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TRANSMISSION FOR ELECTRIC TRANSPORT AND FOR ELECTRIC AND HYBRID VEHICLES

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Abstract. The article proposes the design of a simple transmission that allows, in the entire range of motion, to automatically change the torque and gear ratio on the driven shaft. It allows the drive motor in all driving modes from the moment of start to operate at optimal speed with full power output. For electric transport, it is important that the traction motor works efficiently in all modes of motion. The proposed device provides this. The use of such a transmission in hybrid vehicles, and especially in electric vehicles, is the most cost-effective and allows overcoming and simplifying some of the complex elements of technological solutions.

ТРАНСМИССИЯ ДЛЯ ЭЛЕКТРОТРАНСПОРТА И ДЛЯ ЭЛЕКТРИЧЕСКИХ И ГИБРИДНЫХ АВТОМОБИЛЕЙ

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Ключевые слова: планетарный дифференциал, генератор тока, крутящий момент, коэффициент передаточного отношения, синхронный электродвигатель.
Аннотация. В статье предложена конструкция простой коробки передач, позволяющей во всем диапазоне движения автоматически изменять крутящий момент и передаточное число на ведомом валу. Это позволяет приводному двигателю во всех режимах движения с момента запуска работать на оптимальных оборотах с полной отдачей мощности. Для электротранспорта важно, чтобы тяговый двигатель работал эффективно на всех режимах движения. Предлагаемое устройство обеспечивает это. Использование такой трансмиссии в гибридных автомобилях, и особенно в электромобилях, является наиболее экономически выгодным и позволяет преодолеть и упростить некоторые сложные элементы технологических решений.

The transmission for most vehicles can be configured according to the scheme presented here. Such a transmission may be primarily useful for electric or hybrid vehicles, but is quite applicable to conventional cars with an internal combustion engines, well as for rail electric transport. The transmission in automatic mode provides the entire required range of torque conversion and gear ratio. It consists of three main elements: a planetary asymmetric differentia, auxiliary electric motor located on the traction motor shaft and a generator connected to it, whose rotor is located on the drive shaft. The principle of its operation is based on comparing the force necessary for the movement of the vehicle, with current strength arising from the generation of current by the generator, taking into account the asymmetry of the differential. The scheme for implementing such a solution for electric transport is described in [1] and shown in Fig. 1.

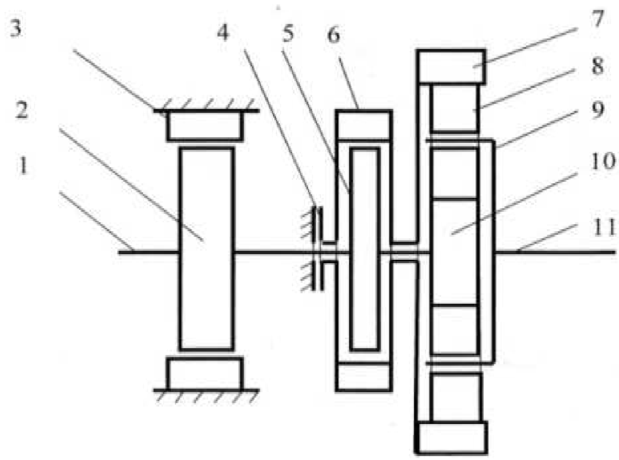

Fig. 1. Transmission scheme: 1 – drive shaft, 2 – electric motor rotor, 3 – motor stator, 4 – coupling, 5 – generator rotor, 6 – generator stator, 7 – the crown of the planetary differential, 8 – satellites, 9 – planetary differential carrier, 10 –central wheel, 11 – driven shaft

