The European Journal of Research and Development

journals.orclever.com/ejrnd

OR CLEVER Science & Research Group

Review Article

Design, Production and Impact Test of Multi-Axle Heavy Commercial Vehicle Cab

Aziz Başdemir [1*], Yiğit Vatansever [2], Şenol Şentürk[3], Emre Tekin[4]

[1] Volkan Firefighting Vehicles Industry and Trade Inc, Izmir, Turkey, https://orcid.org/0000-0001-6372-7264, aziz.basdemir@volkan.com.tr

[2] Volkan Firefighting Vehicles Industry and Trade Inc, Izmir, Turkey, https://orcid.org/0000-0002-6946-225X, yigit.vatansever@volkan.com.tr

[3]Volkan Firefighting Vehicles Industry and Trade Inc, Izmir, Turkey, https://orcid.org/ 0009-0001-1671-330X, senol.senturk@volkan.com.tr

[4]Volkan Firefighting Vehicles Industry and Trade Inc, Izmir, Turkey, https://orcid.org/0000-0002-2454-2491 emre.tekin@volkan.com.tr

[*] Correspondence: aziz.basdemir@outlook.com; Tel.: +90 537 941 92 19

(First received September 14, 2023 and in final form December 22, 2023)

Reference: Başdemir A., Vatansever, Y., Şentürk, Ş., Tekin, E. Design, Production and Impact Test of Multi-Axle Heavy Commercial Vehicle Cab. The European Journal of Research and Development, 3(4), 357-368.

Abstract

The main and most complex superstructure module of heavy-duty and heavy commercial vehicles is the driver-passenger cabin. While cabin design and production; It must be safe, light, rigid, ergonomic, modular, suitable for lean production, user-friendly and serviceable. But the most important of these criteria is the life safety of the crew in the cab. In this context, the cabin strength must be at a very high level. To determine the cabin strength, it is subjected to the R29 - Cabin strength test within the ECE regulations. Thanks to this test, it is possible to see the skeletal strength and behavior of the cabin in the event of an accident or collision. According to this test, the life safety of the crew inside the cabin must be prioritized, and the necessary designs and production must be carried out to ensure that the cabin suffers as little damage as possible in the event of an accident. In this way, it is aimed to maximize the security (safe area) inside the cabin by providing cabin rigidity. This scope of work; The objectives of lighter weight, shorter and easier production, assembly and disassembly, lower production costs, less labor and equipment or consumable expenses have been achieved. Additionally, in this study, the seat configuration in the cabin was increased from 1+4 to 1+5 and a crash test was performed by including another door option.

https://doi.org/10.56038/ejrmd.v3i4.413

Keywords: Heavy Commercial Vehicles, Cab, Impact Test, Composite Sandwich, ARFF, Truck, ECE R29-3, Lean Manufacturing

1. Introduction

Designing heavy duty vehicle is a challenging task. Safety, passenger comfort, agility and quick response are on top of the designer's input list. Manufacturers have to handle too many conflicts while both design and manufacturing phases. The sources of conflicts are directives, regulations and customer expectations. The base regulation for this kind of heavy duty vehicle is NFPA 414 (Aircraft Rescue and Fire Fighting Vehicles Standart). The ARFF vehicle shown in Figure 1.

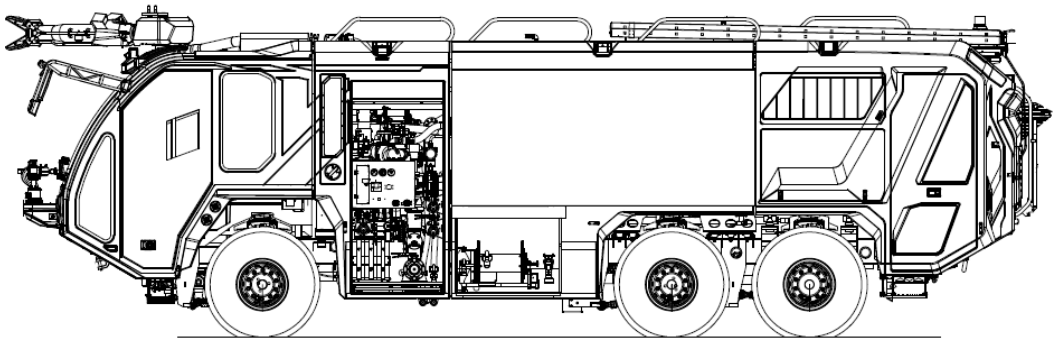

Figure 1: 6x6 ARFF Truck [1]

