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TECHNICAL OPTIMIZATION OF ELECTRIC BIKE POWER TAKING INTO ACCOUNT THE CRITERIA OF SPEED AND BATTERY CAPACITY

Abstract. The article presents the results of technical optimization of the power of an electric bicycle, taking into account the criteria of speed and battery capacity to reduce the cost of electric energy and reduce the cost of the trip. An attempt was made to choose the smallest battery and electric drive-in terms of capacity, but at the same time, the speed of movement should be at the level of 40 km per hour. The article describes the materials and methods of research, as well as the scheme of an electric bicycle. The results of technical optimization of parameters in the form of a comparison diagram of the cost of a trip on various modes of transport and a graph of the dependence of the power of an electric motor, taking into account the criteria of speed and the size of financial investments in the electrification of a bicycle. The issues of choosing and charging the battery are considered.

Keywords: bicycle, electric bicycle, electric drive, electric motor, battery, controller, optimization.

Introduction. The number of bicycles increases annually, this type of transport is being improved and developed. It has a successful experience of using bicycles and electric bicycles as urban transport in Denmark and other EU countries. In the European countries, New York, Moscow, St. Petersburg, Washington, Hangzhou, and Tel Aviv, there have been two extensive rental systems Price and Velib for more than 10 years, with a total number of bicycles of more than 17,000 pcs. About 200 million people use rental services, mobile applications have been created for the convenience of customers. Bicycle sharing systems significantly reduce the load on the transport infrastructure of cities, as well as create an excellent ecological environment for their residents and allow them to lead a healthy lifestyle. It can be said that in the coming years, the general use market will grow by an average of 20% per year, approximately in 2020, it will reach a volume of 3.5 to 5.4 billion. euro. The development of the "Internet of Things" IoT platform will allow you to connect every bike to the network. The system provides in real-time all the necessary information for the administrator, technical services, and users [1]. In this regard, the European Commission has begun negotiations on a future Green Agreement, one of the goals of which is to drastically reduce transport pollution by replacing vehicles with an internal combustion engine with electric ones [2].

Due to the continuous improvement of road infrastructure and transport technologies, electric bicycles (electric bicycles) are becoming one of the most popular types of road transport [3]. With the use of electric bicycles instead of vehicles powered by fossil fuels, the movement of electric bicycles can mitigate the negative impact on the environment [4].

Electric bicycles can complement a traditional bicycle park, as well as fully operate the entire system. Electric bicycles can provide a better, more efficient alternative to motorized modes of transport than traditional bicycles without assistance [5].With technological advances in energy storage systems and the development of lightweight electric motors and pedal-assist systems, modern transport bicycles are flexible vehicles with high load capacity and can travel long distances, overcome slopes and operate in various territorial contexts [6]. The introduction of bicycle-sharing systems (BSS) has been associated with broad economic benefits, improved public health and time savings [7]. Battery efficiency is defined as the ratio of ampere-hours extracted from the battery to ampere-hours recovered in the battery ratio for the same final and initial conditions [8]. It is also generally recognized that electric bicycles can provide solutions to various logistical mobility problems in traffic and parking conditions in congested areas [9]. Practice has proven that the charging control system can solve current charging problems well and has a good market perspective [10].

2. Materials and methods of research. Electrically, a bicycle consists of three main parts: an electric motor; a controller for controlling the modes of operation of the electric drive; a battery. The electric bicycle under study uses a typical electric drive control scheme using a microcontroller. The drive is located on the front axle, and all controls are on the steering wheel. The accepted simplicity of the circuit solution is due to the need to achieve a minimum cost of electrical equipment. Important parameters of an electric bicycle (EV) are the power of the electric drive, the capacity of the battery and the operating characteristics of the drive control controller. The control controller is necessary to adjust the current of the electric drive, allowing to adjust the speed of rotation of the rotor of the electric motor. If the battery is discharged, the EV can move with the help of pedal traction, or we can say using human muscle strength. The capacity of the battery will primarily affect the distance that a cyclist can travel during a day or other time. For convenience, it is better to navigate by the daily mileage of the bike. An important element of the electrical circuit is an electric drive, it plays a crucial role in the development of power and achieving certain speeds. Its power directly affects the speed of the bike and its payload. If you increase the speed, then the consumption of energy taken from the battery increases, and the time at which you can ride a bicycle decreases accordingly. The controller has control functions and speeds limit modes to save energy. Figure 1 shows the appearance of an electric bicycle using a 500-watt motor wheel, which participated in the experiment. This is an ordinary bicycle equipped with an electric drive separately.

