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SPECIALISED CONTAINER FOR THE SAFE TRANSPORT OF ELECTRICALLY POWERED PASSENGER CARS AFTER AN ACCIDENT

ABSTRACT

Summary: The premise for the creation of this study are changes in the scope of new structural solutions, aiming at the implementation of alternative types of propulsion in the automotive industry. More and more electric vehicles are available on the world markets. This trend also applies to passenger cars, the production of which is increasingly abandoning the power units based on internal combustion engines, both diesel and petrol. With an increase in the number of vehicles equipped with alternative propulsion systems, there will certainly be road accidents involving cars equipped with battery electric propulsion systems. This phenomenon will lead to fire hazards and environmental problems in removing the aftermath of such accidents. Due to the fact that relatively large lithium batteries are particularly exposed to the risk of fire as a result of road accidents, it is necessary to develop solutions for the safe removal of electric cars from places of accidents and collisions, both for the environment and for other road users. Because even after effective fire extinguishing at the scene of the accident there is a high risk of self-ignition after the accident, there is a need to develop solutions that will minimize this type of risk.

Methods: Such solutions include a special container for the safe transport of electric passenger cars after an accident. This type of container will have a closed structure, equipped with the ability to automatically extinguish fires, occurring in its interior. This article presents two possible to implement concepts for the operation of a specialized container with a postulated

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profile of functionality. One of the concepts would consist in the use of a mobile pallet on which a post-crash vehicle would be placed, and which would enable the introduction of a damaged car into the interior of the container. The second concept would be to place the damaged electric car in the container by means of a special crane.

Results and research findings: Both functional concepts of this type of container are submitted for scientific discussion after a thorough analysis of the European directives and regulations in this field and after consultation with fire prevention authorities. The optimal solution, according to the authors of the study, is to use the front loading of the container using a mobile loading platform, which is used to place an accident-electric motor vehicle in the structural space of the container.

Keywords: Container, Sicherheitscontainer, Transport, e-Mobile, Feuergefahr, Brandbekämpfung, Feuerlöschung [Container, safety container, transport, e-mobile, fire hazard, fire fighting, fire extinguishing]

INTRODUCTION

In view of the steadily increasing traffic and the environmental risks posed by diesel-powered motor vehicles, there is now a reorientation in the production philosophy of automobiles. In order to significantly reduce exhaust emissions, leading automobile manufacturers in Europe, Japan and South Korea are gradually moving away from the production of exhaust gas vehicles towards electric vehicles. Two main design variants predominate in this respect. The first variant is based on the use of traditional car constructions with built-in engines powered by electric energy from batteries. As such, they create modern concepts for electric passenger cars. Figure 1 illustrates the main components of such design.

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Fig. 1. Electric passenger car: electric motor at the front, battery pack at the rear.
Source: Illustration from Volkswagen AG 2017 resources.

In case of batteries, these are lithium batteries with a total weight of up to 360 kg. The weight of a battery varies from vehicle to vehicle and is related to the expected driving range per charge.

The second option concerns a car design based drive solution, driven by fuel cells integrated in the electric motor. Figure 2 illustrates the main components of this design.

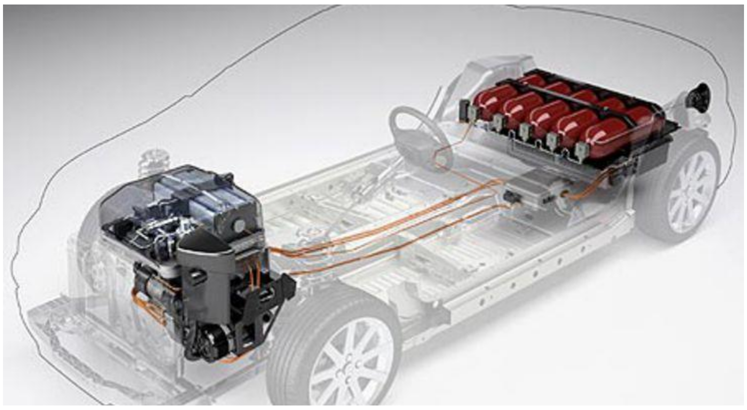

Fig. 2. Diagram of a fuel cell car design.
Source: Illustration from NISSAN Company 2017 resources.

