, a comparison is made between two scenarios: a rigid wall and an RCAR (Rigid Crush Absorption Region) bumper, for both the stationary profile and replaceable bumper models. Each scenario is explained and compared in detail in the final section.

4.1 Rigid Wall with Stationary Profiles Scenario

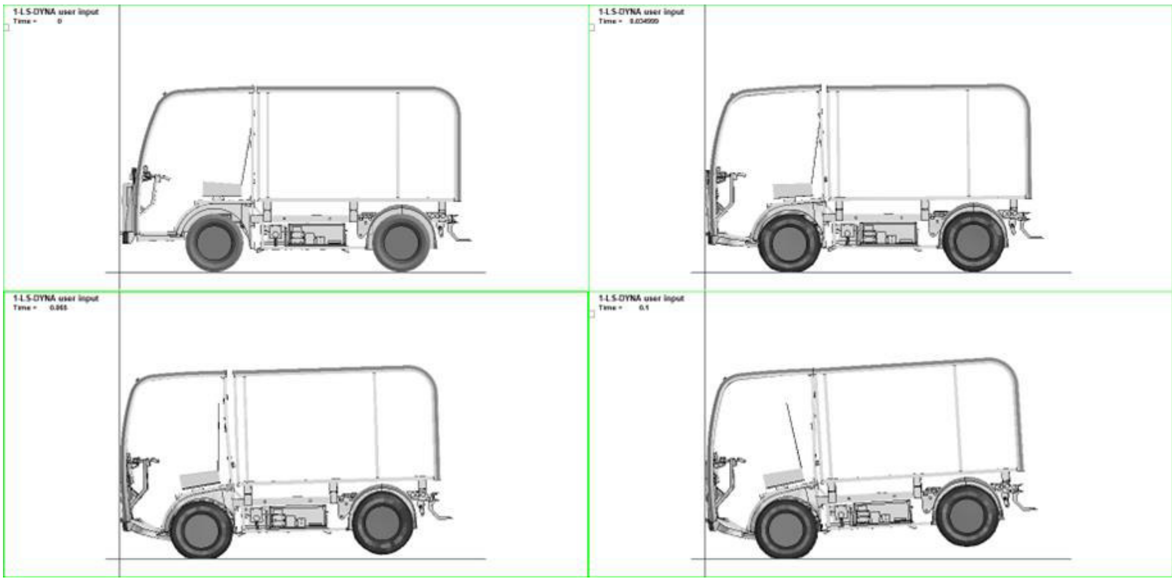

Fig.8: Rigid wall results with stationary profiles scenario

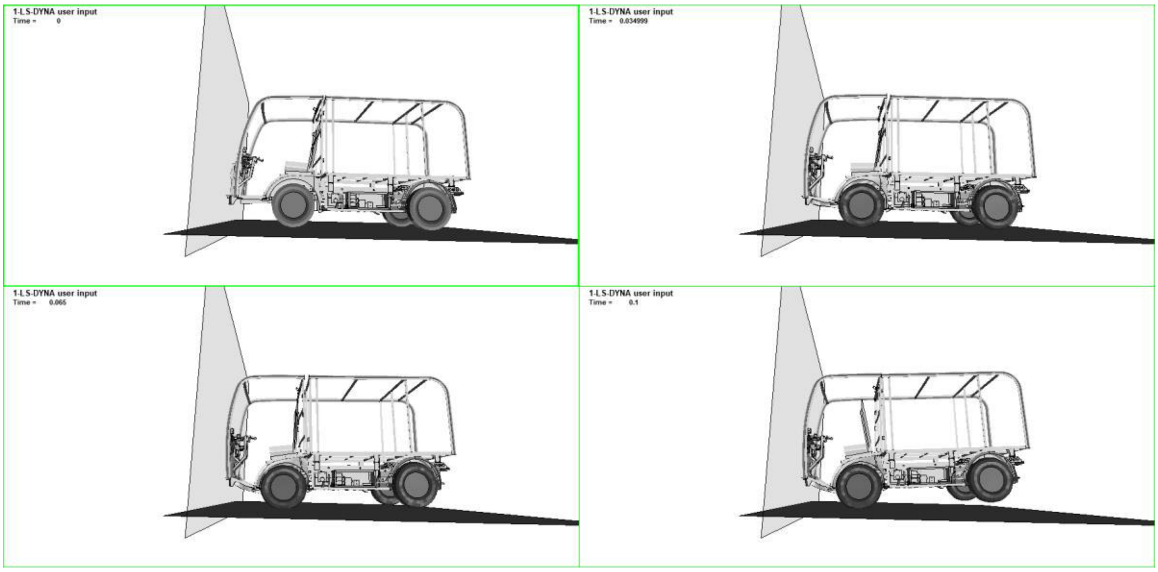

Fig.9: Rigid wall results with stationary profiles scenario – 2

4.2 Rigid Wall with Replaceable Bumper Scenario