Road vehicles need to satisfy a hundreds of regulations for both whole vehicle and its subsystems. One of the important regulation is " Cab Strength" which is called Regulation 29 accroding to ECE(Economic Commission for Europe) Directives. The aim of this regulation is determining the strength of vehicle cab and ensure its safety. According to test results cab is certified and this certificate is complience sheet of that cab's safety internationally [2]. Design and manufacturing processes carried out according to Regulation 29 and its minimum requirements.

The aim of this study; Based on lean thinking philisopy, defining wastes, eliminate unnecessary processes and find out the highest value added methods. New design was created according to this method and eliminated extra weights, connection parts and extra workmanship. The design is not only lighter and more lean but also modular, easy to maintenance and has less manufacturing effort. After the whole design and

https://doi.org/10.56038/ejrmd.v3i4.413

manufacturing steps cab was tested according to Regulation 29 and discussed deformation, deformation zones, mounting points and rigiditiy.

2. Materials and Methods

High strenght sandwich GRP is used as material for the cab. Section of the material is shown in Figure 2.

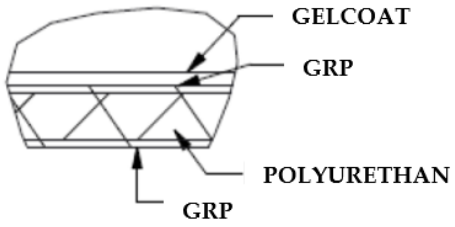

Figure 2: Details of Composite Sandwich [3]

By increasing civil and military aviation activites, needs and expectations from the ARFF vehicles are also increasing day by day. The manufacturers needs to make themselves more agile.

To satisft customer requirements, heavy duty vehicle cabs have too many options for both interior and exterior sides.To make it more clear options are listed below;

- Door type
- Steering wheel (LHD-RHD)
- Seating configuration etc

The vehicle's specifications are shown in Table 1.

Table 1: Properties of ARFF Lion

Drive Type	6x6-6WD
Total Weight (kg)	39 000
Cab Weight (kg)	2341,5
Cab Materials	Composite sandwich
Crew Number	1+5
Door Type	Hinged door
Width (mm)	3000
Height (mm)	4000
Length (mm)	12000

https://doi.org/10.56038/ejrmd.v3i4.413

Cab and vehicle CAD model created on PTC Creo Parametric 3D modelling program. CAD model of test prototype shown in Figure 3 . The cab which is prepared for the crash test includes doors, glasses, seats, elastic mountings and other equipments.

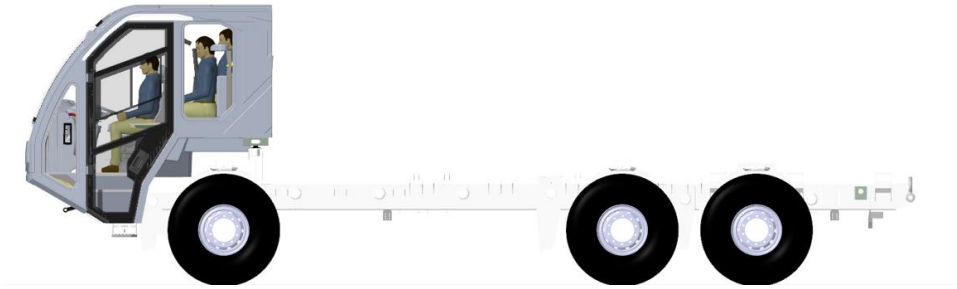

Figure 3: CAD Model of Superstructure-Cab

N category vehicles (heavy duty/commercial vehicles) must comply the Regulation 29 for certification of driver's cab. Regulation includes three sets of test, A (front impact test), B (Front A pillar test), C (Roof strenght test). In addition to that Test C has two separate parts which are C1 (Lateral impact) ve C2 (Roof strenght) [3]. ARFF vehicles has rear engine design vehilces which are exempted Test A. Test B, C1 and C2 was carried out respectively to the cab. Test methods shown in Figure 4.