In this case, the fuel cell drive system is mounted on the rear axle of the vehicle. In electric cars, these types of batteries have a mass of at least 300 kg. They are made in the form of lithium-ion rechargeable batteries and are used to generate the required torque through an electric impulse inside the electric motor located in the front of the car. Other elements of the battery's construction are made of such metals as cobalt, platinum, nickel and copper. Lithium is one of the most susceptible to ignition factors in this system and thus belongs to the most dangerous elements of the drive system. In the case of the above presented Volkswagen car construction (Fig. 1), the battery consists of 264 cells, which are part of 27 modules. This configuration allows you to achieve the required power supply potential of the driving drive.

Fuel cells are hydrogen-oxygen cells that generate electricity, as well as heat, water and steam. Fuel cells are integrated into pressure vessels made of hardened plastic material, which can withstand pressures ranging from 350 to 800 bar. Deeply cooled, liquid hydrogen (-253 degrees) should be used to ensure a driving range of a passenger car of 800 km.

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The problems that arise in this area, and that currently manifest themselves on German roads, are illustrated in photograph No. 3. Namely, there are increasingly frequent situations in which electric cars are ignited or burned due to relatively large batteries. This happens both as a result of accidents and road collisions, as well as in the form of repeated ignitions already during the stoppage of the car after the firefighting action. This may be caused by overloading the batteries themselves and by collisions with other road users, resulting in the destruction of batteries or individual cells in the battery packs. This results in a very high level of heat energy, which can only be extinguished by the fire brigade, protecting human health and life and the immediate vicinity of the incident.

If the battery is ignited, it is very difficult to extinguish it, as the lithium-ion cells themselves produce the oxygen required to start the combustion process. According to Tesla's data, battery fires require very large amounts of water to be used for extinguishing, which cools the adjacent cells. The amount of water required for this can be over 11,000 litres.

After the fire is extinguished, the burnt-out vehicle is loaded onto a towing vehicle and transported to the disposal site. This is where the critical point occurs, namely the secondary risk that the burnt vehicle will ignite again, which can cause a risk to the emergency services, other traffic users and the environment. This type of risk is to be eliminated by the proposed special container for the safe transport of electric passenger cars after an accident.

Photo 3. Burning TESLA vehicle.

Source: www.youtube.com/watch?y=R5 Geert-IdA 2018 (a photo selected from the entire sequence)

In this respect, various types of legal regulations apply, which should also be implemented on the European continent:

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They are:

- United Nations Model Regulations for the Transport of Dangerous Goods Version 17 of 2011, reference 3090/3091/3480/3480/3481, for the transport of lithium-ion batteries
- European Regulation on the International Carriage of Dangerous Goods by Road 1.6.1.20. ADR
- Regulation on the national and cross-border carriage of dangerous goods by road (GGVS)
- In addition, national regulations for this type of transport, which may vary from country to country in the European Union.

PROPOSED DESIGN SOLUTIONS

Potential risks must be taken into account when designing special containers for the safe transport of electrically-powered passenger cars in the event of an accident. In addition, a number of technical requirements need to be met to ensure the success of projects to generate concepts and implement such containers for use. The main operational and construction postulates in this respect are as follows:

- It should be possible to capture the electrolyte leaking inside the container and store it in a removable floor tray integrated with the electrolyte pumping system, thus ensuring efficient liquid removal and thorough cleaning of the tray.
- Since lithium is a highly reactive agent which is predestined for immediate reaction when water comes into contact with oxygen, an explosion or fire can occur and a situation can arise which endangers other road users and the environment.
- A forced ventilation system and structural openings shall be provided to allow explosive energy to escape in the event of an explosion.
- Install a system to dissipate heat and gases inside the container.
- A damaged electrically-powered vehicle can be loaded into a container either by crane or by means of a sliding transport frame which allows the burnt vehicle to be inserted into the container. In this respect, suitable design solutions need to be developed.
- It is essential to ensure that metal structures can be grounded in the event of stray currents.
- Due to the risk of secondary ignition of lithium-ion batteries, an internal extinguishing system based on inertial (passive) gas medium should be installed in the container.

