**ТОРАЙҒЫРОВ УНИВЕРСИТЕТІНІҢ
ҒЫЛЫМИ ЖУРНАЛЫ**

**НАУЧНЫЙ ЖУРНАЛ
ТОРАЙГЫРОВ УНИВЕРСИТЕТА**

ҚАЗАҚСТАН ҒЫЛЫМЫ МЕН ТЕХНИКАСЫ

2001 ЖЫЛДАН БАСТАП ШЫҒАДЫ

TORAIGHYROV UNIVERSITY

НАУКА И ТЕХНИКА КАЗАХСТАНА

ИЗДАЕТСЯ С 2001 ГОДА

ISSN 2788-8770

№ 1 (2023)

ПАВЛОДАР

НАУЧНЫЙ ЖУРНАЛ
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СВИДЕТЕЛЬСТВО
о постановке на переучет периодического печатного издания,
информационного агентства и сетевого издания
№ KZ51VPY00036165

выдано
Министерством информации и общественного развития
Республики Казахстан

Тематическая направленность
Публикация научных исследований по широкому спектру проблем
в области металлургии, машиностроения, транспорта, строительства,
химической и нефтегазовой инженерии, производства продуктов питания

Подписной индекс – 76129

https://doi.org/10.48081/UAET1531

Импакт-фактор РИНЦ – 0,342

SRSTI 73.49.23

https://doi.org//10.48081/HDOM8389

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DEVELOPMENT OF THE CONCEPT OF A HYBRID POWER PLANT BASED ON A CAR

The article reflects information about the current state of development of car designs with a hybrid power plant. The authors are conducting research work to create a prototype of an energy-efficient hybrid power plant based on a passenger car. The result of the work is an increase in the environmental safety of cars and efficiency. The basic schematic diagrams of hybrid power systems of passenger cars have been studied. Hybrid drive options included a version for rear-wheel drive and all-wheel drive layouts. The power plant of a hybrid car with a parallel, sequential and series-parallel construction scheme is considered. Taking into account the advantages and disadvantages of all types of hybrid car drive schemes, the most suitable one has been selected.

A small-sized car «Oka» was chosen as the base for the project. The car is modified to all-wheel drive, the electric motor is installed on the rear axle.

The article contains a brief traction and dynamic calculation of an electric vehicle. According to the calculation results, an electric motor was selected.

The technical solution is to develop an independent rear suspension with a subframe for mounting a gearbox with an electric motor and using hinges of equal angular velocities, which increases the cost of its design, but is the optimal solution for implementing such a scheme.

Keywords: hybrid power plant, drive, electric motor, transmission, generator, car.

Introduction

The transportation sector significantly contributes to the Earths' GHG emissions, which is the primary driver of climate change [1].

The total amount of harmful substances emitted into the atmosphere by automotive equipment is more than three times higher than the emissions of industrial enterprises [2–3].

In recent years, the automotive industry has shown increasing interest in cars with hybrid or electric powerplant. One of the most prominent representatives of hybrid cars of domestic development can be noted the family of concept cars of the brand «E», which are a sequential hybrid car with an electric transmission with combined power from a generator rotated by a gas-gasoline internal combustion engine and a capacitive energy storage [1–3].

Most often, in hybrid cars, the electric motor operates during a period of mixed loads, and at steady loads, the internal combustion engine enters into operation, providing, with the help of a generator, recharging batteries. At the same time, a hybrid car can be forced to work only on an internal combustion engine or an electric motor, and in modes with the required maximum power, use both power units. This determines the convenience of its operation. However, hybrid cars have their drawbacks, the main of which are the complexity and high cost of the design, which does not justify the efficiency at the output from using such a scheme. Nevertheless, almost every automaker has hybrid versions or individual models using a hybrid powerplant in the line of manufactured cars.

At the Faculty of Engineering of the «Toraigyrov University», within the framework of experimental design development, together with students and undergraduates, work is being carried out on the topic «Development of electric drive units for the implementation of the concept of a hybrid power plant based on a car».

Materials and metods

There are several schemes for the layout of power drives of hybrid cars, such as: serial, parallel and series-parallel [4].

With a sequential scheme, the drive to the wheels of the car is carried out only with the help of an electric motor, and the internal combustion engine works to generate electricity used by the first. The main advantages of this scheme are: the operation of the internal combustion engine with minimal fuel consumption and ease of control of the power plant. However, such a scheme has too low efficiency and provides for the mandatory use of two traction electric motors. The schematic diagram of a serial hybrid drive is shown in Figure 1 [4].