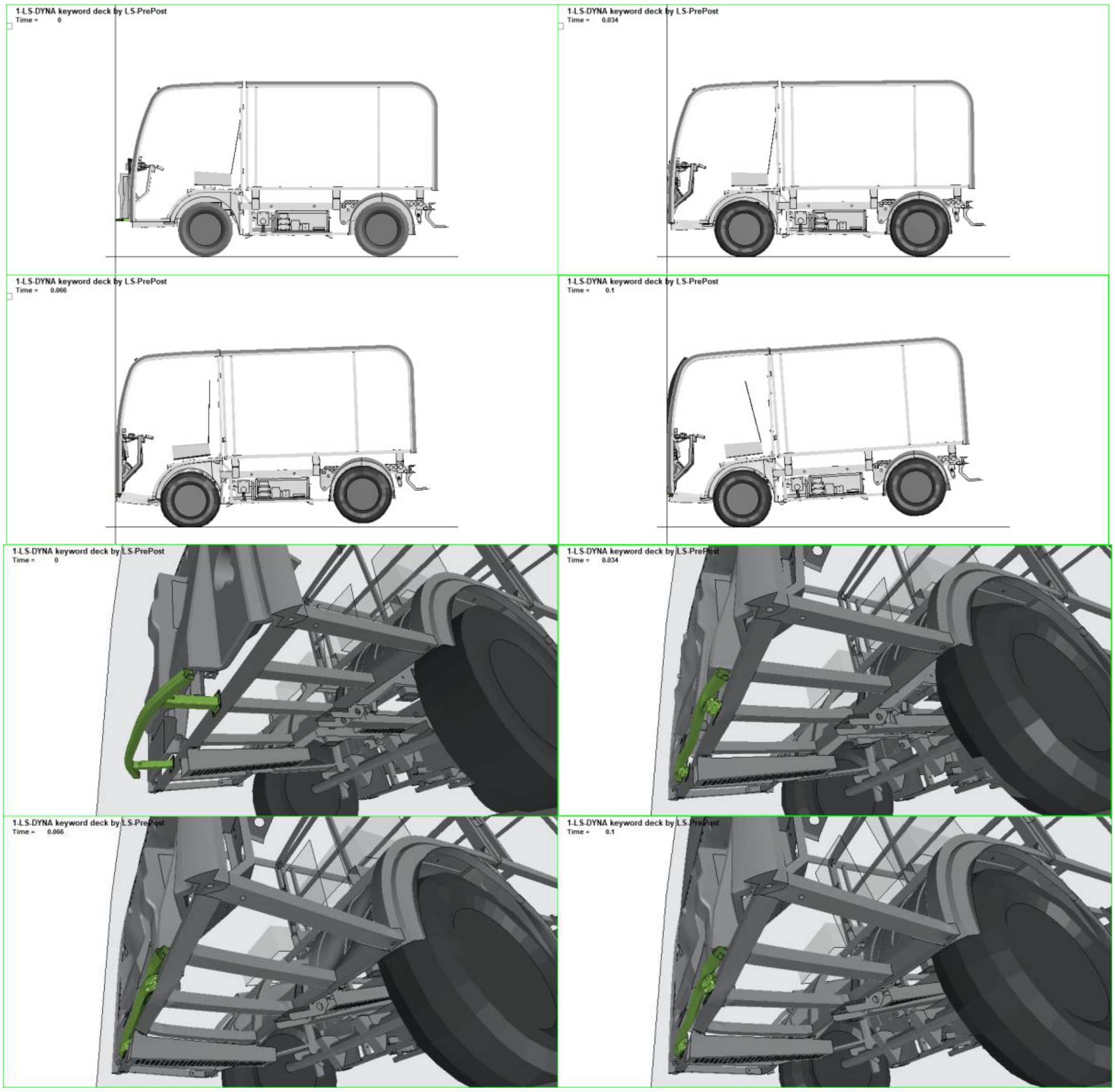

Fig.10: Rigid wall results with replaceable bumper scenario

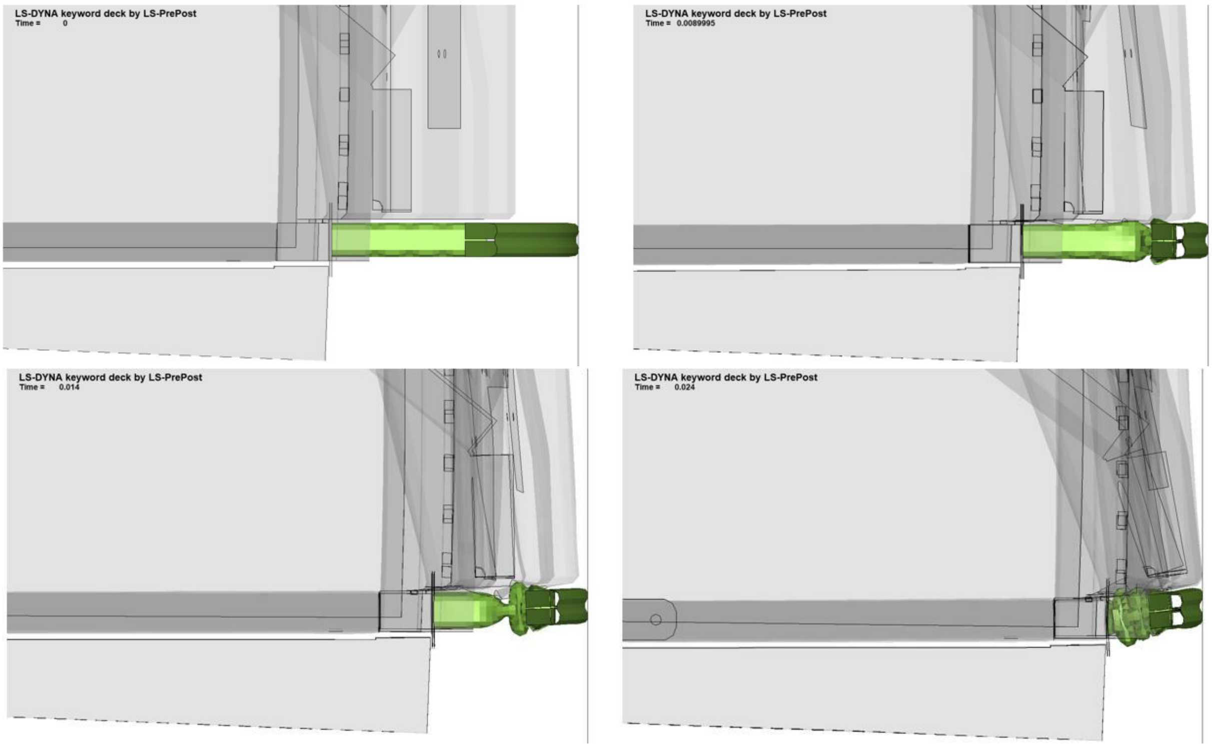

Fig.11: Rigid wall results with replaceable bumper scenario - 2

4.3 The RCAR deformable barrier with Stationary Profiles Scenario