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- International fire and explosion protection classes must be established for this type of container. The degree (class) of flammability according to the European Standard DIN EN 2- 2005-01 and the flammability class category D for combustion processes of metals (aluminium, magnesium, zinc, lithium and their alloys) must be stated.
- The fire resistance class is determined in accordance with DIN 4102-2 ff. as well as DIN EN 13501-2 with reference to category F 30 (fire resistance and ensuring a 30-minute phase of performance under fire conditions).

Within the scope of the framework conditions presented, the concepts of the two basic structural solutions described below should be developed:

1. Built-in, separate container equipped with a front loading capability and equipped with a sliding and pull-out pallet enabling it to be placed and fixed from the ground level of a burnt-out passenger car, then pulled into the container space and finally placed on the transport chassis of a towing vehicle (variant A - use of a normal towing vehicle).
   Difficulty associated with this option: an external crane is required to place an accident passenger car on a pallet.
2. Container with opening ceiling (variant B) as well as with fixed crane equipment (e.g. Palfinger system) with pallet access, as in variant 2.1: the container is completely assembled from the towing vehicle to the ground, loaded with a post-accident vehicle and then transferred back to the trailer of the towing vehicle, or as in variant 2.2: the container remains on the towing vehicle and is loaded by means of a lifting gear which moves the pallet with the accident vehicle inside the container and then, by lowering the pallet in the space of the container, places the damaged vehicle inside the container.

As for the dimensions of the containers concerned, it is generally accepted that 20-foot containers of dimensions (L x W x H): 6,095 m x 2,352 m x 2,393 m should be used.

Wariant A (fig. 4):

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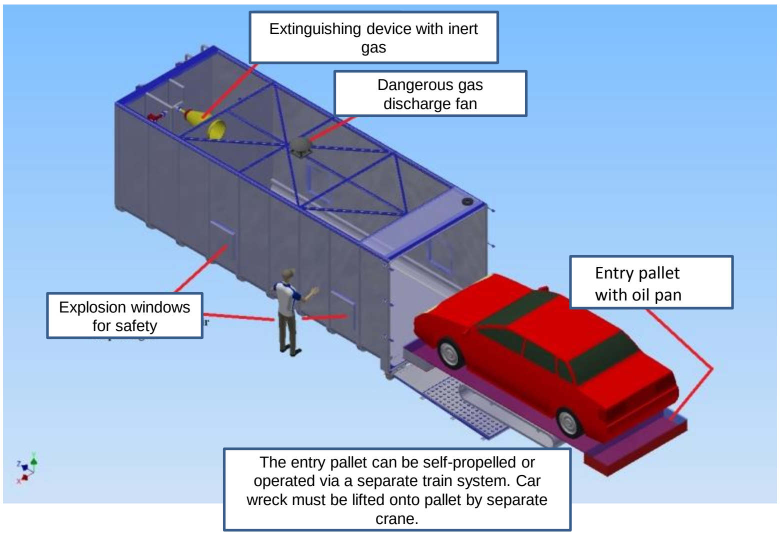

Fig. 4. Container with front loading of a damaged vehicle.

Source: Illustration from company resourcesnumerals Richtsteig Anlagentechnik GmbH & Co KG, Eisenhüttenstadt 2017.

View of the side wall of the container with marked "safety windows" as structurally weakened points for absorbing and discharging explosive energy to the outside of the container - in Fig. 5.

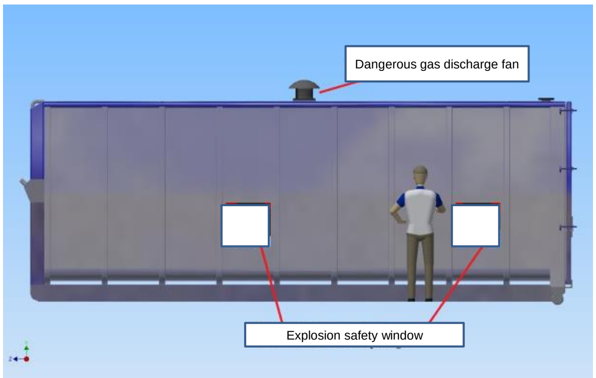

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Fig. 5. View of the side wall of the container with marked "safety windows".

Source: Illustration from company resourcesnumerals Richtsteig Anlagentechnik GmbH & Co KG, Eisenhüttenstadt 2017.