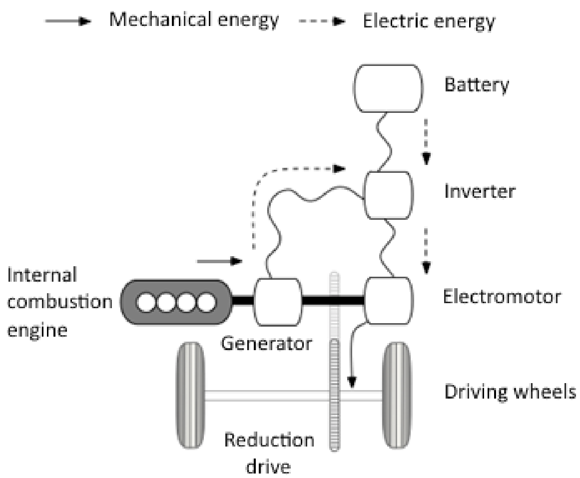

Figure 1 – Schematic diagram of a serial hybrid drive

In the parallel scheme of a hybrid car, the internal combustion engine and the electric motor are connected to the wheels of the car by means of a common transmission. The power supply for the electric motor is provided by a rechargeable battery. The advantages of this scheme are: higher efficiency than in a sequential circuit, as well as the possibility of autonomous operation, both on the internal combustion engine and on the electric motor. The disadvantages are: mandatory use in the transmission drive (sometimes its complication) and the impossibility of continuous operation of the internal combustion engine in the mode of minimum fuel consumption. The schematic diagram of a parallel hybrid drive is shown in Figure 2 [4].

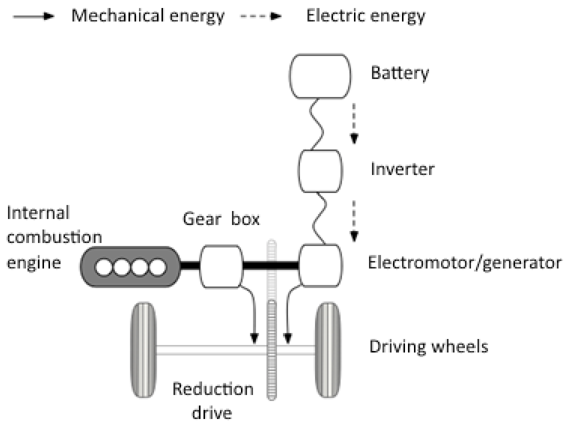

Figure 2 – Schematic diagram of a parallel hybrid drive

In the case of a series-parallel hybrid drive circuit (Figure 3), the internal combustion engine, the generator and the transmission output shaft, which is connected to the drive shafts of the driving wheels and to which the traction motor transmits energy, are connected via a planetary transmission, while the internal combustion engine operates at a constant minimum fuel consumption mode, and the speed of the transmission output shaft is regulated by changing the speed of rotation of the shaft of the traction motor due to the appropriate control, at the same time, it is necessary to synchronously control the power on the generator shaft to ensure constant operation of the internal combustion engine with minimal fuel consumption and minimal toxicity [4].

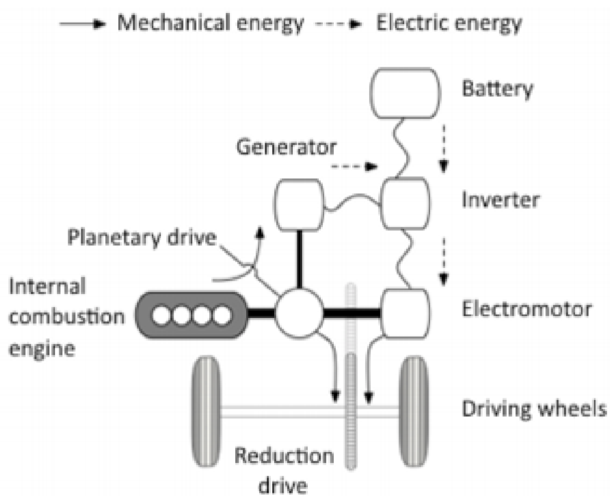

Figure 3 – Schematic diagram of a series-parallel hybrid drive

The advantages of the series-parallel hybrid scheme include high efficiency in the transmission of energy from the internal combustion engine to the drive wheels and the possibility of its operation in a constant mode of maximum efficiency and environmental friendliness. Disadvantages – a complex transmission with the mandatory introduction of a planetary transmission into its design and a complex control system for the entire drive. The schematic diagram of a series-parallel hybrid drive is shown in Figure 3.

