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Study of Faults in Hybrid Vehicles

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Abstract. The article presents the results of the research of hybrid cars faults in Primorskiy Region. The research was carried out according to the data provided by the three enterprises in Vladivostok engaged in repair, maintenance and diagnostics of hybrid vehicles: «DV – Avtoelektronika» Co. LTD, «Forsazh» Co. LTD, «Tesla-service» Co. LTD. The study was conducted in order to identify the main causes of failures of hybrid vehicles in the region. The study includes: processing of initial data on the studied cars for the period from 2015 to 2017. The conducted research allowed to determine systems and components that malfunction the most common cause of the failure of hybrid cars, which gave the opportunity to develop recommendations to reduce failures in the operation of hybrid vehicles.

1. Introduction

In recent decades, hybrid cars have been gaining popularity all over the world and in Russia in particular. Hybrid cars or "hybrids" are vehicles that combine two types of power units: an internal combustion engine (ice) and an electric motor.

Vladivostok is one the cities with a high rate of growth of the automobile range of hybrid vehicles. This is facilitated by a high share of cars coming to Primorskiy Region from the secondary markets of Japan and the United States.

Despite the fact that in the total number of produced and sold cars, the prevailing majority remains the cars with an internal combustion engine, in the last decade, the growth rate of hybrid car sales has been increasing dramatically. 3 million of hybrids were sold in the USA from 1997 to 2017. In Japan for the past period, this figure reached 4.85 million. In 2013, 6 million of cars were sold in the world, for the next two years, in April 2016 the number reached 9 million units [1-4].

2. The problem of exploitation of hybrid cars

According The main factors that determine the demand for hybrids in the market, which increase their competitiveness in the world market are: reliability, environmental safety, fuel efficiency. These factors contribute to the hybrid vehicles operation's efficiency improvement [5-7].

The modern level of the automotive industry in the leading countries of the automotive industry, allows producing cars with a high degree of operational reliability. However, the risk of hybrid vehicle malfunctions increases several times with increasing mileage and operating life, which in turn can lead to the increased accident's level on the roads, environmental safety reduction and other negative consequences.

In this regard, the purpose of this work is to study the main causes of hybrid cars failures in their operation in Russia.



The studies are based on data provided by the three Vladivostok enterprises: "DV-Avtoelektronika" Co. LTD; "Forsazh" Co. LTD and "Tesla - service Co. LTD. All the enterprises provide services to repair, maintain and diagnose the hybrid vehicles. In the period from 2015 to 2017 the database includes 2,786 cases of hybrid vehicles owner's requests to the car service. The database based on the received information included the following data:

- car registration;
- date of the production of motor vehicle;
- mileage since first operation;
- malfunction characteristics.

3. Research methods

At the first stage, there was a task to study the brands of the hybrid cars requests received by the car service company. In order to do this, the entire data package was divided into 17 groups, by car brands. Then, the total number of cases of requests for each car brand and the percentage of the total number of requests were calculated. The data is summarized in a chart (Fig.1).

