Study of Fuel Efficiency of Hybrid Vehicles

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Abstract. The article presents the results of studying the fuel consumption rate of hybrid vehicles operated in Primorsky Krai. The research is directed at the identification of phenomena causing the difference in average fuel consumption rates of hybrid vehicles stated by the manufacturer and the actual values of such consumption provided by vehicle owners. Revealing the factors which have the impact on the average fuel consumption rate of hybrid vehicles is also covered in the paper. The authors compared the vehicle fuel consumption rates of the manufacturers of Honda and Toyota cars.

1. Introduction

According to the data, by 2017 the number of sold hybrid cars in the world reached 10 million pcs. At this, sales dynamics has a sustainable growth tendency [1]. The number of hybrid cars in the world car fleet in a quantitative sense increases every 5 years approximately by 3 million units. With the account of existing trends by 2020 the fleet of hybrid cars can reach 14 million pcs. while annual sales of hybrid cars reached 10% of the general number of cars sold in the world [2-4].

The main factors defining the demand for hybrid cars at the market and increasing their competitiveness at the global market are the following: reliability, environmental safety, fuel efficiency. Particularly these factors facilitate the increase in the efficiency of the operation of hybrid vehicles [5-8].

2. Problem of fuel efficiency of hybrid vehicles

The problem of actual fuel consumption rate defining is quite relevant. The owners of hybrid vehicles provide ambiguous data on the average fuel consumption rate in the process of their operation.

The research is directed at the identification of phenomena causing the difference in average fuel consumption rates of hybrid vehicles stated by the manufacturer and the actual values of such consumption provided by the vehicle owners.

In this connection the purpose of the paper consists in studying the reasons of the discrepancy of the actual average fuel consumption values of hybrid vehicles with those stated by manufacturers.

3. Research methods

All the information about the hybrid vehicle data was collected in automotive clubs of Vladivostok by means of car drivers' interrogating. The information was analyzed in the conditions of the urban cycle. More than 1,000 car owners took part in the poll. The presented vehicles had various mileages in the

territory of Russia. The obtained data are compared with the manufacturer's parameters of Japanese car producers. Table 1 gives the manufacturer's technical characteristics of hybrid cars operated in the Russian Federation.

Table 1. Manufacturer's technical characteristics of hybrid cars operated in the Russian Federation.

Model	Location	Hybrid drive configuration	Fuel consumption rate urban cycle, l/100km	hybrid cycle, l/100km
Toyota Prius (NHW11)	transversal	hybrid	3.23	3.1
Toyota Prius (NHW20)	transversal	hybrid	2.8	2.1
Toyota Prius (ZVW30)	transversal	hybrid	3.9	3.9
Toyota Camry Hybrid	transversal	hybrid	3.7	4.2
Toyota Estima	transversal	hybrid	5.6	n.a.
Toyota Highlander Hybrid	longitudinal	hybrid	8.4	8.4
Honda Civic Hybrid	transversal	parallel	6.7	6.7
Honda Insight	transversal	parallel	3.3	3.3
Honda Fit	transversal	parallel	2.7	3.2

According to the car owners, during real operation the average costs for such hybrid cars are 30-40% higher than the expected ones (based on the manufacturer's statements). The reasons of such higher real values of the average fuel consumption rate in hybrid cars relate to multiple factors.

The International Environmental Transport Council has published the report on 2018. According to the report, in 2018 a record-breaking discrepancy between the indicators of the stated and real fuel consumption rate of cars was registered, in particular, the real consumption rates were by 42% higher. For vehicle owners it means additional costs of 400 euro per year, as it is reported by the periodical of the media groups "Funke" with the reference to the available results of the poll conducted by an independent organization ICCT (International Council on Clean Transportation). [9 -10].

There is a number of factors having the impact on the average fuel consumption rate of hybrid vehicles. The important factors are the fuel quality, climatic and road conditions.

