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COMPARATIVE ANALYSIS OF ELECTROMECHANICAL CHARACTERISTICS OF THE ELECTRIC DRIVE OF URBAN RAIL TRANSPORT

This article describes a schematic diagram of the power electric circuits of tram electric motors, technical characteristics of tram engines, as well as operating modes of traction motors, depending on their design, a comparison between the different types of tramcars.

Keywords: tramcar, trolley, current, voltage, current overload, short circuit, engine.

INTRODUCTION

Currently, five different types of tramcars are operated on the routes of Pavlodar: KTM 71-605, KTM 71-608K, KTM 71-608KM, KTM 71-623 and AKCM-802. By the nature of the operation of the rolling stock of urban electric vehicles, the launch of traction engines occurs under load. In addition, the traction motor must have a wide range of speed control. A relatively small speed of rotation of the engine armature is necessary at high loads (pulling away and accelerating), and as the load on the shaft decreases, the rotation speed must reach the rated speed and then exceed it by 2–2.5 times. With increasing resistance to movement, for example, when the rolling stock moves on a rise, the traction force increases and, therefore, the current consumption and the speed of movement should automatically decrease.

Most of all these requirements are satisfied by engines with series and compound wound, in which the magnetic flux increases with increasing current in the armature, due to which the necessary starting torques are realized at relatively low currents and speeds, and when the load decreases, the magnetic flux decreases, and the motor armature speed increases [1].

Research object: urban electric transport.

Subject of the study: comparison between the different types of tramcars.

Purpose: identify the most advanced types of trams.

Objective: analyze the technical characteristics of trams.

Research methods and results: analysis, description, observation.

A comparison between the different types of tramcars is given in the table 1. On tram cars, the number of tractive motors depends on the number of driving axles. Modern four-axle tram cars most often have four tractive motors, which are connected in two groups. In each group, two engines are connected in series. When starting and driving at low speeds, motor groups can be switched on in series, and then in parallel to increase the speed of movement. The engines of four-axle tram cars are designed for half the voltage of the contact network – 275 V, but their isolation is carried out on the total voltage of 600 V [2].

During operation, the engine heats up, and the greater its load, the greater the loss of power and heating of the electric machine. The permissible payload of an electric machine is limited mainly by its heating.

Severe operating conditions of traction engines determine the features of their design.

The need to fit an engine of relatively high power (up to 150 kW) in a limited space under the body of a rolling stock requires a significant reduction in the size of the engine and thereby increase its electromagnetic loads.

Due to the fact that during the operation of traction engines there are frequent mechanical, thermal and electrical overloads, sharp changes in the ambient temperature, shaking and tremors, dust and moisture, during the development of their design provide increased electrical and mechanical strength of parts and assemblies, heat-resistant and moisture-proof insulation of live parts and windings, stable switching of motors [3].

Table 1 – Technical characteristics of tramcars

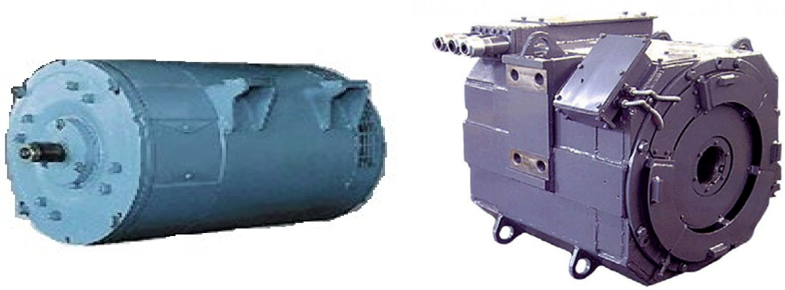
Tramcar model	Year of manufacture	Factory manufacturer	Quantity in Pavlodar	Weight, t	Maximum speed (km / h)	Engine type	Power of electric motors, kW
1	2	3	4	5	6	7	8
 KTM 71-605	1971-1986	Ust-Katav Car-Building Plant named after S. M. Kirov	78	18,65	75	4 × ДК-259	4x45 180

