Optimization of tramcar capacity for major transport routes

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Abstract. Currently, one of the problems of cities with different population sizes is, along with the deterioration of the environmental situation, a constant decrease in the throughput of highways due to a sharp increase in the motorization of the population. One of the ways to solve this problem is to increase the share of environmentally friendly transport of large capacity, which is the tram that has been used for more than a hundred years. The ways of energy improvement of traction electric drives are considered.

1. Introduction

The conducted statistical studies indicate that the increase in the number of individual vehicles leads to a constant decrease in their occupancy rate, which currently does not exceed 1.2 people per vehicle. At the same time, an increase in the number of residents living in settlements causes an increase in transport mobility, which leads to an increase in the fleet of vehicles and, as a consequence, to an increase in the density of traffic flows. At the same time, an increase in the number of rolling stock on the roads occurs mainly at the expense of individual vehicles, which in turn leads to a decrease in travel speeds and a decrease in passenger traffic. Since the expansion of the carriageway is almost impossible, traffic collapse is becoming inevitable in almost all cities. It usually begins with morning and evening peaks, subsequently reaching the whole day.

The analysis shows that there are several ways to solve the problem of traffic congestion on the roads: the use of traffic interchanges at intersections, one-way traffic on the streets, the allocation of separate lanes for vehicles of various categories, etc. However, all these solutions can temporarily reduce the tension on the roads. A radical way to solve the problem is to use large-capacity vehicles for mass transportation of passengers when they move on separate tracks. Taking into account the capital costs of construction and operating costs, the most suitable for these purposes is a large-capacity tram [1].

The recent trend towards an increase in the comfort of travel for passengers of large-capacity vehicles is manifested, first of all, in the desire to maximally lower the floor level of the passenger compartment of the rolling stock. The specificity of the design of the tram running gears makes it possible to lower the floor level only in the area of the doors, which inevitably leads to the appearance of a step in the cabin for the transition to the floor area above the bogies. Such a decision is forced and creates restrictions on the movement of people with disabilities around the cabin, in particular, wheelchair users.
2. Choice of undercarriage designs

Undercarriage parts are rolling stock elements located between the body and track devices and designed to perform the following main functions:

- providing the necessary kinematic connection of the body with the track device;
- transmission of vertical, longitudinal and lateral forces of interaction between the crew and the track device;
- transformation of the mechanical work of the traction electric drive into the work spent on the movement of the crew

Undercarriage designs must provide:

- necessary traffic safety at set speeds;
- the required smoothness of the crew;
- limiting the side roll of the body when driving in curved sections;
- minimal dynamic impact and track device;
- minimal resistance to movement.

The design of the mechanical rolling stock of electric vehicles must meet a number of general and special requirements.

General requirements include:

a) compliance of the design of the mechanical equipment of the rolling stock with the operating conditions, the approved type, the current GOST, the rules of technical operation and standards;
b) the prospects of the design of the mechanical equipment of the newly built rolling stock, the possibility of its long-term use as a basic model for subsequent modernization;
c) high manufacturability, the ability to manufacture using advanced production methods at minimal cost and the use of non-scarce materials;
d) the low cost of operating the rolling stock, even at the expense of a slight increase in the initial cost of the structure;
e) interchangeability and maximum unification of individual units and parts of mechanical equipment;
f) compliance of the weight and basic dimensions of the rolling stock and its units with the optimal values stipulated by GOST;
g) simplicity and expediency of the design of the rolling stock, ease and convenience of its management, maintenance and repair;
h) high reliability and durability of the main structural elements of mechanical equipment within the specified amortization period; the rationality of the assembly scheme, which provides the possibility of priority removal of units with a shorter service life;
i) good maneuverability and stability of the rolling stock when driving;
j) maximum comfort and safety for passengers and service personnel; high aesthetic requirements for the external design of the rolling stock and the interior decoration of the passenger compartment.

The most radical solution to the problem of lowering the floor level is to change the design of bogies, which are used, for example, by the firms "Bombardier", "Kawasaki", as well as on the tramcar UVZ 71-409 of the Ural Carriage Works [2], shown in Figure 1.

