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ANALYSIS OF PERFORMANCE PROPERTIES OF HYBRID PASSENGER CARS IN HOT CLIMATE CONDITIONS OF UZBEKISTAN

Rakhmankulov F. Kh.
Candidate of Technical Sciences

Sadullaev B.
Master's Student

Avliyokulov Zh. S.
PhD Associate Professor

Abdumannoev Z. A.
Master's Student

Abstract
The article is devoted to the analysis of the operation of vehicles with hybrid power plants in the internal combustion engine (ICE) and electric traction modes. The main advantages of hybrid vehicles when driving with an internal combustion engine (ICE) and an electric motor are considered. The influence of road conditions on the range and the energy recovery process is analyzed. Based on the results of the analysis of the performance properties of vehicles with hybrid power plants and experimental data, recommendations are obtained for the technical operation of this type of vehicles in the hot climate of the Republic of Uzbekistan.

Keywords: Batteries, hybrid vehicle, electric drive, electric charge, high-voltage battery (HVB), electronic control unit (ECU), recuperation, range, traction and speed properties, fuel efficiency.

Introduction

The development of a single economic space of the Republic of Uzbekistan largely depends on the level of development of the transport infrastructure of each region, each district. A significant role in the overall transport system belongs by right to automobile transport. At the same time, a high level of automobile transport service is determined by the speed, timeliness, predictability, rhythm, availability and safety of the functioning of the entire automobile transport system and each of its elements, but a special role in large cities of the republic is played by the number of motor vehicles in operation, which create large congestion - traffic jams on city roads, emit a large amount of exhaust gases from cars, pollute the air and the environment.

For the balanced development of the automobile transport system in the regions and the city, reduction of air pollution and protection of the environment, it is necessary to have state regulation of transport activities, introduction of innovative and information and communication technologies into the industry, use in operation of cars with hybrid power plants in the internal combustion engine (ICE) and electric traction mode, which will ultimately save fuel consumption and reduce harmful emissions into the environment. In this regard, the requirements for motor vehicles, including hybrid cars, are constantly increasing, which is why in the republic, the operation of hybrid cars is not used to the fullest extent.

This article is devoted to the analysis of the operation of cars with hybrid power plants, in the hot climate of the Republic of Uzbekistan. The main advantages of hybrid cars are considered, when driving in the internal combustion engine mode and with the help of an electric motor. The influence of road conditions and ambient temperature on the operation of the internal combustion engine, electric motor and its battery, on the power reserve and the process of energy recovery is analyzed.

The use of hybrid systems involves the use of an electric motor as an additional element that helps increase the output power of the wheel drive, as well as significant fuel savings due to the use of an internal combustion engine with a smaller capacity and lower power, which has a positive effect on environmental protection.

Fulfilment of the technical requirements for the operation of hybrid vehicles, when improving existing vehicles, is associated with conducting experimental studies of operational modes, as well as possible control actions and all sorts of diversity of structural design [4,5,7,8,9,12].

Hybrid systems can be conditionally divided into subtypes:

- integrated motor assistance;
- Integrated starter generator.

There are three types of hybrids:

- parallel, this system allows both the internal combustion engine and the electric motor to create conditions for the vehicle to move;
- sequential, this system allows you to turn the generator, which can be both an electric motor and a generator, to charge the batteries;
- series-parallel, this is a system where the internal combustion engine, electric motor and generator are connected to the wheels through a planetary gear.

The hybrid system in the car opens up new operational possibilities, increases the length of the inter-refueling run, when the battery charge is exhausted, a low-power internal combustion engine comes into operation, and the recuperative system accumulates energy.

Thus, in cars equipped with hybrid power plants, the ZEV (Zero Emission Vehicle) mode is becoming increasingly valuable in urban driving conditions. This paper will consider the traction and speed properties of the internal combustion engine and electric motor. Electric traction systems have much lower energy losses than systems with internal combustion engines (ICE). The degree of use of the energy of the electrochemical battery is much higher, the efficiency of electric motors is 85-90%, and accordingly, the acceleration dynamics are much

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higher than that of gasoline analogues. Table 1. Presents the parameters of the battery and electric motors of leading car manufacturers.