 КТМ 71-608К КТМ 71-608КМ	1992-1996	Ust-Katav Car-Building Plant named after S. M. Kirov	13	19,99	75	4хКР-252 (в модификации КМ ДК-259)	4x50 200
1	2	3	4	5	6	7	8
 КТМ 71-619 (КТМ-19)	1999-2012	Ust-Katav Car-Building Plant named after S. M. Kirov	1	19,5	75	4хТАД-21	4x50 200
 КТМ 71-623	2012-2015	Ust-Katav Car-Building Plant named after S. M. Kirov	7	22	75	4хТАД-21	4x50 200
 АКСМ-802 (БКМ-802)	2017, 2018	Belkommunmash	12	19,3	65	4хТАД-21	4x50 200
 Татра Т2	1955-1962	Českomoravská Kolben-Daněk	0	18,1	60	4×ТМ 22	4×40 160
 Tatra T3	1962-1999	ČKD Tatra	0	17	65	4×ТЕ 022	4x45 180
1	2	3	4	5	6	7	8
 Татра Т4	1967-1987	ČKD — Českomoravská Kolben-Daněk)	0	16	65	4×ТЕ 022	4x40 160

 Tatra RT6N1	1996-1998	ČKD Tatra		32,85	60	TE 028A01, TE 028A02	4x104 416
 Tatra T6B5	1983-2007	ČKD Praha	0	18,9	75	TE 023	4x45 180

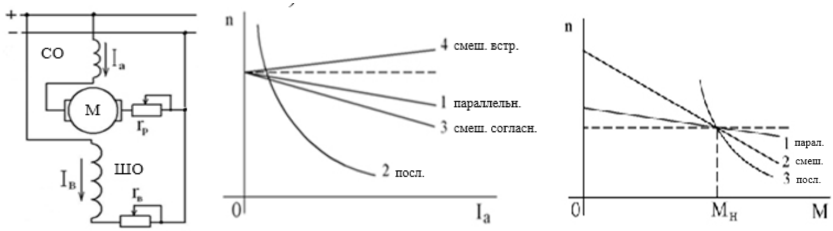
The KTM 71-605 wagon, which is most widely used in Pavlodar, has four M1-M4 tractive motors (Figure 1, a) of the DK-259G-3 type (table 1) with mixed excitation and an hourly power of 45 kW with low-speed characteristics. The motors are connected in two parallel groups of two series-connected motors in each group. A schematic diagram of the power electric circuits of the traction electric motors of the KTM-5M3 tram is shown in the figure 1.

Traction motors of individual tram trolleys of the KTM series (figure 2, b) are connected in series and controlled by a single thyristor pulse Converter. Protection is provided by the regulatory capabilities of the pulse thyristor Converter.



a) b)

Figure 1 – Traction motors:
a) direct current DK-259G -3; b) AC current ТАД-21



a) b) c)

Figure 2 − DC electric drive: ДК-259 Г-3 engine and its characteristics: a − Scheme of the mixed excitation electric motor ДК-259 Г-3; b) speed characteristics of tram engines n=f (I_a) at $U=U_н$ and $I_в$=const (here $I_в$ – is the current in the parallel winding); c) mechanical characteristics of tram engines n=f (M) at $U=U_н$ and $I_в$=const

When the excitation windings are switched on, their magnetomotive forces are added together and the resulting flow of F is approximately equal to the sum of the flows created by both windings. In case of counter-activation, the resulting flow is equal to the difference between the parallel and serial windings. In accordance with this, the properties and characteristics of the mixed excitation motor depend on the method of switching on the windings and on the ratio of their magnetomotive forces.

As the load increases, the resulting magnetic flux increases when the windings are switched on, but to a lesser extent than that of a sequential excitation engine, so the speed characteristic in this case is softer than that of a parallel excitation engine, but more rigid than that of a serial excitation engine.

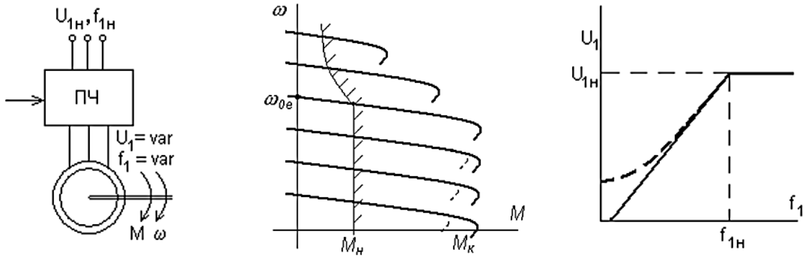
The ratio between the magnetomotive forces of windings can vary widely. Motors with a weak sequential winding have a weakly falling speed characteristic (curve 3, figure 2, b).