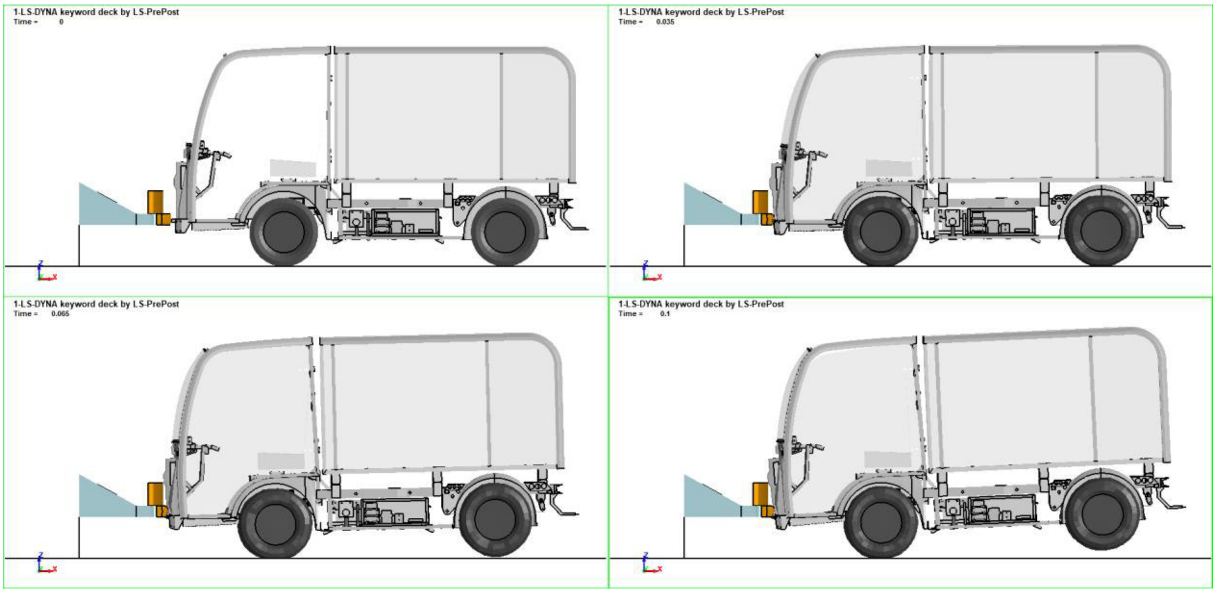

Fig.12: The RCAR bumper results with stationary profiles scenario

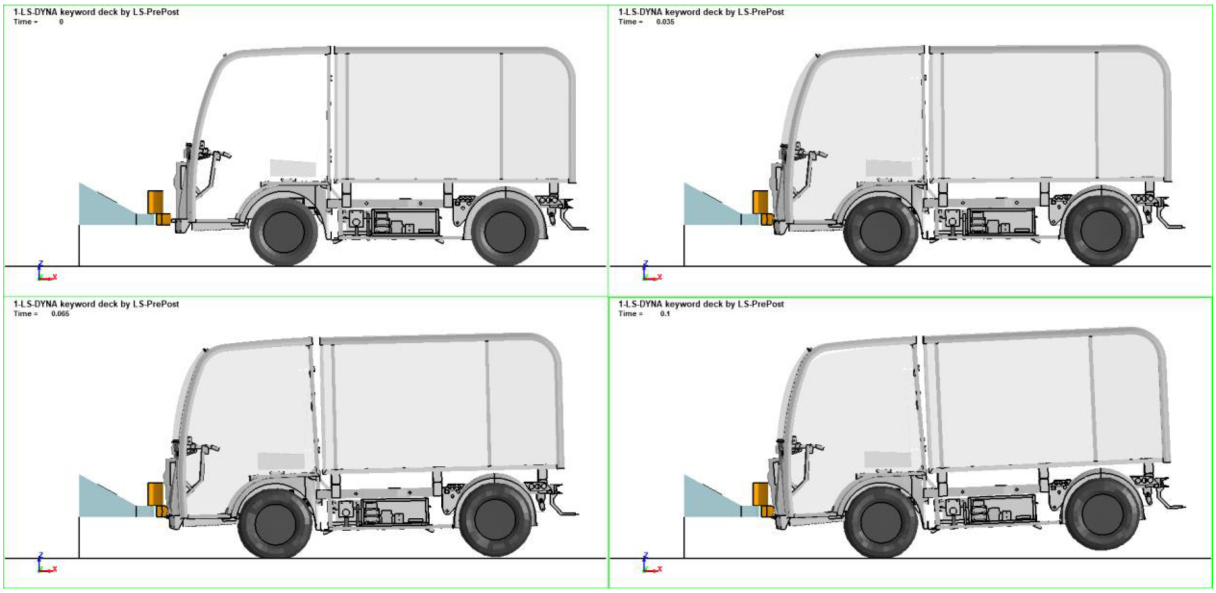

Fig.13: The RCAR bumper results with stationary profiles scenario - 2

4.4 The RCAR deformable barrier with Stationary Profiles Scenario