All measurements were carried out using a digital wattmeter SINOTIMER DDS108 (China), a power and power meter, an analyzer of alternating current and electricity. The device has a European certificate of conformity and certificates: FCC; UL; PSE. The measurement limit is 3680 W, the operating voltage is 220-230 V., the measurement accuracy error is 2%. The device measures voltage, current strength, records measurement time, frequency, cost of electricity and power. The main technical characteristics of the charger used: AC input voltage 110-220 V, maximum charge current 2A DC and voltage 56 V, designed to charge a Li-ion battery with a capacity of 5 to 18 A / h with an operating voltage of 48 V. The device operates in fully automatic mode and does not allow overcharging the battery. The experiment was carried out using a real bicycle, which was upgraded and equipped with an electric drive. All tests were carried out in a real city. The battery was charged during the summer period at night, at a temperature of 25 to 30 0C. Charge monitoring was carried out automatically by the charger. After charging, the EV was operated until the battery was completely discharged. Of the most affordable batteries, Li-ion and lead-acid were considered. When charging the EV, it is necessary to choose the charging current parameters correctly, since exceeding its value will lead to damage to the battery. Figure 2 shows the process of charging a 12 A/h battery.

Figure 1. The appearance of two samples of an electric bicycle with an electric motor of 500 watts

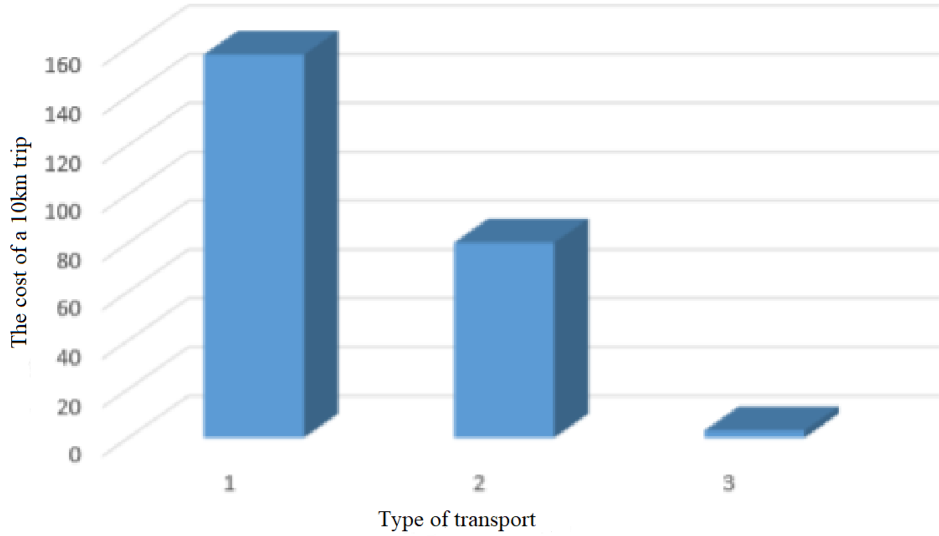
Figure 2. The process of measuring and charging a 12 A/h battery

3 Justification of battery selection. The charge controller monitors the battery capacity. The battery was fully charged and discharged, of course, it has a limited number of such cycles, after which its capacity will begin to decrease, which will lead to a reduction in EV mileage. To achieve optimal EV design, it was necessary to take into account the cost of the traction battery, which will be 30-40%. The selected Li-ion battery with a capacity of 12 A / h will begin to degrade for about 3-4 years of operation, with a planned daily mileage of up to 10 km and a maximum of up to 56 km, in the pedal-assist mode you can drive up to 70 km on a single charge, while the charge should be enough for 4-5 days, and the approximate cost of the trip will be less than 10 times compared to a car with an engine capacity of 2 liters. The speed of the EV is up to 45 km / h, which is quite acceptable for city conditions since the car has a limit of 60 km/h. There is no need to recharge the battery with a dropped capacity of up to 50% since this reduces its resource and will also be a cycle, especially if its capacity has decreased by 10-20%, then charging is generally meaningless. The charge and discharge current should not exceed the current value of its capacity and be up to 80%, for example, for our battery.