The fuel quality significantly affects the fuel consumption rate of a hybrid car. Regardless of the hybrid drive configuration, such fuel use causes consumption growth. The deviation of quality indicators causes serious faults in the engine operation [11-13].

During the winter period to heat the engine and all car systems, one needs fuel using. A running heater and snow tires have an impact on the increase of the fuel consumption rate. In summer the fuel consumption rate increases due to the operation of air conditioning and related systems because of increased environment humidity [14-16].

Road conditions can include the quality of road carpet, road carpet type, mountainous area, location of the road above the sea level. Road carpet quality directly impacts the car economic efficiency, continuous dynamic loads cause fatigue fractures, fixture unfastening, loosening, excessive wear of a driving gear. In the mountainous areas the load on the electrical part increases, engine generators, power inverters and accumulators emit heat more intensively, the cooling system is subject to a higher load. [17 -20].

The research are based on the data provided by car clubs of Vladivostok. The data were gathered by means of interrogating drivers in the period of 2017-2018. The base created included the following data:

- vehicle make;
- vehicle manufacture date;
- vehicle mileage;
- average velocity of a vehicle during fuel consumption measurement.

4. Obtained results

At the first stage the authors set the task to define an average fuel consumption rate of hybrid cars Honda and Toyota. To do this, the whole data package was divided into groups in compliance with their makes and manufacture dates. Fig. 1 shows the curve of the average fuel consumption rate of hybrid cars Honda depending on their year of manufacture.

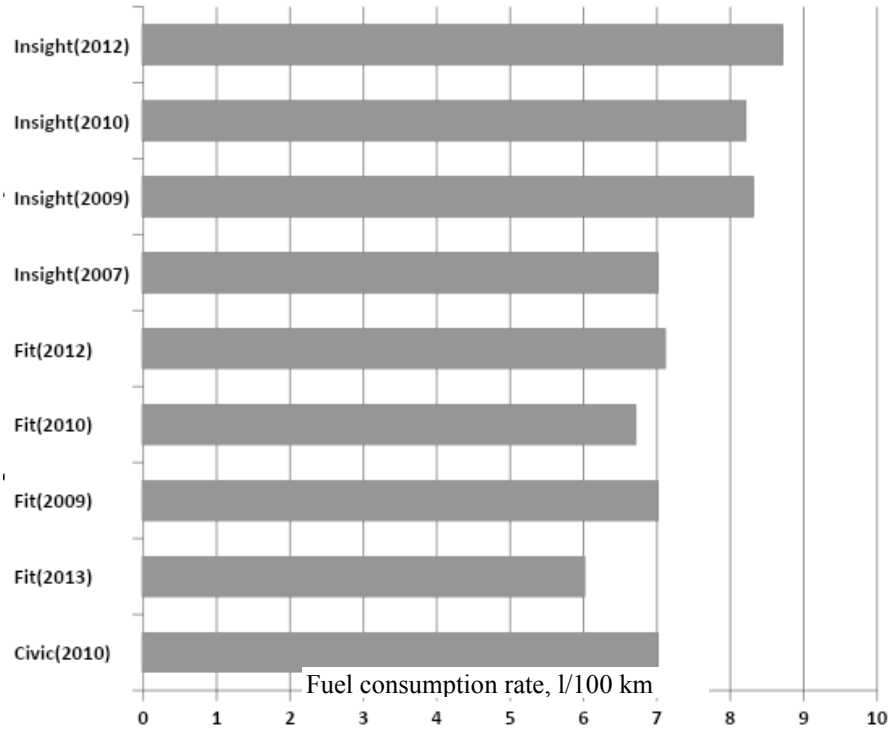

Figure 1. Fuel consumption rate depending on the Honda cars year of manufacture.

The curve showing the dependence of the fuel consumption rate on the year of manufacture makes it obvious that the highest ratio for Honda Insight can be 8.7 l /100 km while the lowest, i.e. the most profitable ratio in terms of fuel consumption for a hybrid car Honda Fit, is 6 l /100 km. The data present an average value for this car make provided by the vehicle owners. The difference in the indicators of these makes is explained by different liter capacity of a vehicle.