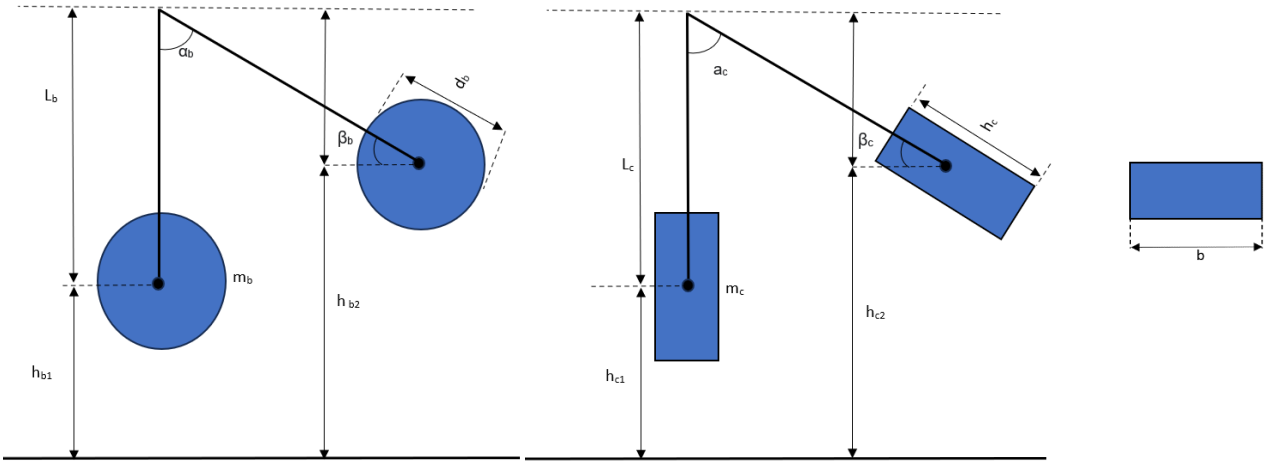

Figure 4: Types of Test B and Test C

https://doi.org/10.56038/ejrmd.v3i4.413

Test parameters are shown in Table 2.

Table 2: Properties of ARFF Lion B Test and C1 Test

Test Paremeters	**Front Pillar Impact Test (B Test)**	**Test Paremeters**	**Roof Strength Test (C1 Test)**
Impact Energy (kJ)	29,4	**Impact Energy (kJ)**	17,6
L_b (mm)	4450	**L_c (mm)**	3920
d_b (mm)	Ø660	**h_c (mm)**	1200
b_b (mm)	3100	**b_c (mm)**	3100
m_b (kg)	1250	**m_c (kg)**	2500
h_{b1}(mm)	2500	**h_{c1}(mm)**	3030
h_{b2}(mm)	4890	**h_{c2}(mm)**	3748
β_b (⁰)	27,4	**β_c (⁰)**	49,559
α_b (⁰)	62,6	**α_c (⁰)**	40,441

B Test: This test carried out for strenght of A pillar. The pendulum converts potential energy to kinetic energy and transmit it to cab pillars and windshield frame. Test pendulum made of high strenght structural steel (Figure 5).

Figure 5: Front Pillar Impact Test (Test B)

https://doi.org/10.56038/ejrmd.v3i4.413

C1 Test; Vehicle parked with side slope position. Another pendulum which works as the same principle impacts the upper edge of the cab. This test is simulation version of rollover incident (Figure 6).

Figure 6: Roof Strength Test 1 (Test C1)

C2 testi; The concrete block which has nearly half of vehicle weight putting on the cab roof (Figure 7).

Figure 7: Roof Strength Test 2 (Test C2)

https://doi.org/10.56038/ejrmd.v3i4.413

The sequence of operations used in the design, producton and test methodology is given in Figure 8.