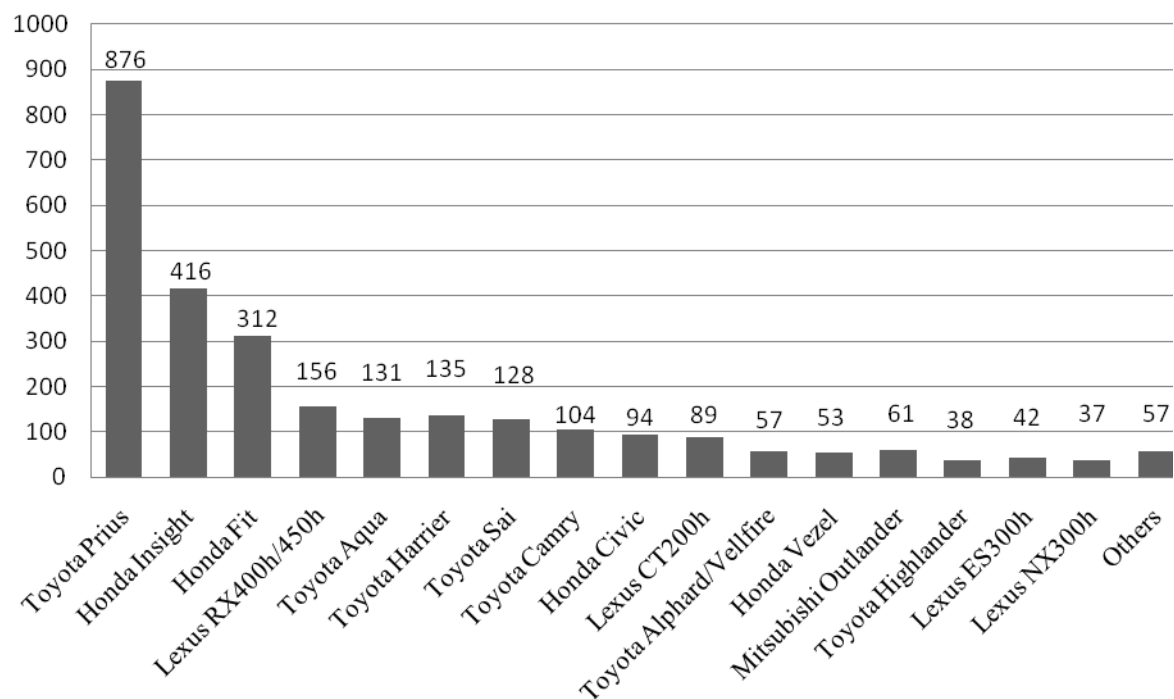


Figure 1. A number of hybrid car owners' requests for service.

It turned out that 31% of the requests belonged to Toyota Prius hybrid cars. In general, 57.5% of the requests refer to the cars of the three brands: Toyota Prius, Honda Insight, Honda Fit. First of all this is due to the fact that these brands occupy a leading position in the secondary market of cars and that they are the most widely used among the car owners in the city. The studies have shown that the other brands of hybrid cars presented today in the city account for less than 5% of the requests.

Figure 2 shows the chart of hybrid car owners' requests in accordance with the year of the car's production and its average mileage.

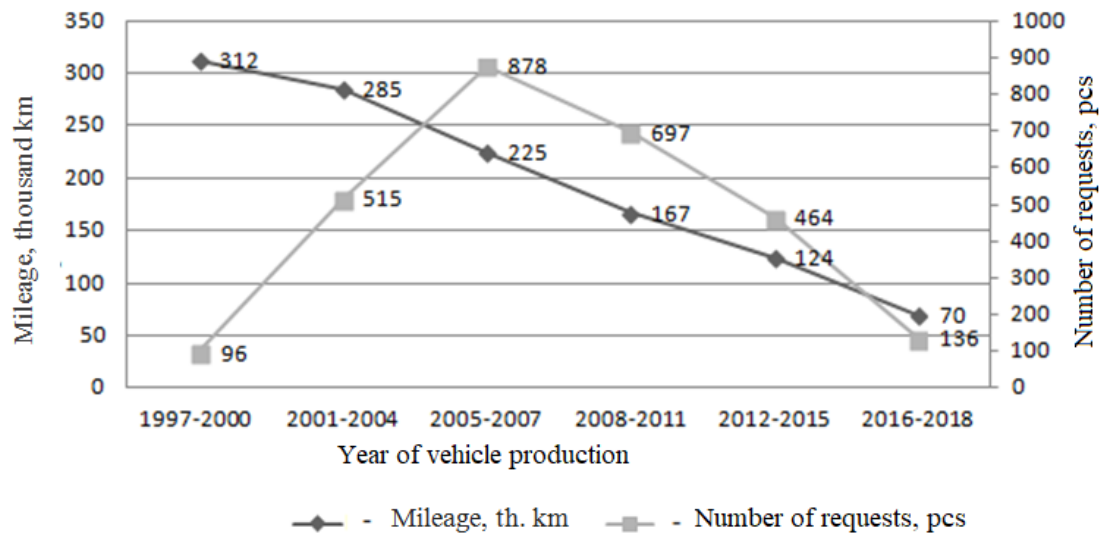


Figure 2. Number of hybrid car owners' requests by the year of vehicle production and average mileage of the hybrid car.

The chart shows that the cars of 1997-2000 year of production account for only 3.4% of the requests. It is more likely that this is because in the late 90-s hybrid cars have not been popular with the car owners. They were still produced in little amounts, and accordingly, they have not been presented in the secondary market in sufficient quantity yet. The peak of requests (31.5%) is accounted for cars of 2005-2007 year of production.

The analysis of the graph showed that the largest number of requests comes from the owners of the cars exceeding the ten-year life of the vehicle, which generally corresponds to average depreciation rates. The mileage of these cars exceeds two hundred thousand kilometers.