As a base for the prototype, an OKA car was taken (Figure 4) with a VAZ-11113 engine – a 0.7–liter gasoline engine with a capacity of 33 hp.

«Oka» is a representative of an «especially small class» (segment «A» according to European standards): it is 3,200 mm long, 1,420 mm wide, and 1,400 mm high.

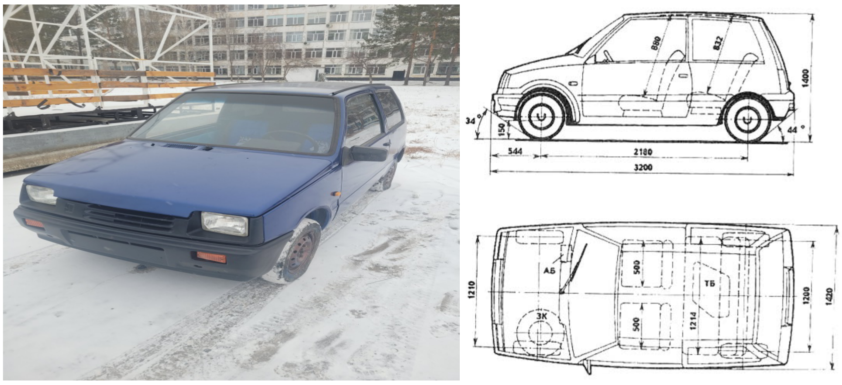

Figure 4 – The appearance of the car body for prototyping

The wheelbase of the car is 2180 mm, and its ground clearance is 150 mm. The machine weighs from 635 to 660 kg, depending on the version, and its gross weight does not exceed one ton.

Taking into account the advantages and disadvantages of all types of hybrid car drive schemes, it is necessary to choose the most suitable one. It is necessary to analyze each scheme for the feasibility of application, based on the requirements of the use of vehicles and compliance with the optimal economic component when introduced into production [5].

You can start the analysis with a serial hybrid drive circuit. The key factor in the application of this scheme is the mandatory use of two high-power electric motors in the drive of the car, as well as batteries of increased energy intensity. To implement such a design, it is necessary to redesign most of the main components of the car. The main disadvantage of using such a scheme on the projected car will be the possibility of its operation on only one type of drive – electric. This causes its unreliability, in case of failure of the drive electric motors. Also, the use of such a scheme requires a significant change in the layout solutions in the car and the development of many nodes from scratch [5–7].

The next circuit is a parallel hybrid drive circuit. This scheme has proven itself well in use on commercial transport. It is possible to leave almost all nodes unchanged and implement the drive in several ways, depending on the purpose of the car.

With the help of the controller, it is necessary to set the algorithm for the operation of this scheme, which will consist in the fact that in transient modes (urban operation at speeds up to 60 km / h), the wheel drive will be implemented using an electric motor, and the internal combustion engine, in turn, will operate at idle, disconnected from the transmission, providing recharging the battery pack. Under steady-state conditions (operation along the highway with maximum efficiency and environmental friendliness), the internal combustion engine will enter into operation. The electric motor will work in generator mode, recharging the battery. It is also necessary to implement the possibility of regenerative braking and the maximum power mode (joint operation of the internal combustion engine and electric motor), with the possibility of forced activation.

This scheme is suitable for rear-wheel drive layout of the car. The advantages of the scheme are the relative ease of implementation and minimal production costs in comparison with other schemes [8].

The second variation of the parallel circuit application may be suitable for all-wheel drive modification of this car. The rear drive axle of a modified OKA car can be used as the basis for the rear wheel drive. To it, through the angular gearbox, connect an electric motor, the body of which will be fixed on this bridge. The algorithm of operation can be implemented in the same way as in the above scheme with a front-wheel drive layout. However, a significant disadvantage of such a scheme is an increase in the unsprung mass of the front suspension, since it will increase by a mass equal to the connected electric motor. The solution is to develop an independent suspension with a subframe for mounting a gearbox with an electric motor and using hinges of equal angular velocities, which increases the cost of its design, but is the optimal solution for implementing such a scheme. Another disadvantage of using a dependent drive axle is the inevitable increase in the clearance of the car, due to the proximity of the crankcase of the front axle to the engine tray. This, in turn, leads to an undesirable increase in the loading height of the car and an increase in the height of the center of gravity, which will have the worst effect on handling.