Variant B (Fig. 6):

In the case of front loading of an electric vehicle after an accident, the damaged vehicle is also placed on a flat pallet equipped with a settling tank in the event of the electrolyte escaping from batteries or other technical fluids. After mounting it on a pallet, it is frontally inserted into the space of the container by means of an external crane. When the front wall of the container is closed, all safety systems are activated and at this point the vehicle is towed away from the danger of secondary ignition by a breakdown vehicle.

Alternatively, a design option could be considered whereby a crane system would be included as standard equipment in the container for the safe transport of electric cars. However, this would be a more cost-intensive solution, which is why research into this solution has been abandoned at this stage. In this context, it should be noted that for this crane integrated in the container structure, pull-out brackets should be provided to stabilise the entire structure.

After having considered all the advantages and disadvantages of all options and in line with today's technical and technological potential, it was decided to develop option "A".

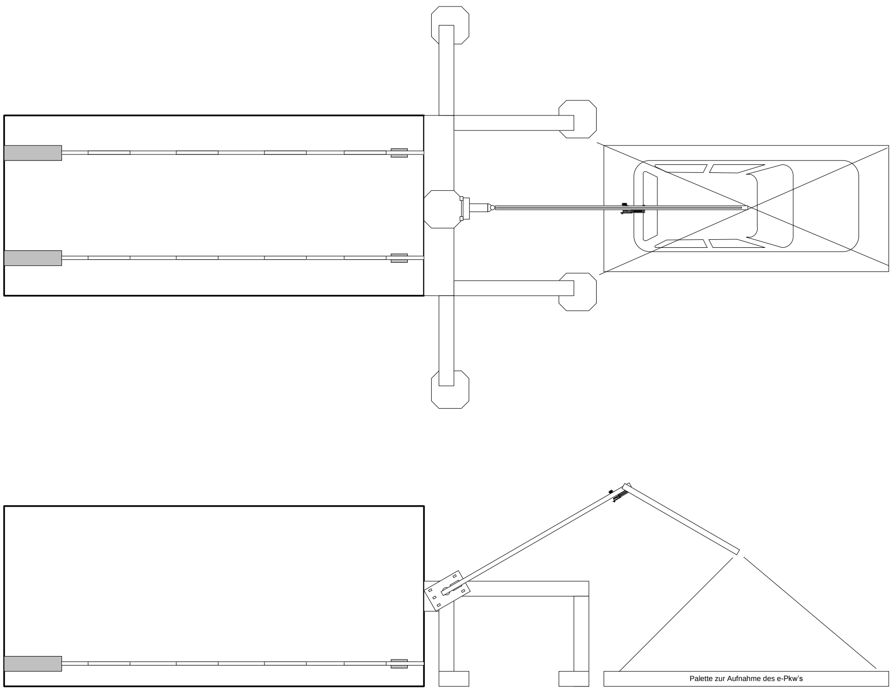

Fig. 6. Variant with front loading of the container.

Source: BERLINOXX structural design - Hentschel 2017.

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CONCLUSIONS

In this article an attempt has been made to face new trends in road mobility, which tends to increase the introduction into traffic of electric passenger cars (using batteries and fuel cells) and to provide solutions to these problems, which arise as a consequence of collisions and fires of this type of vehicles, and which must be predicted because of the type of propulsion and the flammability of the propellants used. The proposed solutions bring with them a very large and significant development potential. This is because of the huge risk of collision with electric vehicles, where the risk of fire or secondary ignition of towed cars is very high. In response to these challenges, two options for containers for the safe transport of electric cars after an accident have been identified. They are an important contribution to the effective resolution of related problems. The preferred solution is to use a container with a front load of a damaged vehicle using a pallet with an accident vehicle attached to it. Even if the vehicle is completely burnt out in a road accident, there is always a risk of secondary ignition of the towed vehicle. The containers in question are therefore fitted with structurally integrated fire-fighting systems and 'safety windows' through which explosive energy is led outwards, which may be generated by possible explosions inside the container. Design openings for the removal of heat energy and gaseous media released during towing of damaged electric vehicles are also important features of the container in the proposed solution.

The solutions presented above can successfully ensure the safe execution of transport processes and thus improve their logistic processes. As such, they are now a challenge for services in charge of traffic surveillance and crash management, including those with electric cars.

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