The greater the share of the sequential winding in the create [4]on of the magnetomotive forces, the closer the speed characteristic approaches the characteristic of the sequential excitation motor. In figure 2, b, line 3 the line represents one of the intermediate characteristics of a mixed-excitation motor and for comparison, the characteristic of a sequential -excitation motor is given (curve 2) [5, 6].

When the serial winding is switched on in reverse (figure 2, b), the resulting magnetic flux decreases with increasing load, which leads to an increase in the motor speed (curve 4). With this speed characteristic, the motor operation may be unstable, since the sequential winding flow can significantly reduce the resulting magnetic flux. Therefore, motors with counter-windings are not used.

The speed characteristic of a mixed-excitation DC motor (figure 2, b) is located between the mechanical characteristics of parallel (curve 1) and sequential (curve 3) excitation motors. By selecting the magnetomotive force of both windings accordingly, you can get an electric motor with a characteristic close to that of a parallel or sequential excitation motor.

Operated in the number of 23 units in Pavlodar, the АКСМ-802 tram is equipped with two motor trolleys with 4 TAD-21 asynchronous motors each with a capacity of 50 kW (table 1). The electronic control system on IGBT power transistor modules allows you to adjust the speed and power within a wide range. Thus, when the speed is adjusted from 0 to the nominal speed, the Mn moment practically does not change (figure 3, b). When the nominal speed is exceeded, the moment falls, but the characteristic is quite satisfactory.



b) c)

Figure 3 − Asynchronous electric drive with Converter:
a) Diagram of a frequency-controlled electric drive,
b) mechanical characteristics, c) voltage dependence on frequency

The use of power transistor IGBT modules makes it possible to reduce high-frequency losses when switching the load current in comparison with thyristor PWMs.

Conclusions

Due to the steeply falling nature of the speed characteristics of engines with sequential excitation of trams $n = f(I_a)$, the use of DC motors with sequential excitation in traction transport is limited, since a slight increase in the load leads to a sharp decrease in the speed and power of DC motors.

The use of sequential excitation engines is limited in traction electric vehicles, because when using them for regenerative braking, an additional exciter machine is required.

The use of mixed excitation motors on KTM-5M3 trams is due to the high speed control limit due to the possibility of changing the current in the parallel excitation winding. Increasing the field by increasing the current reduces the power consumption during start-up and at the same time increases the braking effect. The change in movement at high speeds of the car occurs when there is a slight current in the parallel excitation winding or when it is switched off, i.e. only with sequential excitation.

The use of sequential excitation engines makes it possible to obtain energy savings during regenerative braking in cities with a mountainous profile.

The use of asynchronous traction motors on IGBT transistors can significantly reduce the cost of the electric drive due to the use of AD, but increases the cost due to the frequency Converter, provides the necessary traction and speed characteristics.

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Л. Б. Тюлюгенова, Б. Қ. Шапкенов

Қалалық теміржол көлігінің электр жетегінің электромеханикалық сипаттамаларын салыстырмалы талдау

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Л. Б. Тюлюгенова, Б. К. Шапкенов

Сравнительный анализ электромеханических характеристик электропривода городского рельсового транспорта

Университет Торайгырова,
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Бұл мақалада трамвай Электр қозғалтқыштарының Электр тізбектерінің схемалық диаграммасы, трамвай қозғалтқыштарының техникалық сипаттамалары, сондай-ақ олардың дизайнына байланысты тартқыш Электр қозғалтқыштарының жұмыс режимдері сипатталған, трамвай вагондарының әртүрлі түрлері арасында салыстыру жүргізілді.

Кілтті сөздер: трамвай, троллей, ток, кернеу, шамадан тыс ток, қысқа тұйықталу, қозғалтқыш.

В данной статье описана принципиальная схема силовых электрических цепей трамвайных электродвигателей, технические характеристики трамвайных двигателей, а также режимы работы тяговых электродвигателей в зависимости от их конструкции, проведено сравнение между различными типами трамвайных вагонов.

Ключевые слова: трамвай, троллей, ток, напряжение, перегрузка по току, короткое замыкание, двигатель.

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