COMPARISON OF TWO OPTIONS FOR CONDUCTING THE WINDINGS OF THE TRACTION DC MOTOR OF SEQUENTIAL EXCITATION

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Introduction. The ever-increasing intensity of traffic on urban highways is accompanied by a high deceleration during braking and acceleration when starting moving vehicles. Under these conditions, the requirement for the technical condition of rolling stock increases. In the field of operation, the solution of problems should go by improving the system of maintenance and repair. Low-noise railless electric transport does not pollute the atmosphere, does not lose speed on steep climbs, works stably in winter, realizes more acceleration at start-up, has smooth electric braking. The specific energy consumption by trolleybus per one transported passenger is the lowest compared to other types of land urban transport. From the point of view of electrical safety, the trolleybus is a unique object of technology, because, despite the high voltage (600 V), the body of the trolleybus is not grounded and insulated from the ground with rubber tires. In the conditions of constant rocking of the body of the car by passengers at landing and disembarkation, hit of high potential on the body of the trolleybus represents the increased danger. Therefore, ensuring high-quality repairs, which eliminates the possibility of electric shock to passengers and staff, is an extremely important issue [1].

Isolation of traction motors works in extremely difficult conditions. The engines are located under the floor of the trolleybus at a distance of about 200 mm from the roadway. Pollution, water with chemically active substances, salt, sand in the autumn-winter period and dust in the summer are captured by the engine fans and settle together with the products of the collector-brush unit on the windings, insulators, wires. Intensive internal humidification of insulation continues in non-working engines. During the cooling period of the engine, the pressure in the pores and capillaries of the insulation is below atmospheric. Moisture penetrates into the smallest pores and capillaries, which activates and accelerates the aging and destruction of insulation. The ventilation ducts become dirty, as a result of which the thermal mode of operation of the windings is disturbed. These negative moments act in conjunction with continuous fluctuations of currents and voltages. The most severe consequences are caused by a breakdown of insulation between two sections of the armature, lying in one groove in two layers. In this case, half of the entire armature winding is short-circuited, so there is a significant current in all sections of the short-circuited winding. As a result, there is a circular fire on the manifold, as well as a significant braking torque, which sharply reduces the torque on the motor shaft [2].

The TH-81 DC drive motor is designed to drive the ДАК-217E trolleybus and is designed for operation at an altitude of not more than 1200 m, air temperature from -40ºC up to +40ºC and relative humidity not more than 95% at 20ºC. Nominal operating mode −S1. Insulation heat resistance class − F. Degree of protection IP20 with self-ventilation when supplying air from the collector side. The estimated nominal operating mode is 60 minutes.

The aim of the work is to calculate and compare two variants of DC traction motor windings with sequential excitation TH-81, namely with the laying of the armature winding wire on the edge in the upper and lower part of the groove (option I) and with the laying of the flat armature winding wire (option II).

Materials of research. DC motor TH-81 sequential excitation with self-ventilation. Air purge is carried out through two holes in the housing with protective grilles. The air inside the machine moves from the collector side through the openings between the shaft and the collector and over the collector along the armature. The engine is attached to the trolleybus frame by means of three brackets, two of which are located on the shield on the gimbal side and one on the opposite side. The cross section of the output cables is 50 mm ^{2}. Shaft material steel 40SG10. All motor windings are impregnated twice in vacuum in organosilicon varnish brand KO-916K. The axial distance of the rotor after assembly is 0,4 mm. Radial beating of a collector of 0,01 mm.

The calculation of the armature winding is carried out according to the method described in [3]. According to the recommendations, the linear load

$$A = 280\ A,$$

the number of parallel branches of a simple loop winding of the armature

$$2a = 2p = 4,$$

current in a parallel branch

$$i_a = \frac{I_a}{2a} = \frac{275}{4} = 68{,}75A .$$

Previous number of armature winding conductors

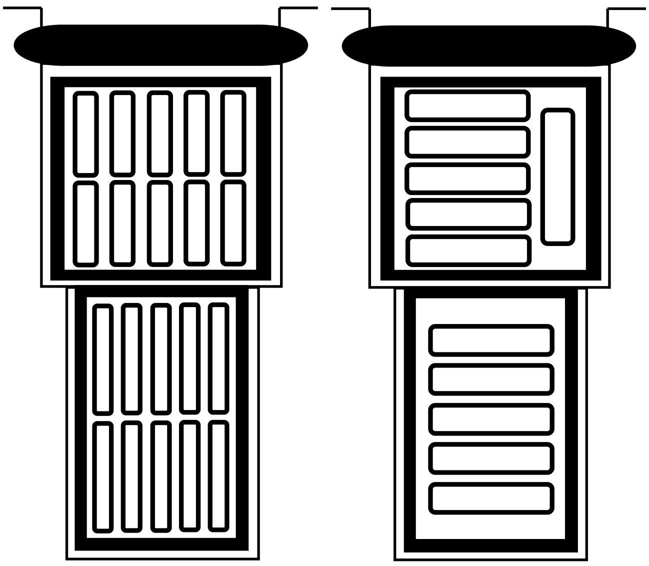
$$N = \frac{\pi D_a A}{i_a} = \frac{\pi \cdot 36 \cdot 280}{68{,}75} = 460{,}6 \approx 460 .$$