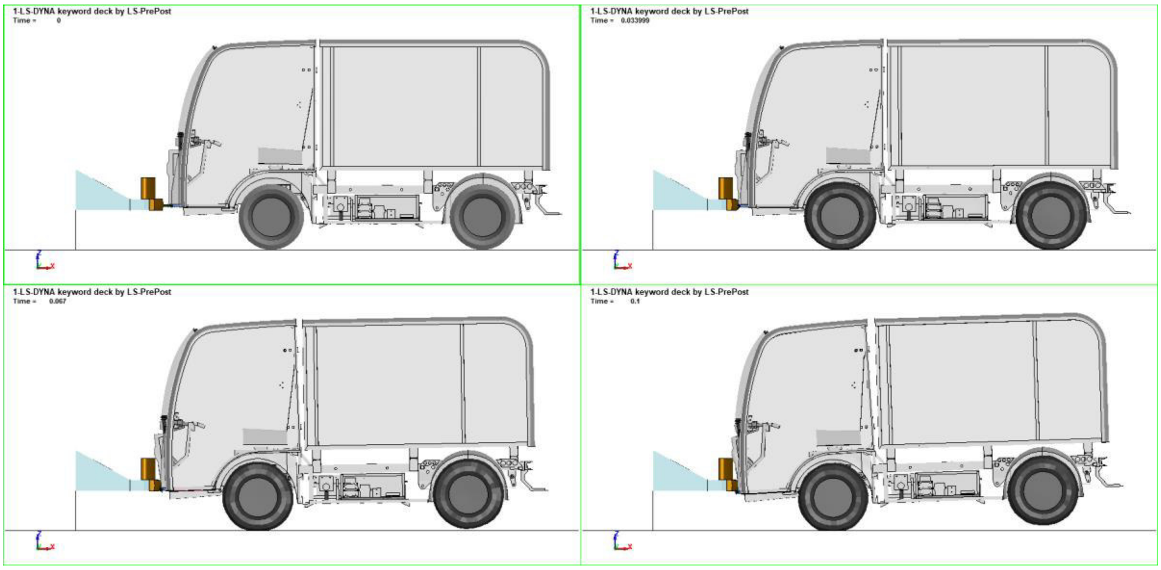

Fig.14: The RCAR bumper results with replaceable bumper scenario

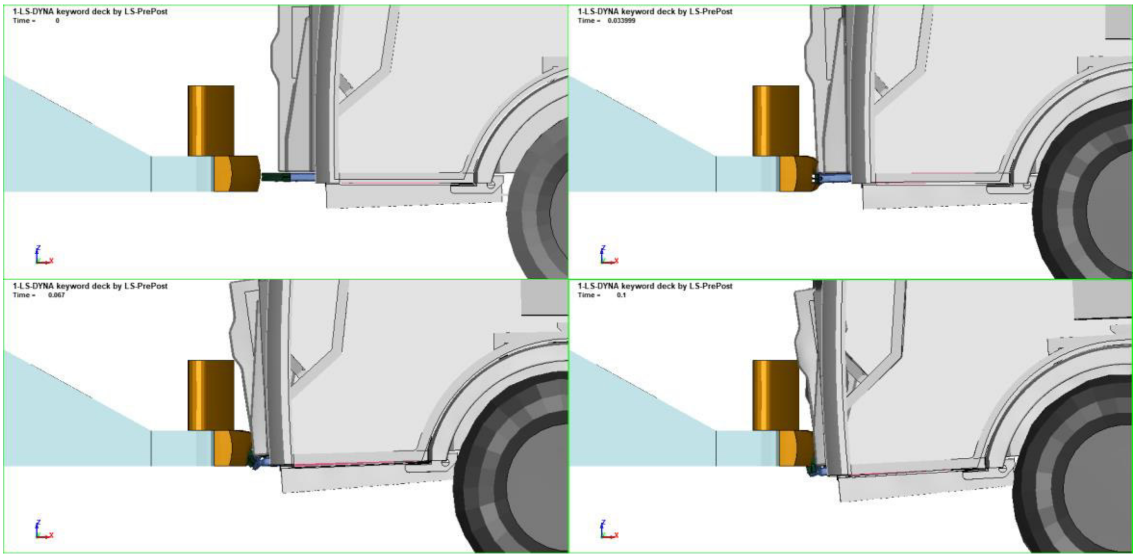

Fig.15: The RCAR bumper results with replaceable bumper scenario - 2

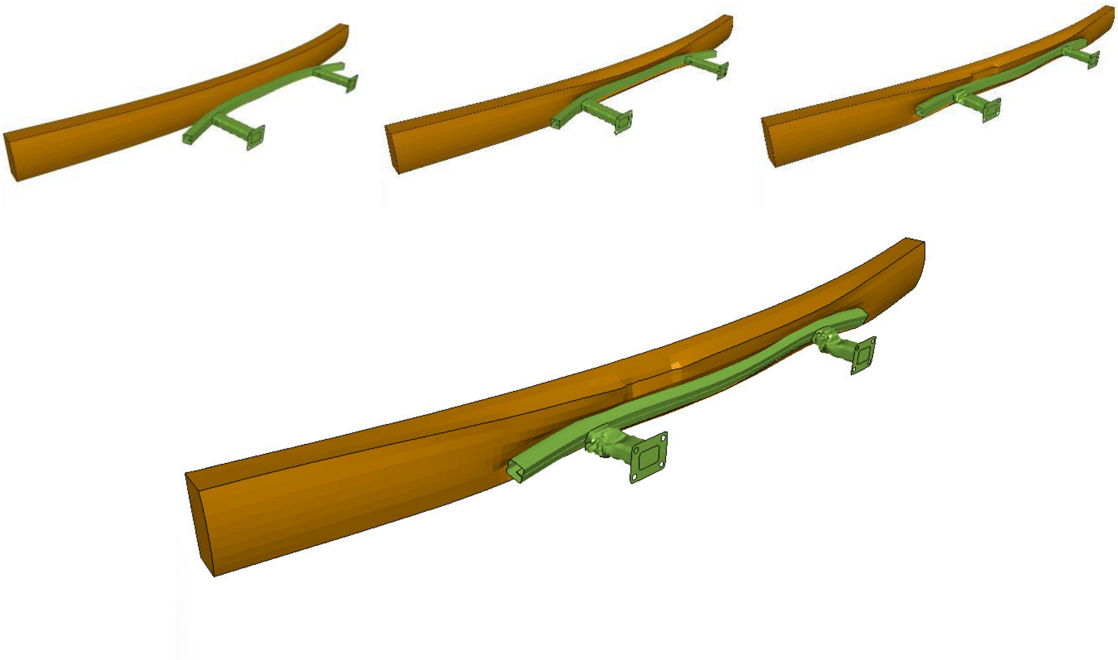

Fig.16: The RCAR bumper results with replaceable bumper scenario - 3

5 Summary

Model & Scenario	Max Acceleration	Ratio %
Stationary model 20km/h rigid wall	17 G	%100
Replaceable Bumper model 20km/h rigid wall	12 G	%70
Stationary model 10km/h RCAR Barrier	11 G	%100
Replaceable Bumper model 10km/h RCAR Barrier	7 G	%63