At the second stage of the study, the main failures (malfunctions) of hybrid cars were determined. To do so, all appeals were divided into 6 groups, in accordance with the main damage (Fig. 3). After calculating the percentage of failures, it turned out that the largest number of failures occurred in the electrical equipment and electronics (34.2%). The share of the failure of the hybrid system in the total number of faults is 27%. The share of suspension is 14%. Failures of the other nodes do not exceed 10%.

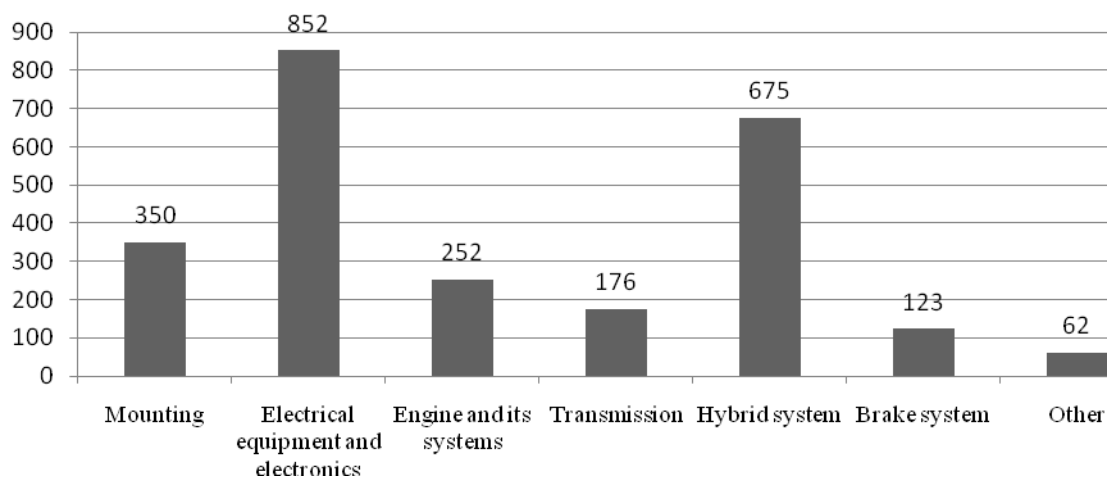


Figure 3. Main types of faults of hybrid vehicles.

4. Received result

Thus, there are two subgroups of faults: “electrical equipment and electronics” and “hybrid system” in the main types of faults of hybrid cars. Then it was necessary to identify the fault of each group. Figure 4 shows a diagram of the major electrical and electronics faults in hybrid vehicles.

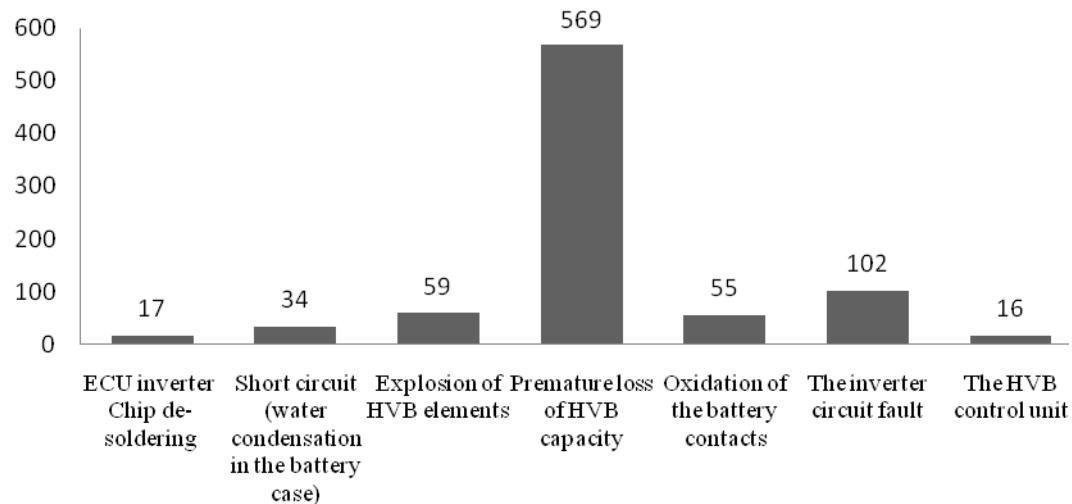


Figure 4. Main faults of hybrid vehicle's electrical and electronic equipment.

The diagram shows that the main reason of the owner's requests is the premature loss of the high-voltage battery capacity. This fault accounts for 67% of the total number of requests related to the electrical equipment faults.