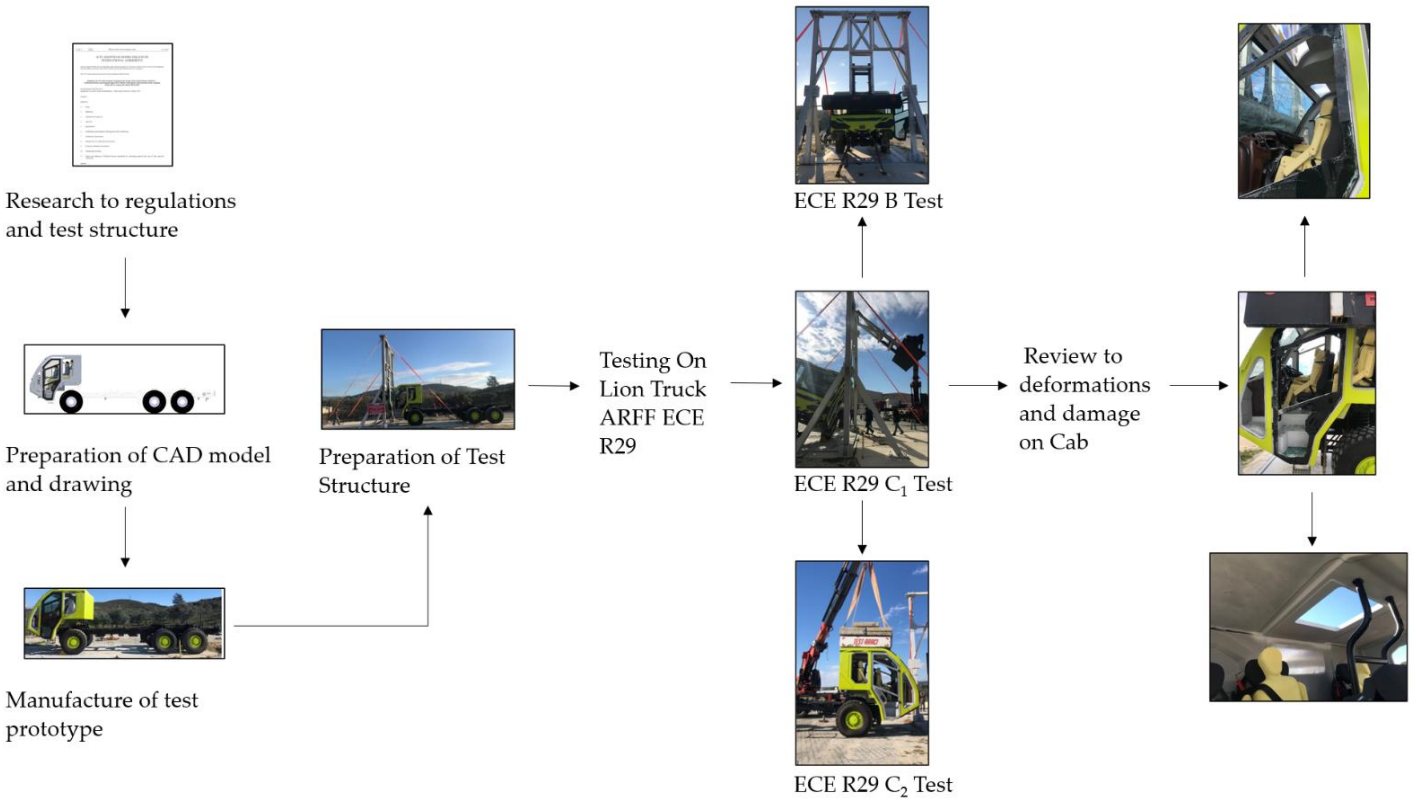

Figure 8: Flowchart of This Study

https://doi.org/10.56038/ejrmd.v3i4.413

3. Result

In this study, vehicle's cab re-designed, tested and approved. Scope of redesign is expanding seating configuration, adding extra cab door option make the cab structure lighter and more lean. As a result of this development, manufacturing time, total part quantity and manpower decreased. Total weight, manufacturing time and process details show in Figure 9 a and 9 b.

