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RISKS AND SAFETY ISSUES RELATED TO USE OF ELECTRIC AND HYBRID VEHICLES

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Abstract: *Nowadays hybrid vehicles take increasing share of new road vehicles, but also the electric vehicles have continuous development which is a sign of a serious beginning of new era of their use. The goals of introducing of these vehicles include lowering of the negative impact on the environment and also reducing of their operational costs. Together with the mentioned trends, there are some specifics related to the risks of using this type of vehicles. This paper gives the key elements related to the development of hybrid and electric vehicles with emphasis of the general distinctions in terms of conventional vehicles with internal combustion engines. The paper has focus on risk identification and hazards that can arise from hybrid and electric vehicles, which are specifically related to their technical differences from conventional vehicles with internal combustion engine. Those risks exist when the vehicles are in use, but also even when the vehicle is not in operation. There is also identification of potential risks for the emergency staff when there is accident with these types of vehicles. The paper also addresses the possible harmful events that can happen later or because of improper repairs of the vehicles. Having in mind that the literature sources are quite moderate and in Republic of Macedonia there is none, the conclusion represent an effort to systemize the available knowledge in order to help vehicle users and professionals to mitigate or lower the recognized risks.*

Keywords: ELECTRIC VEHICLES, HYBRID VEHICLES, RISKS, SAFETY, PREVENTION.

1. Introduction

The constant increase in environmental pollution, and growing fuel prices contribute to the continuous search for solutions for cleaner transportation. The goal to reduce energy consumption, improve energy efficiency and to protect the environment stimulated people to think of owning hybrid and electric vehicles (EV). Therefore, electrical vehicles are seen as a possible alternative of transportation in terms of low cost of energy, high energy efficiency and low emissions. [4]

Hybrid electric vehicles (HEV) represent the technological bridge that points towards care for the environment, for sustainable and efficient vehicles and limited practicality of pure electric vehicles. The general reason for merging the available technologies are to meet the necessary requirements for performance of the vehicle, meet the desired range of drive with "on-board" energy sources, to ensure optimal energy efficiency and reduce the negative impact on the environment. In HEVs common feature is that these vehicles will supplement the batteries by preserving the kinetic energy generated through regenerative braking via the electric motor / generator which is regulated by the controller. PHEV is relatively simple variation of HEV, however it introduces new implications in the transport and energy infrastructure.

The existence of electric and hybrid vehicles as new technical means with certain technical features, except that it makes them available to assist humanity, as in the case with all other products, they still represent certain danger to their users and the environment. Even if they are stationary certain defects can be dangerous. Their use and participation in traffic affects the potential for the occurrence and consequences of any accidents.

There have been performed hundreds NCAP tests of such vehicles and of all of them there has been a case of an accident of a small fire that occurred as a result of electric shock that burned plastic foam insulation near the radiator which was damaged by the impact. Another danger after an accident that is not present in conventional vehicles is the leakage of acid from the batteries.

This means that fully electric and hybrid electric vehicles introduce new types of dangers. However, the literature points out that the experience with electric vehicles is small, so this area will have to be upgraded once there is more information available. It is known that vehicle manufacturers invest significant resources in the development of safe and reliable electrical systems for the current generation of electric vehicles. Also, it is very important organizations for testing and safety to understand this and be ready for potential hazards [2].

2. Main features of electric and hybrid vehicles

Electric and hybrid vehicles at this stage of development are considered as a significant factor in reducing the harmful effects of emissions from mobile sources and hence the potential of their application especially in urban areas is considered to be high.

A vehicle is considered a hybrid if there is more than one source of energy propulsion of the vehicle, typically an internal combustion engine and electric motor. Electric vehicle though, it is equipped with one or more electric motors. Both vehicles hybrid and electric, have batteries under high voltage, which often are referred to as "rechargeable electric storage systems" (RESS). [2]

In the literature there are several definitions of electric and hybrid vehicles. Most definitions of electric vehicles point out that it is a vehicle powered by power which is provided by the batteries or energy stored in electrochemical device. There are more variations and subclasses of electric or hybrid vehicles and they include: BEVs (battery electric vehicles), HEVs (hybrid electric vehicles), PHEVs ("plug-in" hybrid electric vehicles) and NEVs ("Neighborhood" electric vehicles). In addition, the extended range (range of motion, autonomy) with respect to electric vehicles it allows to compare or to be better than vehicles with internal combustion engine (SAF).