Fig. 2 shows the curve of the average fuel consumption rate of hybrid cars Toyota depending on their year of manufacture

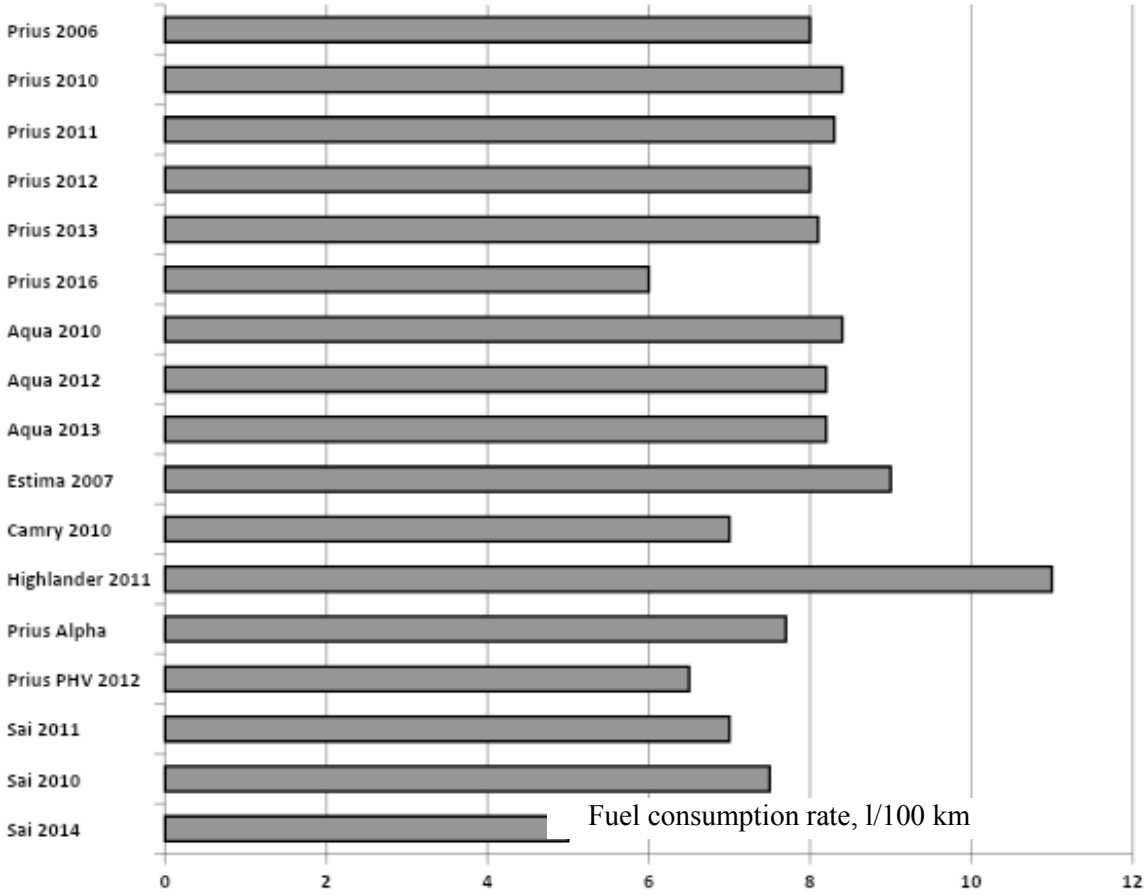

Figure 2. Fuel consumption rate depending on the Toyota cars year of manufacture.

The curve showing the dependence of the fuel consumption rate on the year of manufacture makes it obvious that the highest ratio for Toyota Highlander can be 11 l /100 km while the lowest, i.e. the most profitable ratio in terms of fuel consumption for a hybrid car Toyota Sai is 5 l /100 km. The data present an average value for this car make provided by the vehicle owners. The difference in the indicators of these makes is explained by different liter capacity of a vehicle.

