Algorithm for improving energy efficient wheel motor for electric vehicles

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Abstract. In accordance with the tendency to reduce the number of mechanical assemblies in electric driven machines and mechanisms, attempts are made to bring the electric motor and the actuator of the mechanism into a single whole. Thereby increasing the quality and productivity of the machines. A motor-wheel is a kind of a driving wheel, an actuator of a traction electric drive system of a pneumatic-wheeled transport vehicle. The work is devoted to the modernization of urban electric transport by equipping it with high-energy efficiency motor wheels, based on the frequency converter system - asynchronous motor. This paper describes the improvement algorithm and technological features

1. Introduction
The peculiarity of motor-wheels is its very expedient arrangement, in which the electric motor is fully or partially located inside the rim directly at the wheel, and the number and dimensions of the mechanical transmission parts are also minimized [1]. One of the most curious models of an electric motor installed in the inner area of a movable wheel was designed by the inventor Vladimir Shkondin in the early 90s [1, 2]. The motor-wheel proposed by him, the design of which is considered one of the most perfect today, consisted of only 7 elements. Back in 1990, V. Shkondin was awarded the Great Gold Medal of the World Innovative Salon of Inventions in Paris for his development.

2. Technical Characteristics and Overview of the Wheel Motor
The motor-wheel is a complex unit in which all elements of the actuator are structurally combined:

- wheel;
- electric motor;
- brake system;
- mechanical transmission;
- the mechanism of articulation of the motor shaft with the external link of the gearbox;
- mechanisms or elements of suspension of the motor-wheel to the vehicle frame.

Thus, each wheel motor is individually driven. The motor-wheel converts electrical energy into mechanical energy, which is realized when the machine is moving [3].

The choice of the power drive of the driving wheels is a serious technical problem that has to be solved when creating a vehicle. In many cases, preference is given to an electric drive, the use of
which relatively simply solves the problem of rational separation and transmission of power from the power plant to the drive wheels for any wheel arrangement [4]. The use of electric motor wheels opens up real technical prospects for the creation of vehicles of new designs, for which the transmission in the form of an individual electric drive of the driving wheels is possible and expedient [5].

The principle of operation of a motor-wheel is quite simple; a rotating magnetic field is created in a stationary stator, which interacts with the magnets of the rotor, causing it to rotate. The stator is made from plates of electrical steel and looks like a star. There are windings on its many beams. When a current passes through them, the rays acquire magnetic qualities and attract the permanent magnets located on the rotor [6, 8].

![Figure 1. General view of the motor-wheel.](image)

3. The main components of the wheel motor

The main components of the wheel motor are:

- a) A wheel consisting of a tire with a rim and a hub or with a rim only;
- b) Electric motor;
- c) Power mechanical transmission, consists of a gearbox/

The main criteria that determine the advisability of using an electric drive with motor-wheels on transport vehicles in comparison with mechanical and hydromechanical drives are:

- a) Weights of units and assemblies;
- b) Operational properties (reliability in operation, labor intensity, frequency and ease of maintenance, etc.);
- c) Efficiency of the drive system;
- d) Service life of the units;
- e) The cost of units, drive units, and operating costs for the service life established by the technical specification.

The main parameters of the electric motor-wheel are determined by the technical and operational characteristics of the projected transport vehicle (in this case, urban electric transport).

One of the ways to reduce the weight and axial dimension of the motor-wheel is the use of a switchable gearbox, which makes it possible to operate the motor-wheel with two different gear ratios.
The appropriate choice of the parameters of the electric motor and the gearbox ensures the implementation of the preset traction and speed indicators of the car and the limitation of overloads of the electric motor during operation of each of the two gears of the gearbox of the two-speed motor-wheel [7].

At the same time, it is possible to create transport vehicles based on existing electric motor-wheels with the use of an appropriate engine-generating installation, which provides power supply to a certain number of electric motors of motor-wheels of this design.

Here it becomes possible to unify a number of vehicles of various classes and to designate such a complex and expensive unit as a motor-wheel.