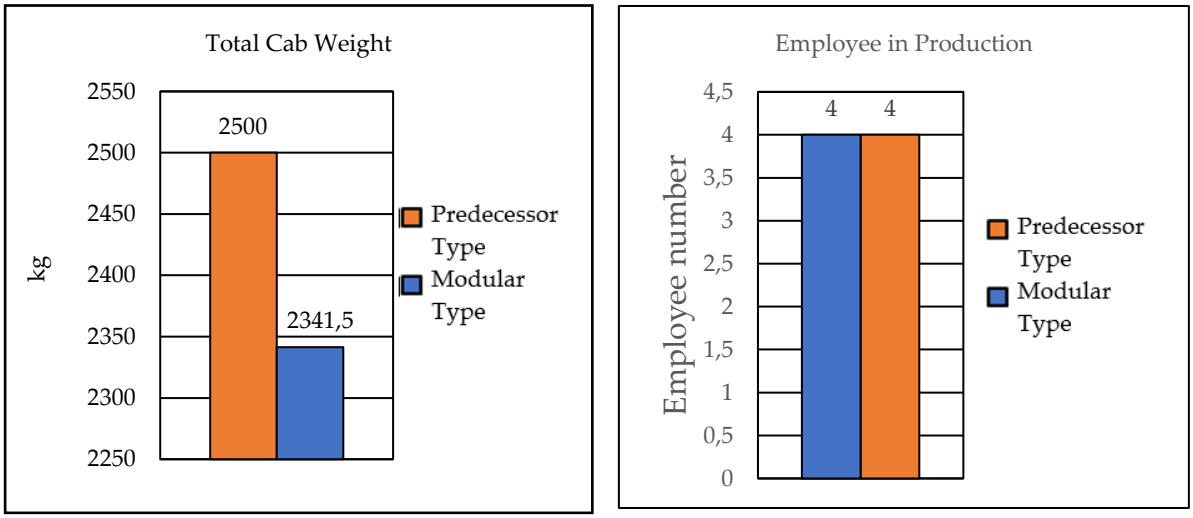

Figure 9 a: Total Cab Weight and Employee In Production

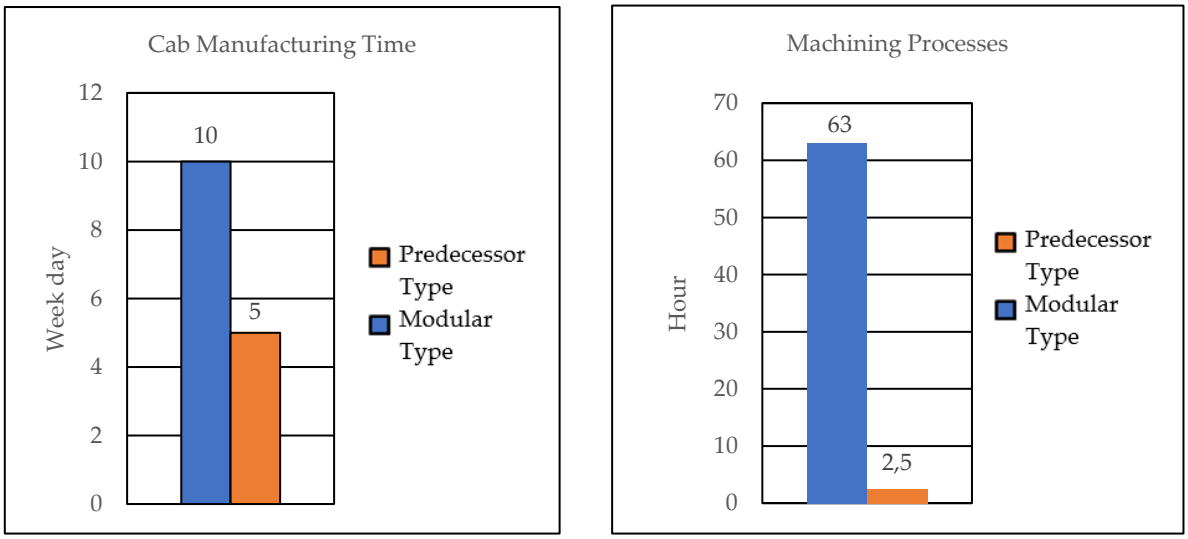

Figure 9 b: Cab Manufacturing Time and Machining Processes

https://doi.org/10.56038/ejrmd.v3i4.413

The cab which is developed based on lean design and manufacturing approach, tested according to ECE Regulation 29. The whole damage and displacement of critical points were reviewed and discussed. Right after the test, cab approved and certified according to UNECE Regulation. Front pillar impact test (B Test) shown in Figure 10.