The use of a series-parallel circuit, which, although it has the highest efficiency of power use, is impractical in this car, because it requires a radical change in all the components of the car and the development of a planetary gear to combine the drives. In addition, it is difficult to implement in the on-board version of the car and will entail the irrational use of the cargo compartment or will require significant processing of the cabin.

Traction and dynamic calculation of an electric vehicle.

Determination of the traction and speed properties of the car is necessary when designing new models, as well as when choosing types of cars in accordance with different operating conditions [9-10]. This problem is solved by the methods of the theory of the automobile - the science of operational properties, which characterize the possibility of effective use of the car in certain conditions and allow us to assess to what extent its design meets these conditions.

When starting the calculation, you should first study the relevant sections of the theory of the car, master the methods of analyzing such characteristics of the car as power and power balances, dynamic characteristics, etc.

Results and Discussion

To select the required engine power, it is necessary to calculate the dynamic parameters

Initial data

Car type - rear-wheel drive passenger car of the especially small class

Wheel formula - 4x2

Number of people - n = 1 (people)

Length = 3200 mm.

Width = 1420 mm.

Height = 1400 mm.

Curb weight =m_0 650 kg.

Tire dimension : 135/80R12

Air resistance coefficient – C_x = 0.3

Rolling resistance coefficient – f_0 = 0.013

Coefficient depending on the slope of the road – a_{max} =0.25

Maximum speed – V_{max} = 30 km/h

The maximum speed of the motor shaft ω_e^{max} 418 s^{-1}(4000 rpm)

Transmission efficiency – η_{tr} = 0,85

Determination of the total mass of the car

$$M_a = M_0 + (M_{man} \cdot n) + M_b \quad (1)$$

$$M_a = 650 + (75 \cdot 1) + 10 = 735\ kg$$

M_0 – curb weight of the vehicle

M_{man} – weight of a person (75 kg.)

M_b – weight of cargo per person

n – number of people in an electric car

Determination of the static radius of the wheel

$$r_{st} = 0{,}5 \cdot d + \lambda \cdot H \quad (2)$$

where d = 12 – is the landing diameter, inches (= 0.304 m)

λ = 0.92 – is the coefficient of vertical deformation of tires, depending on the specifics of the tires used

H/B = 65 – is the height of the tire profile relative to its width, %

B = 65·0.175 = 0.114 – is the height of the tire profile, m

$$r_{st} = 0{,}5 \cdot 0{,}304 + 0{,}8 \cdot 0{,}114 = 0{,}243\ m$$

Determination of the coefficient of streamlining

$$k = \frac{C_x \cdot \rho}{2} \tag{3}$$

$$k = \frac{0{,}3 \cdot 0{,}293}{2} = 0{,}19$$

where C_x – is the air resistance coefficient

ρ = 1.293 – air density under standard conditions

Calculation of rolling resistance coefficient

$$f = f_0 \cdot \left(1 + \frac{V^2}{2000}\right) \tag{5}$$

$$f = 0{,}013 \cdot \left(1 + \frac{40^2}{2000}\right) = 0{,}023$$

First, the power of the electric motor is determined at the highest speed of the electric vehicle , taking into account the efficiency of the transmission according to the power balance formula

$$N_V = \frac{1}{\eta_{tr}}\left(G_a \cdot \psi V \cdot V_{max} + \frac{C_x}{2} \cdot \rho \cdot F \cdot V_{max}^3\right)$$

ψV – is the coefficient of road resistance at the maximum speed of the car.

For light cars, the road resistance coefficient is assumed to be equal to the rolling coefficient at maximum speed.

$$\psi V = f = 0{,}023$$

$G_a = mg$ – is the total weight of the car,

p = 1,293 – is the air density under normal conditions

$$N_V = \frac{1}{0{,}85}\left(735 \cdot 9{,}81 \cdot 0{,}023 \cdot 60 + 0{,}15 \cdot 1{,}293 \cdot 30^3\right) = 12{,}07\ kW$$

Conclusion

The basic schematic diagrams of hybrid power systems of passenger cars have been studied. Hybrid drive options included a version for rear-wheel drive and all-wheel drive layouts. The power plant of a hybrid car with a parallel, sequential and series-parallel construction scheme is considered. Taking into account the advantages and disadvantages of all types of hybrid car drive schemes, the most suitable one has been selected.