Tech.char.	Peugeot3008 Hybrid 4	LexusNX 300h	Honda Insight	Toyota Prius	KIA Optima Hybrid	Ford Fusion Hybrid	Chevrolet Volt	BMV X3 xDrive30e (Plug-in gibrid)
Ext.weight, kg	1735	1785	1208	1445	1585	1650	1721	3355
Battery type	Ni-MH	Ni-MH	Ni-MH	Ni-MH	Li-ion	Li-ion	Li-ion	Li-ion
Battery weight, kg.	48	40	38	45	41	48	198	41
Battery capacity, kW/h	1,1	1,6	0,58	1,3	1,4	1,4	16,5	1,6
Power	27	105 50	10,3	60	35	88	111	81
Electric motor, kW	200	270 139	78,5	207	205	239	320	207

Modern car manufacturers often resort to the combined use of an internal combustion engine (ICE) and an electric motor, which allows avoiding the operation of the ICE in low-load mode, as well as implementing the recovery of kinetic energy, increasing the fuel efficiency of the power plant. Another common type of hybrids are cars in which the ICE is combined with electric motors operating due to the battery. [1,2,3,4,5,7,8,9,13]
Features of using hybrid systems. The use of hybrid cars not only has its advantages, such as environmental ones, but also pursues certain goals of the current players in the automotive market. Companies intend to maintain the established conveyor production of internal combustion engines. And the constant tightening of emission standards for harmful substances is further evidence of this. The use of hybrid systems involves the use of an electric motor as an additional element that helps increase power and save fuel. After all, all such cars start moving thanks to the internal combustion engine [4]. The system, like the previous one, allows the car to start moving only if a smaller electric motor is used. The motor is turned off when its power is not used, and then it starts immediately as soon as it is needed. In this case, the batteries transmit energy to the electric motor, and the tank transmits fuel to the internal combustion engine. Both units are capable of creating conditions for the movement of the vehicle. Most of the currently existing hybrid cars are parallel. A good solution is a vehicle with recharging. It opens up new operational possibilities, leveling out the disadvantage of limited mileage. When the battery charge is exhausted, a low-power internal combustion engine comes into operation.
The hybrid system significantly reduces the level of exhaust gases and increases fuel efficiency, which is especially important in a relatively large populated area. And the recuperative system accumulates energy. Driving a hybrid vehicle is similar to driving a regular car with an automatic transmission. Only in this case, low noise levels, better controllability and increased power are ensured. At the same time, there is no need to specially recharge the battery, this happens when the car is running. Let's consider the device

of a gasoline-electric hybrid. Gasoline-electric hybrids include the following elements [4,5,8,9].

A hybrid car uses almost the same gasoline engine as a conventional car. However, the hybrid engine is smaller and uses improved technologies to reduce emissions and fuel consumption. The fuel tank of a hybrid car is an energy storage device for the gasoline engine. The energy density of gasoline is significantly higher than that of the battery. For example, 45.3 kg of batteries are required to store the energy of 1 liter of gasoline (750 g).

Hybrid cars use modern and complex electric motors. Modern electronics allow the engine to be used as a generator as well. For example, if necessary, the battery power is consumed to accelerate the car. But also, working as a generator, the electric motor can reduce the speed of the car and charge the battery. The principle of operation of the generator is similar to that of an electric motor, but the generator only works to generate electricity. It is mainly used in serial hybrids.

The batteries in hybrid cars act as energy storage for the electric motor. Unlike the gasoline in the fuel tank, which can only power the gasoline engine, the electric motor can not only consume energy, but also charge the batteries.

The transmission of a hybrid car performs the same functions as the transmission of a regular car. Some hybrid cars, such as the Honda Insight, have regular transmissions. Others, such as the Toyota Prius, have completely different ones. There are different combinations of energy sources in a hybrid car. For example: a parallel hybrid uses a fuel tank that powers the gasoline engine and a set of batteries that power an electric motor. Both engines can turn the transmission at the same time, and the transmission, in turn, turns the wheels. In a series hybrid, the gasoline engine turns the generator, and the generator either charges the batteries or powers the electric motor, which turns the transmission. Thus, in this type of hybrid, the gasoline engine does not directly participate in turning the wheels. A hybrid vehicle is designed to use two energy sources to improve fuel economy and performance.

The key feature of hybrid cars is that they use much smaller gasoline engines than conventional cars, but they are more efficient. Many cars use fairly large engines to provide sufficient power during acceleration. However, in a small engine, efficiency can be increased by using smaller, lighter parts, reducing the number of cylinders, and running the engine at near maximum load. The engine size of a conventional car is designed to use maximum power. In reality, most drivers use the car's maximum power less than 1% of the time. Hybrids use a smaller engine that is designed for average power requirements, not maximum loads.

In the world, most hybrid cars are equipped with nickel-metal hydride batteries, which have mechanical reliability and high energy density, reaching 80 W/kg. However, this type of battery has disadvantages: high self-discharge, especially when fully charged, a small number of working cycles after a long discharge. Lithium-ion batteries are also widely used in hybrid cars. The main advantages of these batteries are: energy capacity, service life and potential cost reduction in large volumes. [4,5,6,12,13].