Front pillar impact test (Test B) failure shown in figure 10.

Figure 10: Front Pillar Impact Test of Failure Assessment (Test B)

Roof strength test 1(Test C1) failure shown in figure 11.

Figure 11: Roof Strength Test 1 of Failure Assessment (Test C1)

https://doi.org/10.56038/ejrmd.v3i4.413

Roof strength test 1(Test C1) shown in Figure 12.

Figure 12. Roof Strength Test 2 of Failure Assessment (Test C2)

At the final of tests damaged zones were inspected. Main structure of cab was stable. There is no damage and interferene on living space.

Regulation 29 includes three key points;

- Safety space for driver and passengers
- Mountings between cab and vehicle
- Doors of the cab.

As a result in addition to fulfill legal requirements and certification processes total working hours for cab manufacturing decrease %50 compared to previous version.

Thanks to re-designed base and prepared holes total machining process time (such as drill, threads, screws, etc..) decrease %90..

Due to the steel reinforcement elimination approximately %6.5 weight gain was achieved.

https://doi.org/10.56038/ejrmd.v3i4.413

4. Discussion and Conclusion

In general, the driver-passenger cabin used in the heavy-duty vehicle that subject to the study was redesigned to make it suitable for more than coach type door option and to make it lighter. In this process, in addition to design inputs, a development activity was carried out by taking into account constraints such as manpower-hour consumption in the production process, disassembly and service time, and use of machinery and materials.

As a result of this study; In accordance with the lean production and lean design philosophy, waste is primarily prevented. Then, the steel reinforcement parts, especially reduced from the base part, both saved weight and prevented production complexity. There has also been a significant decrease in the total number of parts contained in the semi-finished product. Many operations that had to be done manually due to production routing have been eliminated and thus a significant decrease in total production time has been achieved.

All these improvements, lightening and part reduction efforts have been tested in accordance with the R29 regulation to and no negative difference in terms of strength and performance has been observed.

5. Acknowledge

This endeavor would not have been possible without the support of Volkan Fire Fighting Vehicles. Thanks to Volkan Fire Fighting Vehicles management.

https://doi.org/10.56038/ejrmd.v3i4.413

References

[1] Başdemir, A., Kaynak R., & Tekin E. (2022). Structural Analysis of Different Types of Chassis Designs for a Multi-Axle Heavy Commercial Vehicle. The European Journal of Research and Development,2(4), 338-355.

[2] Regulation No 29 of the Economic Commission for Europe of the United Nations (UN/ECE) — Uniform provisions concerning the approval of vehicles with regard to the protection of the occupants of the cab of a commercial vehicle, 2011. ECE R 29.03 Supp.05.

[3] Capar, G., Kuralay, N.S., & Karaoglan, M.U. (2020). Özel Maksatlı Bir Ağır Hizmet Aracı için Kabin Darbe Test Düzeneğinin Tasarımı/Uygulanması ve Kabin Dayanımının Regülasyona Uygunluğunun İncelenmesi. DEUFMD, 22(65), 611-618.

[4] Pasha, H., Madhuchandra, K.S., Rajesh, P., & Basavaraja, J. (2018). Reinforcement Design and Crash Analysis of Medium Duty Trucks for Rollover Crash Accidents International Journal of Engineering Research in Mechanical and Civil Engineering, 3(5).

[5] Cengiz, A. (2007). Kompozit çubukların enerji sönümleyici özelliklerinin incelenmesi. Kocaeli Üniversitesi, Fen Bilimleri Enstitüsü, Doktora Tezi.

[6] Büyük, M., Atahan, A.O., Kurucuoğlu, K. (2018). Impact Performance Evaluation of a Crash Cushion Design Using Finite Element Simulation and Full-Scale Crash Testing. İstanbul Teknik Üniversitesi, İstanbul.

[7] Yaşar, F. (2011). N3 sınıfı ağır ticari bir aracın ECE R29 standartına uygun önden çarpma analizi ve iyileştirme çalışmaları. İstanbul Teknik Üniversitesi. Fen Bilimleri Enstitüsü, Yüksek Lisans Tezi, İstanbul.

[8] NFPA-414, (2020). Standard for Aircraft Rescue and FireFighting Vehicles.