When assembling the battery at the factory, the elements are installed as close to each other as possible. But with time an imbalance in capacity, internal resistance and many other parameters occur, which reduce the battery efficiency as a whole. The copper contact plates in the high-voltage battery get oxidized. The car reacts to the decrease of the high-voltage battery quality by the increased fuel consumption, incorrect indication of the battery charge and discharge level, warning alarm and power decrease in general [8-11]. With further operation of the car with such a battery, the risk of explosion of the faulty element increases (Fig. 5), this may cause the ignition of the vehicle.



Figure 5. High-Voltage battery after a faulty element has exploded.

Repair of the HVB is carried out in order to align the parameters of the individual bundles of the battery elements, and bring its capacity to factory values. In this case, the battery itself is disassembled into separate elements, each of which is tested on a special stand. After rejecting the weak elements, they are replaced and control and training cycles (equalization) are carried out, the purpose of which is to equalize the capacity of individual pairs of battery elements under a certain load [12-14].

As it was mentioned above, the second type of the most common faults in hybrid cars is associated with a hybrid system (HS). The numerical relationships of faults in this group are shown in Figure 6.

Analysis of the data showed that the main cause of HS faults is the failure of the pump of the inverter cooling system. This fault accounts for more than 70% of failure cases. The share of the other failures in the total number of failures of the hybrid system is insignificant (less than 5%). The only exception is the failure of the power module. This failure occurs in 11.3% of cases.

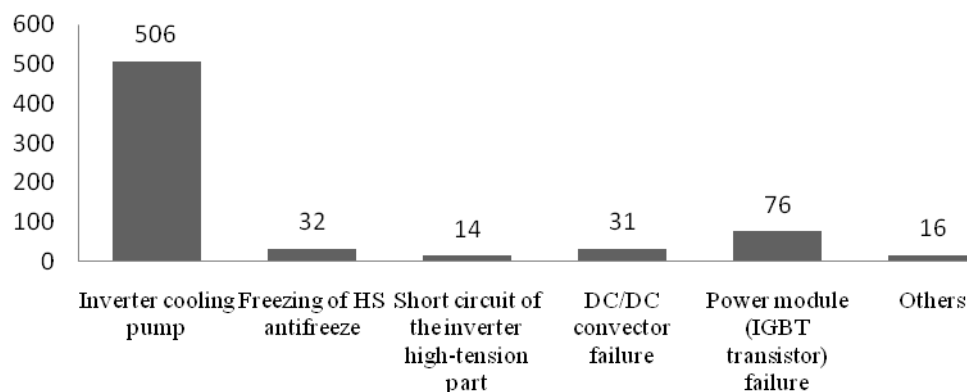


Figure 6. The main faults of the vehicles HS.

There are two cooling systems in a hybrid car. The first, as in cars with an internal combustion engine has a contour: an internal-combustion engine/ interior heater/ radiator. The second system cools the hybrid part, namely the powertrain with an electric motors and the inverter. The fluid in the hybrid contour is circulated due to the electric pump [15, 16]. Two cooling circuits operate autonomously and have their own volume of cooling fluid and, respectively, two expansion tanks with liquid level controllers. The circulation stop in the hybrid circuit (pump's stopping down, the circuit air locking) causes the inverter overheating with the subsequent failure. The inverter converts the direct current from the traction battery into an alternating current to supply an alternating current to the traction motor. It is necessary to take rigorous care of the cooling fluid level, its freezing temperature, and the cleanliness of the hybrid system-cooling radiator [17 - 20].

5. Conclusion

Thus, as a result of the study, the following conclusions were drawn:

Firstly, the dependence of the decrease in the reliability of a hybrid car on its lifetime and mileage was established.

Secondly, the main reasons for failures (malfunctions) of the hybrid cars are: a) high-voltage battery capacity loss; b) failure of the cooling system inverter pump.

Thirdly, in order to reduce the risk of failures (malfunctions) of the hybrid cars, the following recommendations are proposed:

- to carry out regular battery testing in order to extend its lifetime and to avoid its premature replacement.
- to avoid the battery overheating and to equalize the battery components twice a year, after one hundred and fifty thousand kilometers of mileage. The driver must remember that a high-voltage battery requires a constant maintenance of the ventilation system.

- to monitor the level of the cooling liquid and to replace it in time.
- not to allow the car operation when the cooling liquid is frozen during the cold season.
- to replace the cooling pump of the inverter every one hundred and fifty thousand kilometers of mileage. To remember that the cooling system pump requires a seasonal maintenance.

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