Drive shaft 1 is connected to the rotor mounted on it of the electric motor 2, with the generator rotor 5 and with the central gear of the planetary differential 10. One differential output, its carrier 9 with the satellites 8, connected to the driven shaft 11 and transmits rotation to the shaft, and the second output of the differential, its crown 7 rotates freely on the drive shaft and connected to the generator stator 6. The generator stator 6 and its rotor 5 form the double rotation machine. If necessary, a second output of the differential and the stator connected to it can be fixed by the coupling 4 connecting it to with hull. The motor stator 3 is mounted on the housing and connected to it. When drive shaft 1 rotates, carrier 9 rotates in the same direction, but increases the torque and reduces the revolutions of the driven shaft 11 proportional to the gear ratio of the planetary differential. The second output of the differential, its crown 7, tends to rotate in the opposite direction., but if there is an electrical load in the generator circuit, then there is electrical induction force, entraining the stator 6 behind the rotor 5 and partially blocks the differential, increasing the speed of rotation of the driven shaft 11. When an increase in the load on the driven shaft, it slows down, the sliding between rotor and stator increases. Output connected to generator stator slows down rotation, even stops and rotates in the opposite direction, and torque is transmitted to a greater extent through the gears of the differential, gear ratio and torque on the driven shaft increases. Both channels transmit rotation to the driven shaft. If necessary, when the stator is stopped, the generator is used to start the traction synchronous electric motor. The synchronous motor has a number of advantages. These are efficiency, smaller dimensions and weight with the same power, high overload capacity. Its use is complicated by the fact that it only works at constant speed. This explains its rare use in transport, where engine speed cannot be constant. But in the proposed transmission scheme, any engine can operate at constant speed from the moment of start, and the change in gear ratio and torque is made in the transmission mechanism. A synchronous electric motor connected to the network is economical at idle. When a load appears on the motor shaft, it maintains speed, automatically increasing its power. He doesn't need control. But the transmission can work with any motor.

The main advantage of such a transmission is that when the load on the driven shaft increases, it slows down, the rotation is transmitted to a greater extent through the gears, while the torque on the driven shaft increases and, conversely, when lightened the load on the driven shaft, it accelerates, and the gear ratio transmission is automatically reduced. Is only need to control the operation of the generator. With an increase in the current generated by the generator and an increase in the induction force that occurs between the rotor and stator of the generator, the slip between them decreases, the rotation of the differential elements relative to each other decreases, and the movement on the driven shaft is transmitted to a greater extent through the rotation of the differential around the axis, while the total the gear ratio decreases, the speed of rotation of the driven shaft increases. The torque on the driven shaft, in the case of using such a transmission, increase by 2.5 times relative to the torque capability of the electric motor used. This greatly simplifies and reduces the cost of the design, and if we take into account the fact that a synchronous motor is much more economical than any other, and that it operates in the optimal mode during the entire movement, the expediency of using of such a transmission can be considered undeniable. Such an increase in torque is sufficient for dynamic acceleration.

The electric current generated by the generator returns to the network, and also feeds the traction motor, the excitation winding, if the electric motor is synchronous, as well as other consumers. With this method of transmission of rotation on electric trains, there will be no need for a gearbox connecting the traction motor with a wheel pair, as well as an expensive and still imperfect high-voltage element base for control It is important: both, the engine and the generator are rigidly mounted on a common shaft. There is no need for current collectors for power transmission, which means that the resource, efficiency and reliability are increased. Generators of this power have an efficiency of eighty-five percent. Both differential outputs rotate the driven shaft in the same direction, and the energy generated by the generator is also fully utilized, with losses up to five percent.

For an electric vehicle, it must also be taken into account that the efficiency depends heavily on the load of the traction motor, and when using such a transmission, power can be divided into a traction motor and an auxiliary one, ensuring optimal load in various. Typically, the maximum efficiency range is between half load and eighty percent of maximum power. When the motor delivers less power, losses increase. During operation, in order to maintain high efficiency, the traction engine of the vehicle should be loaded mainly 0.6-0.8 of the optimal load. In many cases, during operation, the vehicle engine is loaded at a lower power. This leads to a decrease in efficiency, to a decrease in efficiency.