BEV electric vehicle is powered primarily by electricity stored in batteries. EREV electric vehicle is equipped with an electric generator powered by an internal combustion engine that replenishes the electric propulsion system and extends the operating range of the vehicle. HEV is a vehicle powered by two or more energy sources, one of whom is electric. NEV is a vehicle on four wheels, powered by battery with low speed, with total weight not exceeding 1,400 kg and a top speed of 32 to 40 kilometers per hour. PHEV's a vehicle whose batteries can be recharged from an external source in the same way as the electric vehicles.

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3. Main characteristics of the hybrid and electric vehicles regarding safety

Electric and hybrid vehicles represent a totally different technology compared to internal combustion engines. This means that new dangers mainly are related to high voltage electrical equipment that is present in the vehicle. Standards already exist for the construction of such vehicles in terms of reducing potential risk towards the passengers and the rescue team who could be exposed to hazards such as corrosive chemicals, toxic gases, fire and electric shock. [2]

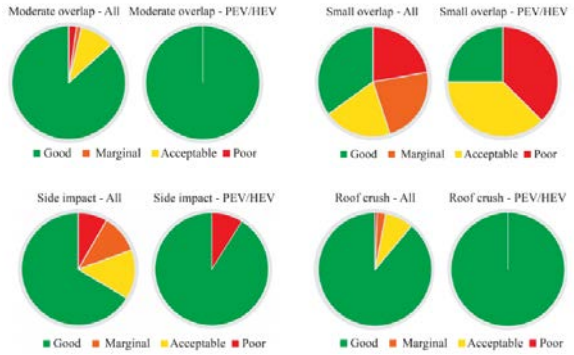

Fig. 1 *Comparison of results from tests on plug-in / hybrid electric vehicles and conventional vehicle [2]*

There are various aspects of electrical safety which should be recognized in electric vehicles:

- Safety of the electrical system;

- Safety in the systems function;

- Safety while charging batteries;

- Maintenance and operation of the vehicle, as well as training [1].

In continuation is a more extensive description for the meaning of the mentioned terms.

3.1 Safety of the electrical system. The safety of the electrical system or the protection against electric shocks encompasses levels of voltage in electric vehicles, protection against direct and indirect contact. Typical levels of voltage for cars and small vans varies from 48V to 120V, for large vans from 96V to 240V and buses from 300V to 600V. For drives with AC using higher voltage, 200V or more can be found even in small vehicles. These voltage levels should be compared to safe voltage levels. Voltages used in electric vehicles are potentially dangerous and should therefore be taken to prevent electric shock in direct or indirect contact. Parts under voltage that are in the electric propulsion system must be protected from direct contact with people in or outside the vehicle through the insulation or inaccessible position. Removal of protection devices and opening of doors or protective covers where there is access to electrical equipment under voltage should be possible only with tools or keys. The problem of indirect contact is closely connected with the mistakes of the car body. Any secondary connection between the drive circuit and the vehicle is considered to be an error. Errors of the car body can lead to several hazards like short circuit, electric shock, or uncontrolled operation.

3.2 Safety regarding the functioning of the systems. The drive system of the electric vehicle must ensure reliable and safe operation of the vehicle. The topology of the drive system in an electric vehicle is fundamentally different from vehicles with internal combustion engine and therefore certain measures should be taken to avoid or prevent unsafe operation. When the electric vehicle stands in place it is completely silent. To prevent inadvertent movement through activation of the drive circuit there must be a warning device. Procedure access must be properly organized in order to avoid possible harm through excessive torque, amperage or excessive acceleration, which means that it should be impossible to activate the controller when the accelerator is pressed. For electric vehicles it is mandatory to have presence of a device (switch) in case of emergencies. Electromagnetic interference coming from outside or from the controller mustn't affect the functioning of the controller.

Auxiliary power supplies are used for lighting, wipers of the windscreen and other similar burdens. It is powered by the drive battery through the DC/DC converter even though with most vehicles there is auxiliary battery. Regardless of the power supply the work of additional consumers (especially lights) must be assured in all conditions.

In terms of regenerative braking there should be some security references. Regenerative braking only operates through a transmission shaft and operating at very low speeds or at a standstill. In some cases the level of deceleration is limited and is not sufficient for immediate braking. The effect of regeneration braking can be reduced when the battery is fully charged. For these reasons primary friction braking system should be able to stop the vehicle under any circumstance.