A distinctive feature of these bogies is that they are non-rotating and the traction drive in them is located between the wheels, forming a kind of modules. At the same time, in the bogie of domestic production, in contrast to foreign ones, an individual wheel drive is used. Such a constructive solution allows reducing the production area for the manufacture of undercarriages.
3. The choice of the body

An increase in the capacity of a tram rolling stock can be achieved in a known way - using articulated bodies [2]. One of the variants of such an execution of a tramcar of model 71-633 produced by the Ust-Katavskiy Carriage Works named after S.M. Kirov is shown in Figure 2.

It uses swivel bogies, on which the head and tail body sections and an intermediate shortened insert are supported. The length of the sections is limited by the conditions for fitting into the curves of the minimum radius. In addition, the use of swivel bogies did not allow the cabin floor level to be lowered.
The use of fixed bogies under the body allows increasing the length of the shortened insert, thereby increasing the capacity of the section. Despite the fact that the use of fixed bogies shortens the lengths of the head and tail sections, the total capacity of the tramcar can be increased by increasing the number of inserts. In Figure 3 shows a version of a tram with a capacity of 300 passengers, calculated according to the method [2].

4. Determination of the type and power of the traction motor

Currently, there are several methods for calculating the power of a traction motor. The power value can be determined by empirical dependencies tied either to the weight of the rolling stock or to its capacity [5].

The specific power of the trolleybus or tram engine, referred to the unit weight of the rolling stock, is determined by the formula

\[ P = \frac{7}{G} \sqrt{\frac{a v_{\text{start}}}{1.3 \cdot 20} \cdot \frac{v_{\text{set}}}{60}} \cdot \text{kW} \]

Where \( P \) - is the motor power [kW]; \( G \) - is the weight of the crew [t]; \( a = 1.5 \text{ m/s}^2 \) - numerical value of acceleration at start; \( 1.3 \) - basic acceleration; \( v_{\text{start}} = 20 \text{ km/h} \) - projected speed of reaching the automatic characteristic; \( 20 \) - the numerical value of the value of the speed of reaching the automatic characteristic of the tram at basic acceleration; \( v_{\text{set}} = 75 \text{ km/h} \) - maximum speed of the designed vehicle (structural); \( 60 \) - is the design speed of the tram.

The total power of rolling stock engines can also be determined:

\[ P = (1\ldots1.5) \Omega, \]

Where \( \Omega=300 \) - the numerical value of the capacity of the substation.

The magnitude of the motor power can also be determined from the condition of reaching the automatic characteristic at the maximum permissible acceleration:

\[ P = aG v_{\text{start}} \]

Passenger load weight:

\[ G_{\text{pass}} = qg (A_{\text{sid}} + A_{\text{st}}). \]

Where \( q = 70 \text{ kg} \) is the estimated mass of one passenger; \( g = 9.81 \text{ m/s}^2 \); \( A_{\text{st}} \) and \( A_{\text{sid}} \) - the number of standing and seated passengers, respectively, then:

\[ G_{\text{pass}} = qg (A_{\text{sid}} + A_{\text{st}}) = 70 \cdot 9.81 \cdot (78 + 224) = 2.07 \cdot 10^5 N \]

Tare weight with a weight utilization factor of 0.4:

\[ G_t = \frac{G_{\text{pass}}}{k_g} = \frac{207}{0.4} = 517.5 kN. \]

Total weight of PS:

\[ G = G_t + G_{\text{pass}} = 5.175 \cdot 10^5 + 2.07 \cdot 10^5 = 7.25 \cdot 10^5 N \]

Further, based on the resulting power values, the type of traction motor is selected.

5. Conclusions

The algorithm and the mathematical model for the optimization calculation of the capacity of a tramcar for large transport routes are presented. The accepted version of the design of the car is not final, since for routes ending in the central part of cities, a significant area will be required for rolling stock turning, which is not advisable for reasons of architectural and urban planning improvement. Therefore, it is necessary to work out the option of placing two control posts. This will entail changes in the layout of the cabin, since it will be necessary to install doors on both sides of the body.

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