Table 1: Acceleration in X direction for Battery box component

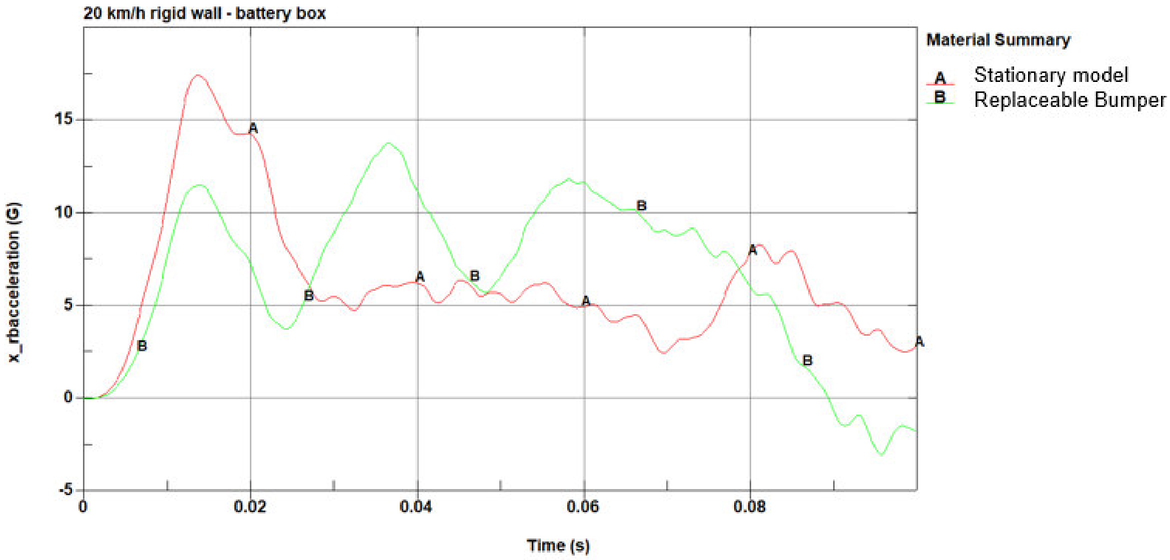

Fig.17: Battery box accelerations of rigid wall results

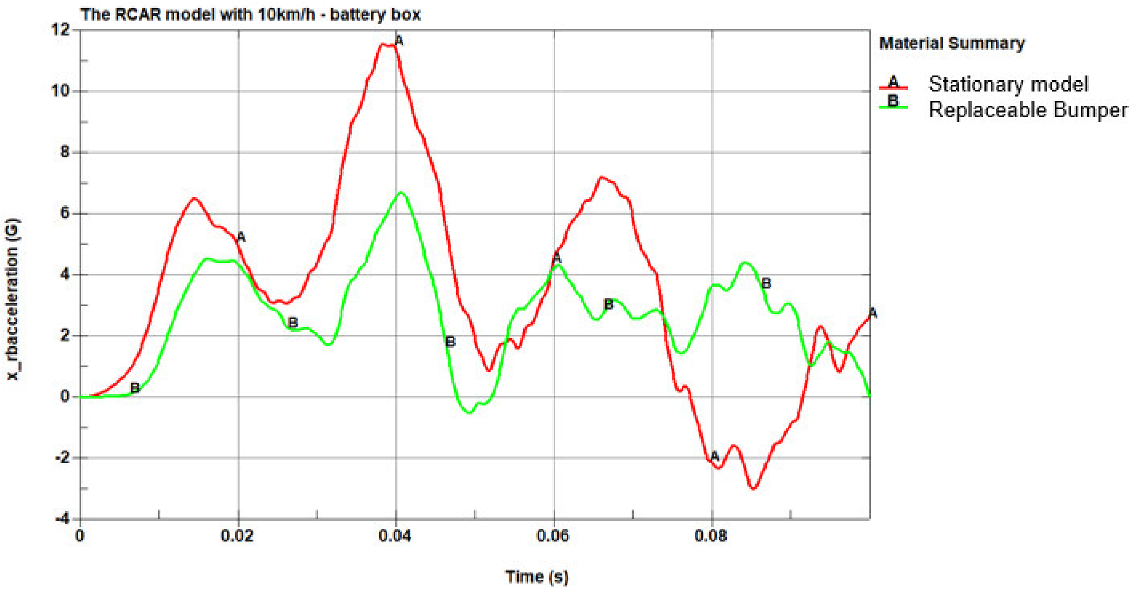

Fig.18: Battery box accelerations of The RCAR bumper results

Crash energy management (Wang, D., Zhang, J., 2022) is a critical aspect of vehicle production, and both models have successfully survived the collision scenarios. The examination of the replaceable bumper with its purposed design achieved a significant 30% reduction in accelerations of the battery box, and fewer deformations on the chassis structure. The aim of the RCAR design was met, as the replaceable bumper is capable of absorbing energy and allowing the vehicle to continue driving with minor defects even after a low-velocity collision.

6 Literature

[1] Wang, D., Zhang, J., Wang, S., Hu, L. Frontal Vehicular Crash Energy Management Using Analytical Model in Multiple Conditions. Sustainability 2022, 14, 16913. https://doi.org/10.3390/su142416913

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[3] URL1: THE RCAR Test procedure https://www.rcar.org/published-works https://www.rcar.org/Papers/MemberPapers/Effects%20of%20RCAR%20Bumper%20Test%20issue%201_0.pdf