3.3 Battery safety. The battery is the most critical part for electric vehicles. It presents several potential hazards: electrical, mechanical, chemical and danger of explosion. The electrical aspects include protection against electric shock and short circuit. Therefore, it should be provided for protective devices – fuse of the battery. When using multiple batteries it should provide more locking connections. Also the department that houses the batteries must be designed so it will avoid any unintentional direct contact or short circuit.

With regard to the mechanical aspects, since the battery is heavy part of its position it should be determined as to avoid instability of the vehicle and it should be limited to avoid damage in case of accident.

The dangers from chemical aspect depend on the type of battery and on each of the types prescribed way of handling and recycling. Batteries with aqueous electrolyte emit hydrogen due to electrolysis this electrolyte. This especially occurs at the end of charging and should therefore be taken under certain measures to avoid the risk of explosion. During the process of charging the battery, electric vehicle is connected to the main distribution network and should take all precautions to avoid risk of electric shock.

They should consider several cases. "Off-board" battery chargers are commonly used for large vehicles and rapid charging. With these chargers it is essential to connect the vehicle to the ground while the vehicle is full, because it can lead to danger in case of emergency. With "on-board" battery chargers the vehicle must be linked to the ground during charging, except when used Equipment Class II (double insulation). It is recommended to check the correctness of ground through a control device for grounding. When the charger doesn't have electrical division monitoring is necessary of the drive battery isolation and must be isolated from the vehicle body.

Partial "on-board" chargers are based on inductive power transmission. Because they do not involve electrical contact between the vehicle and the power grid, their electrical safety is very high. The absence of cable also reduces mechanical risks. However, the characteristics of the electromagnetic environment in these chargers are still under consideration.

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3.4 Maintenance. In the first line of maintaining is the user. Ordinary consumer is not a trained electrician and must therefore be protected against all risks of direct contact. The second row in the maintenance is the workshops. Employees at workshop (service) must be thoroughly trained in the safe maintenance actions in servicing of electric vehicles. The battery should be disconnected before any kind of intervention. Third row are holding workshops manufacturer and include the main electrical repairs. This should be done only by trained personnel. Besides maintenance of mechanical parts it is necessary to have electrical and routine maintenance for safe operation. These include testing the resistance of insulation and earth leakage functioning controller, battery status as well as its maintenance and cleaning.

The electric car is not similar to petrol, diesel and other kind of vehicles. The electric motor has the characteristics of torque and power that are quite different from the internal combustion engines. Safe and energy efficient electric driving vehicle requires appropriate skills. For electric vehicles there is no room for everyday driving style as it is with petrol vehicles. Especially the charging should be done properly and with the necessary discipline. Therefore buyers of electric vehicles must be provided with the necessary information through the seller.

4. Groups of risks associated with hybrid and electric vehicles

Various risks associated with the new technology of electric vehicles must be carefully weighed. It is necessary at the same time to be aware of new risks, but their levels should not be overvalued because of fear or ignorance.

In circumstances where there is no richer experience, as with conventional vehicles, risk assessments can be based on known differences that electric and hybrid vehicles are introduced in the not as numerous examples of adverse events and associated accidents with them.

Fig. 2 *Chevrolet Volt car that caught fire in the garage [6]*

As stated above, electric and hybrid vehicles have a number of security issues that are not related to conventional vehicles, and include electric shock, explosion, flood of the electrolyte and fire. There are examples of practice where electric vehicles are burned in an accident or burned in the garages where they were kept. In some cases this happened while the vehicle is being filled. [2]

Regardless of whether the vehicle is in use or idle greatest concern with electric or hybrid drive is the uncertainty associated with the state of the battery after mechanical damage. Sometimes, the connectors may be defective and to lose communication with one or all parts of the battery with unknown amount of energy remaining in the system. In this case handling and removing becomes a significant problem. Issues related to the malfunction of the battery after damage will be evidence of leakage, leaking electrolyte (carbon solvents are flammable), thermal hazards (observed battery temperatures exceeding 1200˚C after malfunction) and hazard particles. Therefore prescribed tests that simulate different environmental, mechanical and electrical conditions where the batteries will be tested.

The most widely publicized incident involving a fire happened in 2011 with Chevrolet Volt after it has undergone a crash test in MGA research center. The batteries ignite three weeks later after being subjected to a side impact of 30 km/h as part of the NCAP test. The fire quickly spread to neighboring vehicles. Extensive investigation into the fire showed that a small amount of coolant entered into the housing of the battery at high voltage collision, which caused a short circuit and eventually led to uncontrolled heat state in terms of the temperature.