To test the choice of a Li-ion battery with a capacity of 12 A / h. the use of a lead-acid battery had to be abandoned. Despite their reliability and low cost, they have considerable weight and are dangerous to humans, since they contain an electrolyte dangerous in terms of chemical burns. Good quality and the durable lead-acid battery should have a significant weight of cans since lead is used in its design, so the weight of one can in a curb state with a capacity of 10 A / h and a voltage of 12 V is 2.8 kg, respectively, at least 4 cans are needed, while the serial connection of such cans is not the best option in terms of operation. If we calculate, we will get a weight of more than 11 kg, respectively, if we bring its capacity to 12 A / h, then its weight will be about 12 kg, which is not quite optimal in terms of weight ratio compared to a Li-ion battery with a capacity of 12 A / h, which will weigh within 3 kg, while its dimensions will be several times smaller. For the study, a Li-ion battery with a capacity of 12 A / h was adopted, the approximate mileage before replacing the battery can be 50,000 km or more, it all depends on the operating conditions, at a temperature of -200C, there will be an increase in the self-discharge current. The maximum indicator of electric energy consumption achieved in 8 hours of charging lies within 0.67 kW / h, while the mains voltage ranges from 214 to 221 V, and the charging current did not exceed 0.8 A. We can say that there are some kinds of losses in the charging unit we use since its efficiency lies within 90%. Accordingly, in practice, there may be a slight deviation towards an increase in electrical energy consumption during charging compared to the theoretical calculation in the range of +10 ... 12%. Even with such an increase, the cost of a trip of 10 km using an electric bicycle will not exceed 3 tenge, which is beyond any competition concerning a car or public transport.

4 Results of technical optimization of electric bike power taking into account the criteria of speed and battery capacity. As a result, the cost of an electric bike ride is the most profitable compared to other modes of transport. It is also possible to note the benefits for human health since part of the way can be done using a pedal drive, thereby saving battery power. An electric bicycle allows you to use an electric motor to a greater extent, and a lesser extent a mechanical drive. Figure 3 shows a comparison diagram of the cost of traveling by various modes of transport, which shows that a bicycle with an electric motor with a power of 500 watts is the most optimal type of urban transport in terms of the cost of traveling short distances.

Optimization of the choice of an electric bicycle power supply system, depending on the speed of movement, the total cost of an electric bicycle, and the power of an electric motor is shown in Figure 4.



1 - Car with internal combustion engine; 2 - Public transport;3 – Electric bicycle

Figure 3. Comparison diagram of the cost of a trip on different modes of transport

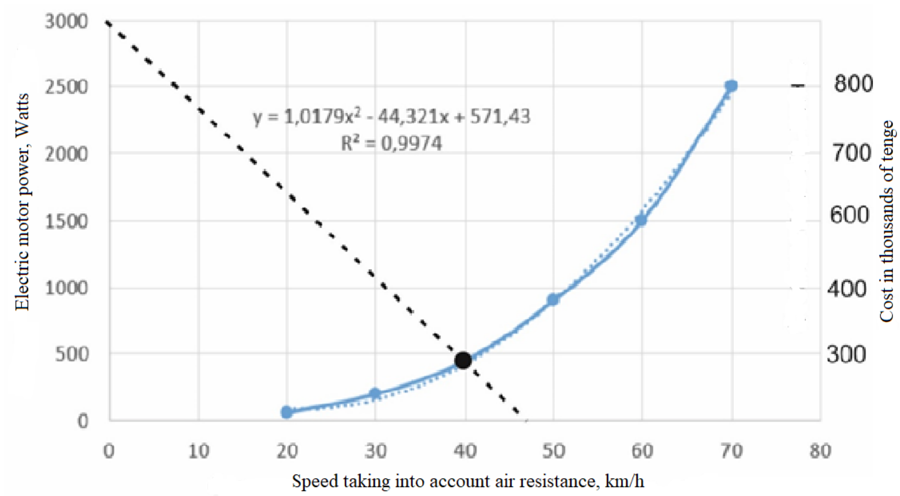


Figure 4. Technical optimization of the parameters of the dependence of the power of the electric motor, taking into account the criteria of speed and the size of financial investments in the electrification of the bicycle

The results of the experiment allow us to find the optimal solution for choosing the power of an electric motor of 500 watts and a battery with a capacity of 12 A / h, which allows travel speeds up to 40 km / h at a minimum cost of EV equal to 300 thousand tenge. The mileage on one charge of the battery is on average about 56 km, the daily mileage was about 10 km at a speed of about 40 km / h, while about 0.6 kW/ h of electricity was spent on one charge. If the average cost of one kWh of electricity in the city of Nur-Sultan is equal to 12 tenges, then one charge will cost 7.2 tenges and this will be enough for 4-5 days of travel at a distance of up to 10 km every day. When using pedals, you can seriously increase mileage. With the accuracy of the mileage assessment, it is necessary to take into account the road surface, driving style, the strength of the oncoming or tailwind, and weather conditions, these factors may make some changes, as well as reduce the declared mileage. To drive 10 km on cars with an internal combustion engine volume of 2 liters will consume at least 1 liter of AI -92 gasoline for 157 tenges (at 2020 prices), since the car moves in a stream and can stand idle in traffic jams, and a trip on an electric bike can cost about 2 tenges.