This article is devoted to the analysis of the efficiency of operation of a hybrid vehicle in the electric traction mode (ZEV) in terms of the power reserve. The analysis was carried out on

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the basis of experimental data obtained on the GNFA HE-3020 "Hybrid Vehicle" stand, simulating the operation of the BMW X3 Hybrid. The general appearance of the drum stand is shown in Figure 1.

Fig. 1. Test on a drum stand.

On drum stands, the wheels rest on a relatively large drum and the rolling conditions of the tire are almost the same as the rolling conditions on a flat road. During the tests, by braking the drums, it is possible to create different conditions for moving uphill, connecting the drums to a descent (slope), the free rotation of the drums is a horizontal road. To record the studied parameters of movement, i.e. speed, acceleration and torque, a computer is connected to the corresponding units, without any intermediate processing.
Based on the experimental results, the following regression equations were obtained:
• for horizontal road:

$$S = -0{,}0014 \cdot v^2 + 0{,}0378 \cdot v + 4{,}446$$

• slope 2%:

$$S = 0{,}0004 \cdot v^2 - 0{,}0462 \cdot v + 2{,}838$$

• slope 5%:

$$S = -0{,}0001 \cdot v^2 - 0{,}0019 \cdot v + 1{,}286$$

• slope 8%:

$$S = -0{,}0003 \cdot v^2 + 0{,}0152 \cdot v + 0{,}696\,.$$

Based on the results of the experiment on the running drums, we can conclude:
- that on a horizontal section of the road, the gasoline engine began to turn on when the battery charge level dropped below 22%;
- only at a speed of 60 km / h did the ICE begin to work already at a discharge of 49%;
- when moving uphill, the ICE began to work at a battery capacity of about 42% of the maximum;

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- at the same time, on an 8% slope, the car began to move due to the ICE at a speed above 45 km / h.

Fig. 2 shows the results of the experiment in the form of graphs of the dependence of the distance traveled on the speed of movement only on the electric motor and the corresponding regression equations of the type S = /(y)