In 2012 after the Sandy Hurricane at the port in New Jersey sixteen electric vehicle Fisker Karma were burned and destroyed. Presumably flooding caused a short circuit in the battery which led to disruption of the thermal condition. Then the fire spread to finally ignite fifteen other neighboring vehicles.

Fig. 3 *Tesla S vehicle on fire due to penetration of the batteries and causing a short circuit [6]*

In 2013 two Tesla model S vehicles caught fire while being driven in USA. First in Washington sparked after the car hit a metal object on road. The second vehicle accident occurred after the vehicle has run over the plug trailer - hook in Tennessee. In both cases remains on the road penetrated through the floor causing damage to the batteries leading to battery failure and thermal instability. After both cases the company Tesla said they will add extra protection to the undercarriage of the vehicle to protect the battery.

In 2014, car thief crashed into another car at high speed where the vehicle broke in two. Battery flew out of the vehicle and caught fire.

For each type of today's common battery systems (such as lead acid, nickel-metal hybrid and lithium-ion) there are recommended methods for handling by the emergency staff, depending on whether the incident was a fire in the collision which damaged the housing of the battery or other hazardous event (ex. flooding). Manufacturer literature often provides specific details on how to deal with specific batteries. However, this information is not always consistent and not always easily accessible for the emergency staff. [3]

Despite the danger that may arise from these vehicles for users themselves SAE (Society of Automotive Engineers) highlighted the risks for those who are the first help assistance in case of accident and towing services. These risks include potential electric shock from damaged systems that are turned off during or immediately after crash. Because of this, the association recommends that manufacturers of electrical vehicles install switches that will stop the energy from the battery case in accident. The location of these

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switches must be standardized for security. Drivers of towing services also need to be well informed and trained on how to deal with hybrid and electric vehicles. The danger can be reduced if people from emergency services have easy access to batteries and if vehicle manufacturers create unique location for exclusion to all electric and hybrid vehicles.

Another fact that is not sufficiently emphasized is that hybrid and electric vehicles create low noise at low speeds. Pedestrians that are visually impaired use traffic sounds to detect intersection, go parallel to the road, to identify the right time for crossing the street and to know on which street they are located. They use traffic sounds to reveal the presence of vehicles and predict their movements. They also use the lack of noise to choose the right time to cross the street. Cyclists can interpret lack of noise as the right time to change lane or a sign they can relax because there is no vehicle approaching from the rear. However, information exists or can be interpreted only when the sound is at an appropriate level. Too high sound means impossible to make a difference and too low impossible to detect. Every vehicle should produce enough noise to recognize and interpret his movements, which is not the case with hybrid and electric vehicles moving at low speeds. Therefore, hybrid and electric vehicles must be equipped with a warning that will allow pedestrians to reveal their presence and direction of movement.

It is expected in the next 20 years the number of small light electric vehicles (SEVs) to significantly increase and become future solution for urban mobility because of their dimensions. These vehicles will have short front and rear overhang and will be allocated to less than 5 passengers. Clashes between SEVs and vulnerable road users and other heavier vehicles will differ from those of current traditional vehicles. Protection of vulnerable road users, compatibility with heavier vehicles and new active safety systems must be taken into account to ensure adequate security of SEVs in the future regulations [5].

5. Conclusion

It is clear that the use of electric and hybrid vehicles in the future will be one of the main landmarks in the development of transport. Their use will be encouraged in order to protect the environment and depletion of fossil fuels.

By applying this completely different technology people must be ready for new risks that come with it. It applies to all segments of using hybrid and electric vehicles: the habits and rules of participation in traffic, storage, maintenance, charging, and procedure in case of an accident.

The introduction of electric vehicles will require compliance with security rules that are inherent for the electrical drive. Electric vehicles will become safe and reliable way of transport which will improve traffic and the impact on the environment in the future.

People who are professionally working in this area must be trained on how to react in case of an accident. Although the use of this type of vehicles will enter later in our country we should be prepared to support the vehicles that will be passing through the country. They should be aware of and trained for challenges arising from an accident involving an electric or hybrid vehicle.

Performed crash tests are made with particular attention to the unique dangers associated with high voltage batteries. However, the market introduces new types of electrical drives and therefore the laboratories security practice will need to develop. Current procedures for safety of electric or hybrid vehicles are a good starting point for developing new ones.

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