At the second research stage the authors determined the ratio between fuel consumption and the mileage of hybrid cars Honda and Toyota. Car mileage definitely has an impact on the average fuel consumption rate. Fig. 3 shows the curve of the average fuel consumption rate of hybrid cars Honda depending on their mileage.

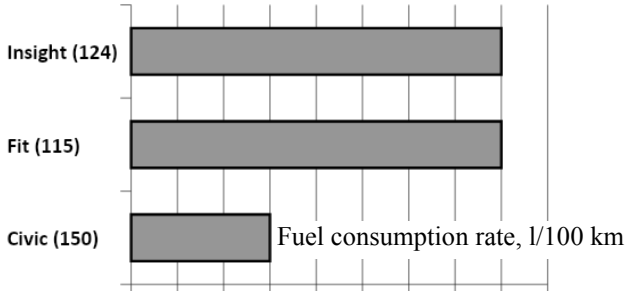

Figure 3. Fuel consumption rate curve depending on the Honda cars mileage.

The curve of the ratio "fuel consumption rate - Honda mileage" shows that the average value relates to a Honda Insight as it has a profitable ration of consumption and mileage. Car mileage definitely has an impact on the average fuel consumption rate.

Fig. 4 shows the curve of the average fuel consumption rate of hybrid cars Toyota depending on their mileage.

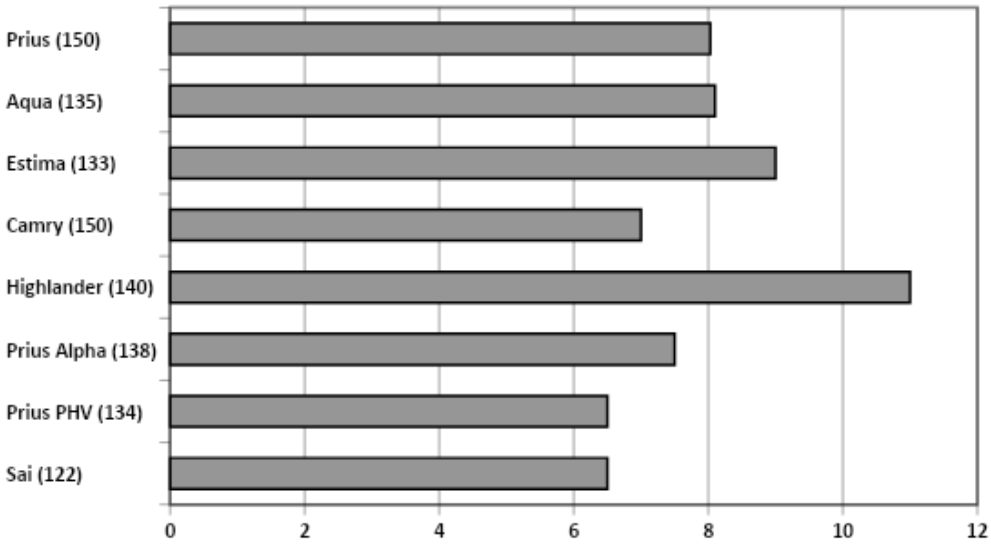

Figure 4. Fuel consumption rate curve depending on Toyota mileage.

The curve showing the dependence of the fuel consumption rate on a Toyota mileage presents an average mileage value for this model. The models Toyota Prius PHV and Toyota Sai are the most profitable hybrid cars while the cars Toyota Aqua and Toyota Prius are less cost-effective.

At the third research stage the authors determined the ratio between fuel consumption and the average velocity of hybrid cars Honda and Toyota. For hybrid vehicles one should use the indicator of the distance covered at one fuel liter. Fig. 6 shows the curve of the distance covered at 1 fuel liter in relation to the velocity of hybrid cars Honda depending on their mileage.