Gearboxes of motor-wheels of transport vehicles, in accordance with their purpose and the need for placement, in whole or in part inside the wheel rim, must provide:

1) The required gear ratio in accordance with the preset traction and speed indicators of the vehicle;
2) Sufficiently high efficiency, which allows not only to reduce fuel consumption, but also to simplify the cooling of the gearbox;
3) The minimum axial size and weight due to the location of the gearbox and the electric motor in a limited installation volume inside the wheel rim;
4) A rational arrangement with other elements of the motor-wheel;
5) Ease of manufacture and repair, reliability in operation.

In the motor-wheel, shown in Figure 2, the front-end shield 1 of the electric motor is bolted 2 to the housing 3 of the gearbox, which is the support of the bearings 4 of the wheel. This method of installing the electric motor is quite simple, but it requires reinforcing the front-end shield and its attachment to the motor housing, as well as performing it on the mounting surface for the end part of the gearbox housing.

The way the electric motor is coupled with the gearbox can have a certain effect on the operation of the mechanical transmission and on the assembly conditions of the motor-wheel. When installing the electric motor and the gearbox in the wheel motor, some relative displacement of their axes is possible, because of which, with a sufficiently rigid connection of the electric motor shaft with the
input link of the gearbox, the individual parts of the gearbox are skewed. Therefore, when designing a joint, a solution should be envisaged to avoid these undesirable phenomena. The development of the articulation of the traction electric motor with the input element of the motor-wheel in most cases is not reduced only to the creation of a rational design of the articulation mechanism, but requires taking into account possible dynamic processes in the torsion system of the motor-wheel.

Figure 3. Motor-wheel structure.

4. Calculation of the power of the motor-wheel using the example of the TROLZA-5265 trolleybus

Overall characteristics of the trolleybus:
- Maximum technical weight of a trolleybus, kg: 17380;
- Dimensions, m: height-3.41; length-11.7; width-2.5.

Let us determine the value of the engine power from the condition of reaching the automatic characteristic at the maximum permissible acceleration:

\[ P = F \cdot V, \]

Where \( V = \frac{V_{\text{const}}}{3.6} = \frac{60}{3.6} = 16.67, \text{ m/s}, \)

The starting thrust is found by the formula:

\[ F = (1 + \gamma) \frac{G_{ps} \cdot 10^3}{9.8} \cdot a + W \]

Where: \((1 + \gamma) = 1.15 - \) coefficient of inertia;
\( a = 0.63 – \) acceleration for trolleybus;

Basic resistance to movement for a trolleybus:

\[ W = w \cdot G_{ac} = 26.4 \cdot 170.5 = 4501.2\text{H}, \]

Where \( w = 12 + 0.004V^2 = 12 + 0.004 \cdot 60^2 = 26.4 \text{ N / kN}. \)
\( G_{ps} = 170.5\text{kg- gross weight of the trolleybus.} \)

Substituting all the values, we get the thrust force equal to:

\[ F = 1.15 \cdot \frac{170.5 \cdot 10^3}{9.81} \cdot 0.63 + 4501.2 = 17,093 \cdot 10^3N \]

The power will be equal to:

\[ P = 17,093 \cdot 10^3 \cdot 16.67 = 284.94 \text{ kw} \]

The calculated power is valid for the entire rolling stock consisting of one section and four motor-wheel motors. Therefore, the power of one engine will be equal to 71.236 kW. In addition, in order to
ensure reliable engine operation, it is necessary to take into account three times the load experienced by the engine. Taking into account all the assumptions, we get that the power of one engine will be equal to 23.745 kW.

Accordingly, we will choose an electric motor - 200/1 200-200 W, with a rated power of 24 kW.

5. Conclusion

Thus, in the work, it was found that out of the whole variety of urban electric transport used at a given time, one of the most optimal options is an electric transport equipped with a motor-wheel. An algorithm was drawn up, the main task of which is to develop such a concept for urban electric transport in the near future, in which productivity was increased, energy efficiency and quality of vehicles were increased by reducing the number of mechanical units. With this arrangement, the engine and the actuator of the mechanism are combined into a single whole. Also, the number and dimensions of mechanical transmission parts and rubbing elements are minimized, due to their rational arrangement, taking into account all kinds of changing requirements for the rolling stock.

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