According to the calculations obtained, an electric motor can be selected. We have selected an electric motor HPM-10KW with liquid cooling. The motor is controlled by a VEC500 sine controller for a 10 kW BLDC motor. This model is designed to control the operation of a BLDC motor, or a 10 kW brushless electric motor. It is equipped with reliable protection against moisture, overload and overheating. It is installed on almost any type of electric transport: bicycles, motorcycles, cars, boats, golf carts and even tricycles.

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Material received on 06.02.23

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Материал 06.02.23 баспаға түсті.

АВТОМОБИЛЬ НЕГІЗІНДЕ ГИБРИДТІ ЭНЕРГЕТИКАЛЫҚ ҚОНДЫРҒЫ ТҰЖЫРЫМДАМАСЫН ӘЗІРЛЕУ

Мақалада гибридті электр қондырғысы бар автомобиль құрылымдарының қазіргі даму жағдайы туралы ақпарат берілген. Авторлар жеңіл автомобиль негізінде энергия үнемдейтін гибридті электр қондырғысының прототипін жасау бойынша ғылыми-зерттеу жұмыстарын жүргізеді. Жұмыстың нәтижесі автомобильдердің экологиялық қауіпсіздігі мен үнемділігін арттыру болып табылады. Жеңіл автомобильдердің гибридті энергетикалық жүйелерінің негізгі схемалары зерттелді. Гибридті автомобиль опциялары артқы Доңғалақты және төрт доңғалақты орналасуды қамтыды. Параллель, сериялық және сериялық параллель орнату схемасы бар гибридті автомобильдің қуат қондырғысы қарастырылған. Гибридті автомобильдердің жетек схемаларының барлық түрлерінің артықшылықтары мен кемшіліктерін ескере отырып, олардың ішіндегі ең қолайлысы таңдалады.

Жобаның негізі ретінде шағын көлемді «Ока» автокөлігі таңдалды. Автокөлік толық жетекке дейін өзгертілген, электр қозғалтқышы артқы оське орнатылған.

Мақалада электромобильдің тарту және динамикалық есептеулері қысқаша сипатталған. Есептеу нәтижелері бойынша электр қозғалтқышы таңдалды.

Техникалық шешім-беріліс қорабын электр қозғалтқышымен бекітуге арналған қосалқы жақтауы бар тәуелсіз артқы суспензияны әзірлеу және оның құрылымын қымбаттататын, бірақ мұндай схеманы жүзеге асырудың оңтайлы шешімі болып табылатын бұрыштық жылдамдықтары бірдей буындарды қолдану.

Кілтті сөздер: гибридті қуат блогы, жетек, электр қозғалтқышы, беріліс қорабы, генератор, автомобиль.

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Материал поступил в редакцию 06.02.23.

РАЗРАБОТКА КОНЦЕПЦИИ ГИБРИДНОЙ СИЛОВОЙ УСТАНОВКИ НА БАЗЕ АВТОМОБИЛЯ

В статье отражены сведения о современном состоянии развития конструкций автомобилей с гибридной силовой установкой. Авторами ведется научно-исследовательская работа по созданию прототипа энергоэффективной гибридной силовой установки на базе легкового автомобиля. Результатом работы является повышение экологической безопасности автомобилей и экономичности. Изучены основные принципиальные схемы работы гибридных энергетических систем легковых автомобилей. Варианты гибридного привода включили в себя версию для заднеприводной и полноприводной компоновок. Рассмотрена силовая установка гибридного автомобиля с параллельной, последовательной и последовательно-параллельной схемой построения. Принимая в расчет достоинства и недостатки всех типов схем привода гибридных автомобилей подобрана наиболее подходящая из них.

В качестве базы для проекта выбран малогабаритный автомобиль «Ока». Автомобиль модифицирован до полного привода, электродвигатель устанавливается на заднюю ось.

Статья содержит краткий тяговый и динамический расчет электромобиля. По результатам расчета подобран электродвигатель.

Техническим решением является разработка независимой задней подвески с подрамником для крепления редуктора с электромотором и применением шарниров равных угловых скоростей, что удорожает ее конструкцию, однако является оптимальным решением для реализации такой схемы.

Ключевые слова: гибридная силовая установка, привод, электродвигатель, трансмиссия, генератор, автомобиль.

Теруге 06.02.23 ж. жіберілді. Басуға 30.03.23 ж. қол қойылды.
Электрондық баспа
5,07 Mb RAM
Шартты баспа табағы 1,09 Таралымы 300 дана. Бағасы келісім бойынша.
Компьютерде беттеген: Е. Е. Калихан
Корректор: А. Р. Омарова, Д. А. Кожас

Тапсырыс № 3998

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