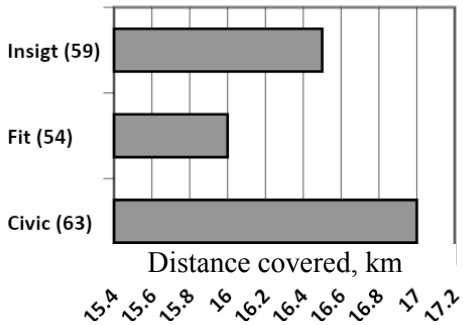

Figure 5. Curve of the distance covered at one fuel liter in relation of a Honda average velocity.

The curve showing the ratio "fuel consumption rate - average Honda velocity" makes it obvious that in case the velocity rate is normal, the fuel consumption rate can be rather low as well. The curve shows that at various velocities the fuel consumption rate is virtually the same which is explained by various engine liter capacities.

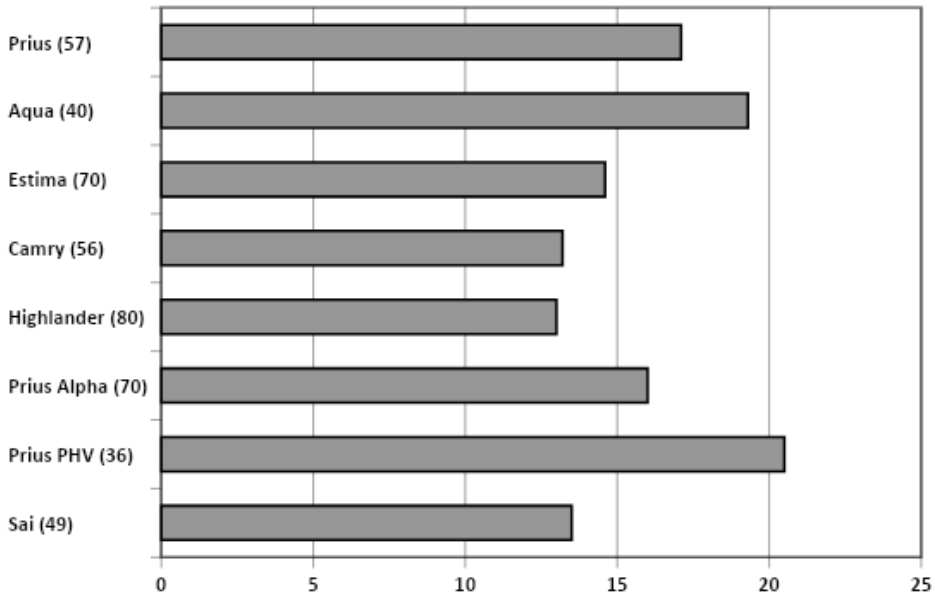

Figure 6. Curve of the distance covered at one fuel liter in relation of a Toyota average velocity.

The curve of the distance covered at one fuel liter in relation to a Toyota average velocity shows that most cars have the difference of only 2-3 km at one 1 liter. It is mostly connected with vehicle liter capacity as it varies significantly.

5. Conclusion

Therefore, the authors made the following conclusions on the research outcomes:

Firstly, the fuel consumption rate depends of the year of manufacture: for Honda cars - starting from 3 l /100 km for Toyota cars - up to 7.2 l /100 km.

Secondly, depending on the mileage after 120,000 km the consumption rate increases by 3.7 l/100 km of the stated 3.3 l/100 km for Honda; up to 40% Toyota cars at the mileage from 85,000 km to 150,000 km inclusive

Finally, depending on the average velocity the fuel consumption rate of Honda and Toyota cars increased by 40% of the stated technical specifications.

In addition, the fuel consumption rate of hybrid vehicles depends on fuel quality, climatic and road conditions but the latter are not covered in the poll organized in Vladivostok car clubs.

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