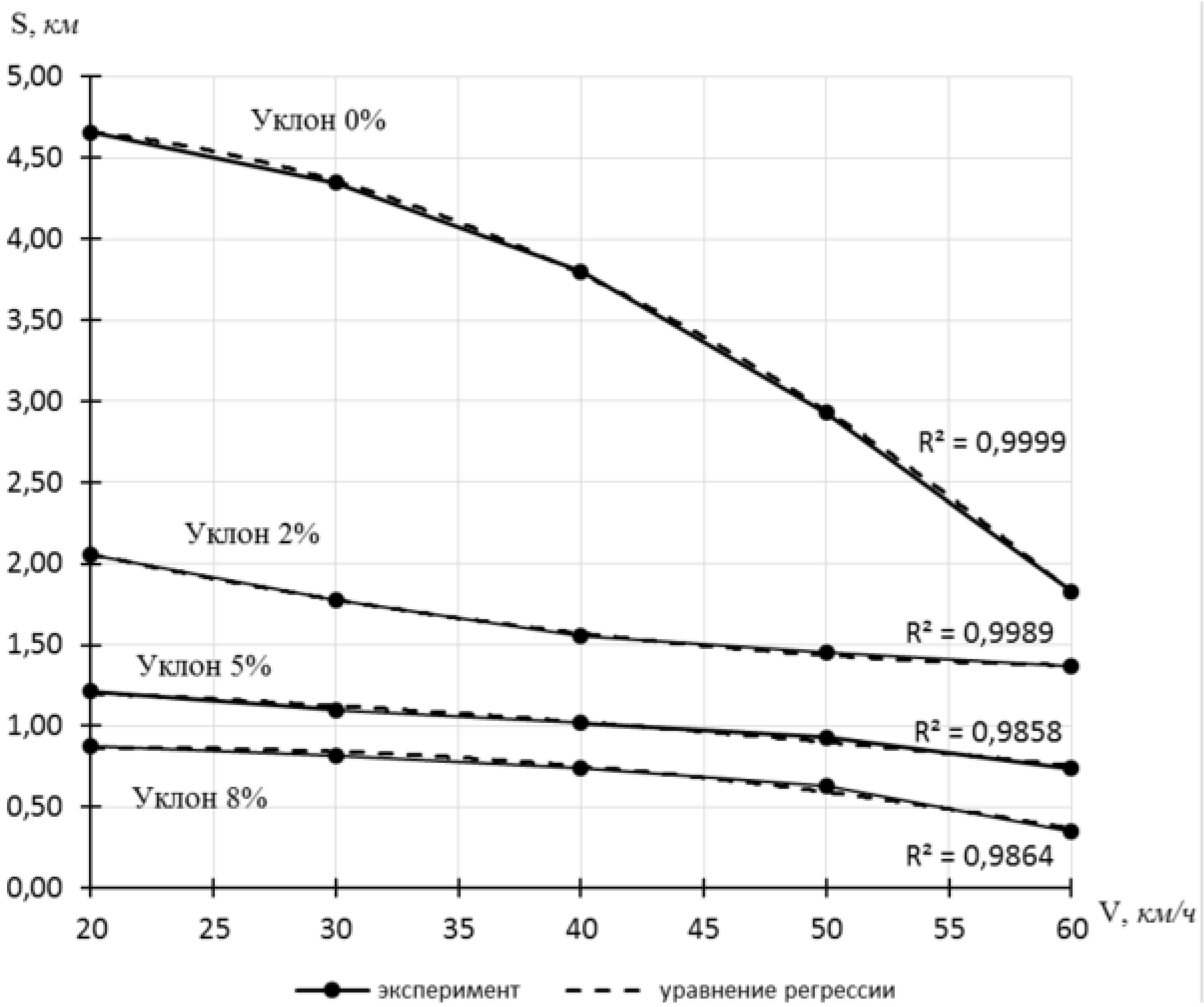

Fig. 2. Power reserve in electric traction mode, dependence of the distance traveled on the speed of movement.

An experiment to study the operation of the regenerative braking system was also conducted at the stand. Based on the results of the experiment, graphs of the dependence Z = /(v) were constructed, where Z is the % of the battery charge, shown in Figure 3.

During regenerative braking, the traction electric motor switches to the generator mode, the electric energy generated by the motor-generator during braking is used for additional recharging of the traction high-voltage battery [13,14]. Measurements of the duration of charging the power source were carried out when releasing the gas to a complete stop from

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speeds of 20, 40, 60, 80 and 100 km / h. The experiment was carried out under three different road conditions: horizontal surface, ascent and descent with an inclination angle of 5%.

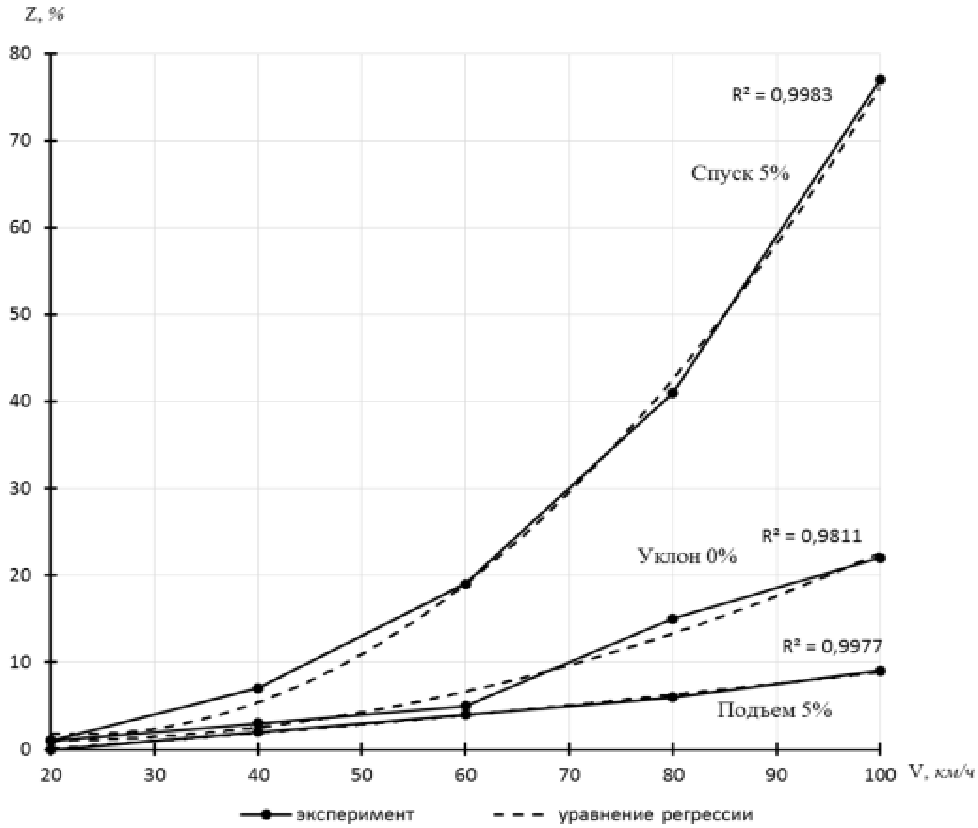

Рис.3.Зарядка аккумуляторной батареи рекуперативным торможением

На основе результатов эксперимента были получены следующие уравнения регрессии:

• horizontal surface:

$$Z = 0{,}0032 \cdot v^2 - 0{,}1157 \cdot v + 2$$

• rise 5%:

$$Z = 0{,}0004 \cdot v^2 + 0{,}0671 \cdot v - 1{,}4$$

• descent 5%:

$$Z = 0{,}0125 \cdot v^2 - 0{,}57 \cdot v + 8{,}2 .$$

Thus, as a result of the experiments, the dependences of the power reserve and battery charging on the speed and driving conditions of a car with a hybrid power plant were obtained. On the one hand, a hybrid car in electric traction mode with minimum driving speeds can travel quite a long distance. On the other hand, with such movement it is impossible to use regenerative braking to the fullest extent. In any case, the internal combustion engine will be included in the work to recharge the battery or accelerate the car.

The obtained regression equations can be used for approximate calculations of the driving range and battery charging for hybrid vehicles with similar characteristics.

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As you know, a hybrid car has two types of engines - electric and internal combustion, which reduces fuel consumption and emissions of harmful substances. However, how does a hybrid car behave on hot days, there is no precise scientific research? In this article, we will consider the features of a hybrid car at high temperatures and the effect of heat on its performance.

One of the key features of hybrid cars is the use of a battery as an additional source of energy. On hot days, temperature can significantly affect the operation of the high-voltage battery (HVB). High temperatures have a destructive effect on the chemical structures of the battery and accelerate its degradation. Overheating is one of the main enemies of any battery. To ensure efficient operation of the system and maximum service life of the hybrid, at high air temperatures and the influence of heat, the "brains" of the electronic control unit (ECU) of the car closely monitor the temperature of the high-voltage battery (HVB) and, if it increases, gradually take the following measures:

Turn on cooling (VVB) in advance, when the temperature has not yet reached dangerous levels.

1. Increase the cooling capacity of the battery as its temperature rises.
2. Begin to limit recuperation as the temperature continues to rise.
3. Gradually reduce the use of (HVB).
4. Virtually turn off the hybrid system when the battery temperature approaches dangerous values.

These measures preserve the high-voltage battery, but affect the efficiency of the hybrid vehicle. The efficiency of the hybrid decreases in hot weather. Starting from point 3 of the previous section, the computer introduces restrictions into the operation of the hybrid system and increases them as the temperature (HVB) increases further. This proportionally reduces the efficiency of the hybrid and leads to the following consequences:

- Increased fuel consumption. As recuperation is limited, more and more braking energy is lost in the brake pads instead of being converted into electrical energy. Energy savings are reduced and fuel consumption increases compared to colder weather.
- • Limitation of the electric vehicle mode. This is inevitable when the use of the high-voltage battery is limited. And when the hybrid system is almost completely switched off, the car switches to operation using only the internal combustion engine. So, as it warms up (HVB), the hybrid gradually turns into a regular car.

To operate a hybrid vehicle in the hot weather most efficiently, it is necessary to create conditions for the best cooling of its high-voltage battery. Recommendations for this depend on the type of the high-voltage battery cooling system.

Recommendations for operating a hybrid vehicle in hot weather:

1. For the air-cooling system from the vehicle's passenger compartment:
   • Always turn on the air conditioner and close the windows in hot weather.
   • Keep the air intake grilles of the air-cooling system clean.
   • Do not block the grilles with foreign objects.
   • Keep the passenger compartment clean. Dust and debris get into the cooling system and block the openings between the air-cooling system elements.
   • Visit a service center at least once every few years to clean the cooling system.

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2. For air cooling system with separate air conditioner - have the air conditioner serviced regularly by professionals.
3. For liquid cooling system - perform scheduled maintenance according to the requirements of your vehicle manufacturer.
4. For plug-in hybrids, it is recommended to limit the charging speed from the network in hot weather.

If, despite following the above recommendations, the battery quickly overheats, then visit a qualified service center to eliminate possible malfunctions.

Заключение

Hybrid vehicles provide good performance and acceptable efficiency in all weather conditions. However, it is important to consider the impact of high temperatures on the battery. Following recommendations for improving the cooling of the high-voltage battery in hot weather will help maintain efficiency and increase the driving range. Hybrid vehicles continue to evolve, and their performance is getting better every year, regardless of the ambient temperature.

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