Choose the number of conductors in the groove

$$Z/2p \geq 13{,}5,\ u = 5,\ w_c = 1;$$

$$S_n = 2uw_c = 10.$$

Laying of conductors in a groove can be executed in two ways: according to the scheme of the serial engine (Fig. 1, a) or according to the offered more technological scheme which does not demand soldering of front parts with groove dampers (Fig. 1, b).



a) *b)*

Figure 1 – Placement of conductors in the groove: a) on the edge (option I), b) flat (option II).

The amount of current in the groove does not exceed the maximum allowable value of 2000 A

$$s_n \times i_a = 10 \times 68,75 = 687,5\ A.$$

The number of grooves was specified

$$Z = \frac{N}{s_n} = \frac{460}{10} = 46$$

In the Table 1 summarizes the main calculated values that allow to evaluate and compare the performance of the two variants of the traction motor windings TH-81– with the laying of the armature winding wire on the edge in the upper and lower part of the groove and with its laying flat.

Comparison of the results of the calculations given in table. 1, shows the undeniable advantages of using the second option of laying the armature winding according to thermal, energy and economic criteria.

Conclusions. Even a cursory comparison of options I and II shows that:

- due to the reduction of current displacement losses in the grooves, option II makes better use of the machine's copper: at lower mass and higher current density, the total losses in the armature winding are less than in the existing design (option I);

Table 1 – Comparison of winding options

№	Estimated value		Option I	Option II
1	The dimensions of the winding wire of the armature winding, mm×mm	The top of the groove	$2\times\frac{1{,}4\times 5}{1{,}91\times 5{,}51}$	$1\times\frac{1{,}9\times 7{,}1}{2{,}34\times 7{,}37}$
		The bottom of the groove	$2\times\frac{1{,}12\times 6{,}3}{1{,}66\times 6{,}84}$	$1\times\frac{1{,}9\times 7{,}1}{2{,}34\times 7{,}37}$
2	Cross section of armature winding conductors, mm^2		13,6	13,13
3	The current density in the armature winding, A/mm^2		5,05	5,24
4	Resistance of the armature winding at operating temperature, Ohm		0,0325	0,0337
5	The mass of the copper armature winding, kg		38,06	37,9
6	The coefficient of increase of resistance for the groove part of the armature winding	The top of the groove	1,29	1,015
		The bottom of the groove	1,524	1,019
7	Losses in the armature winding, Wt	Groove part Frontal part	1548 1358	1160 1408
		Total	2906	2568
8	Efficiency, %		91,1	91,32
9	Exceeding the temperature of the armature core, К		42,7	38,4
10	Temperature difference in the thickness of the groove insulation, К		10,47	9,69
11	Exceeding the armature winding temperature, К		31,5	32,6
12	The average excess temperature of the armature winding, К		41,20	39,53
13	Maximum design temperatures ºC at ambient temperature 35 ºC groove part of the armature winding front part of the armature winding core of the anchor		 108,27 86,5 97,7	 103,09 87,6 93,4

- excess and temperature differences, and, as a consequence, heating, in the most critical parts of the machine − core and groove part of the armature winding − less in option II;
- option II requires one winding wire type denomination to perform the armature winding, in contrast to Option I, where two type denominations are required; reducing the range of materials used causes a positive economic effect, reducing the cost of manufacturing and repairing the product.

References

1. Надійність електричних машин [Електронний ресурс].- Режим доступу до ресурсу: https://do.ipo.kpi.ua/course/view.php?id=2208

2. Методика розрахунку двигуна постійного струму [Електронний ресурс].- https://lemzspb.ru/raschet-dvigatelya-postoyannogo-toka-smeshannogo-vozbuzhdeniya/

3. Тягові двигуни постійного струму [Електронний ресурс].- Режим доступу до ресурсу: https://kodtnved.ru/podbor/dvigatel-postoyannogo-toka.html