5. Discussion and conclusions. In conclusion, it can be noted that a great prospect is the use of an electric bicycle as an everyday individual type of urban transport for short-distance trips, for example, to work or to shops, as well as for commercial needs related to the delivery of small goods and various correspondence. The use of electric bicycles for the delivery of small loads in the range of 50-300 kg is the most profitable from an economic and environmental point of view, it is also possible to transport unloading of roads and overpasses of cities. To increase the load capacity, the EV is equipped with a trailer with sides. It is also possible to use specialized electric bicycles (EV) for taxi needs. Studies have shown that the start of a bicycle is more rapid and to gain a speed of 40 km / h, less energy is spent than that of a car. In some cases, an EV can arrive at its destination faster than a car, due to greater freedom of movement on the streets of the city. The conditions of the city of Nur-Sultan allow you to comfortably travel by bike within 6 months, we can theoretically travel 2016 km spending about 300 tenges. Even public transport cannot compare in cost with a ride on an electric bike, which clearly shows the advantage over traditional modes of transport. EV is much cheaper in maintenance, does not require qualified repairs, expensive spare parts, fuel, and oil. A rather big disadvantage of EV is the inability to use it in the cold season, for example, for the city of Nur-Sultan, this is about 6 months in years. To overcome this problem, it is necessary to improve the design of the EV and equip it with a protective shell, which would reduce the discomfort when traveling on the EV in the cold season.

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ЭЛЕКТР ВЕЛОСИПЕДІНІҢ ҚУАТЫН ҚОЗҒАЛЫС ЖЫЛДАМДЫҒЫ МЕН БАТАРЕЯ СЫЙЫМДЫЛЫҒЫН ЕСКЕРЕ ОТЫРЫП ТЕХНИКАЛЫҚ ОҢТАЙЛАНДЫРУ

Аңдатпа. Мақалада электр энергиясының шығынынжәне сапар құнын азайту үшін электр велосипедінің қуатын қозғалыс жылдамдығы мен батарея сыйымдылығын ескере отырып, техникалық оңтайландыру нәтижелері келтірілген. Сыйымдылығы бойынша ең аз аккумулятор мен электр жетегін таңдауға әрекет жасалды, бірақ қозғалыс жылдамдығы сағатына 40 км деңгейінде болуы керек. Мақалада зерттеу материалдары мен әдістері, сондай-ақ электрлік велосипед схемасы сипатталған. Велосипедті электрлендіруге қаржы салымдарының мөлшері мен қозғалыс жылдамдығының өлшемдерін ескере отырып, көліктің әртүрлі түрлеріндегі сапар құнын салыстыру диаграммасы және электр қозғалтқышының қуатына тәуелділік графигі нысанындағы параметрлерді техникалық оңтайландыру нәтижелері. Қайта зарядталатын батареяны таңдау және зарядтау мәселелері қарастырылады.

Тірек сөздер: велосипед, электрлік велосипед, электр жетегі, электр қозғалтқыш, батарея, контроллер, оңтайландыру.

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ТЕХНИЧЕСКАЯ ОПТИМИЗАЦИЯ МОЩНОСТИ ЭЛЕКТРИЧЕСКОГО ВЕЛОСИПЕДА С УЧЕТОМ КРИТЕРИЕВ СКОРОСТИ ДВИЖЕНИЯ И ЕМКОСТИ АККУМУЛЯТОРА

Аннотация. В статье приведены результаты технической оптимизации мощности электрического велосипеда с учетом критериев скорости движения и емкости аккумулятора для сокращения затрат электрической энергии и уменьшения стоимости поездки. Осуществлена попытка выбрать наименьший по ёмкости аккумулятор и электропривод, но при этом скорость передвижения должна быть на уровне 40 км в час. В статье описаны материалы и методы исследования, а также схема электрического велосипеда. Результаты технической оптимизации параметров в форме диаграммы сравнения стоимости поездки на различных видах транспорта и графика зависимости мощности электромотора с учетом критериев скорости движения и размера финансовых вложений в электрификацию велосипеда. Рассмотрены вопросы выбора и зарядки аккумуляторной батареи.

Ключевые слова: велосипед, электрический велосипед, электропривод, электромотор, аккумулятор, контроллер, оптимизация.