The torque of such a differential is limited. This is detailed in [2]. Its maximum value can be reached under the condition that the crown and the central wheel are taken in the ratio of 1.618. With such a ratio of the number of teeth of the gears of the crown (z_{cr}) and central wheel (z_{cw}), the gear ratio of the planetary gear to the driven shaft: $i_{carrier}$:

$$i_{carrier} = 1 + z_{cr} / z_{cw} = 2.618\ldots$$

The torque can increase up to this value from the torque value on the drive shaft. But the energy of the drive shaft is divided into the carrier and the crown, and from the central wheel to the crown, the moment acts in the opposite direction with the gear ratio:

$$i_{carrier} = –z_{cr} / z_{cw} = –1.618\ldots$$

The crown, on the other hand, transmits rotation to the carrier from the force that drags the stator behind the generator rotor, which is connected to the drive shaft, acting in the direction of rotation of the drive shaft. Its value can be determined through the gear ratio i_{cr}:

$$i_{cr} = 1 + z_{cw} / z_{cr} = 1 + 1/1.618\ldots = 1 + 0.618\ldots = 1{,}618\ldots$$

This force counteracts the reverse torque and balances it, which allows you to get a torque on the driven shaft that is 2.6 times the torque on the drive shaft. With an increase in the gear ratio of the planetary gear, the maximum torque on the driven shaft decreases, and with a selected ratio corresponding to the number φ, the balance of forces in the planetary differential is observed to ensure the transmission of torque to the driven shaft. If the ratio of the crown gears and the central gear, for example, is set equal to two, then the gear ratio on the carrier will be equal to three. But on the driven shaft, the torque will not increase, but decrease, because the gear ratio from central wheel to the crown will increase to two, and decrease to one and a half from the crown, and this will lead to a decrease of the gear ratio on the driven shaft to two and a quarter. When accelerating a vehicle with such a transmission, the engine operates in the optimal mode, there is no clutch mechanism, and the electric motor will add another third of the traction engine power. This provides enough momentum during acceleration.

Both outputs of the differential rotate the driven shaft in the same direction, and the energy generated by the generator is also fully utilized, losses are minimal. Modern generators of this power have an efficiency of eighty-five percent. But, one way or another, electricity is in any case necessary for the operation of vehicle systems, for excitation power, if the electric motor is synchronous [3], for battery charging, for lighting and heating, therefore, it is incorrect to consider losses when comparing transmission in terms of efficiency. Two percent is lost in the planetary gear. One percent of the traction drive power will be consumed by the inverter. It is necessary to add another percentage for losses in seals and bearings. It turns out in any case less than in modern transmissions. In addition, in such a transmission there is no large increase in losses with the development of the resource, the losses grow insignificantly.

Such a transmission operates automatic, and if necessary, electronically controlled throughout the entire range [3]. No switching, no disconnection of the engine from the driven shaft. The engine always runs at optimum speed. Even at the start, when the vehicle is stationary, the traction motor operates at optimal speed, while the generator stator rotates in the opposite direction, and the maximum torque is realized on the driven shaft. Both the electric motor operating in the generation mode and, in fact, the generator can participate in recuperation during braking. An additional power impulse during start-up and acceleration can be given by a generator used as an engine, the stator of which must be coupled to the housing.

For the electric vehicle there is another amazing and very useful property of such a device. The magnetic field strength created by the permanent magnets of the generator, made of modern magnetic materials, creates an electrical induction in the circuit, which makes it possible not only to ensure the rotation of the generator by the electric motor, but also to obtain additional energy that can be used to charge the batteries during periods of stop when the traction motor is turned off. To do this, you need to give a rotation impulse for starting, connected on a common shaft, the rotor of the electric motor with the rotor of the generator, with the stator fixed by the coupling to the housing. It is known that the energy of a magnet can be used, and is already being used, to increase the efficiency of electrical machines. For example, a synchronous generator, with an efficiency of 98 percent, spends up to ten percent on excitation power. If you replace its rotor with a permanent magnet rotor, then these costs will disappear. This probably does not mean that the efficiency has become more than one, but only that the energy of the magnet is used here. There are highly efficient electrical machines also new electric motors that use the power and energy of a permanent magnet, for example, an electric motor developed in Rostov by a group led by G.M. Kornilov. Such an electric motor allows you to get much more power on the shaft compared to costs. This allows you to get an excess of energy using the energy of a permanent magnet. The proposed vehicle transmission device will in the future allow autonomous charging and heating of the battery in the parking lot and, without urgent need, not to use charging stations.

This transmission can be used on conventional vehicles with an internal combustion engine. Such a vehicle will not need a starter, generator and clutch mechanism. Due to the high responsiveness of electrical systems, such a transmission can be used as an anti-lock system during braking and traction control during acceleration.

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