VENTILATION CALCULATION OF THE DC MOTOR FOR THE ELECTRIC DRIVE OF THE SUSPENDED-AXLE STRUCTURE

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Introduction. The Ukrainian railway network is one of the most developed among European countries and occupies a leading position in terms of traffic and plays an important transit role on the Eurasian continent. Railway transport is the basic branch of the national economy and the basis of its transport system that provides more than two thirds of the total freight and passenger turnover. In the future, taking into account the requirements of the European Union on the need to reduce the harmful effects of road transport on the environment, the share of rail transport will increase. Today, the reserves of technical capacity of railway transport, its carrying capacity are almost exhausted, which jeopardizes the possibility of uninterrupted satisfaction of the growing needs of society in transport services. Traction motor (TM) is an electric motor designed to drive vehicles [1] such us electric locomotives, electric trains, diesel locomotives, trams, trolleybuses, electric cars, electric vehicles, electric trucks, tanks and tracked vehicles with electric transmission, etc. The main difference between TM and conventional high-power electric motors is the conditions of installation of motors and limited space for their placement. This led to the specificity of their designs (limited diameters and lengths, multifaceted frames, special devices for fastening, etc.).

Traction engines of urban and railway transport as well as engines of motor wheels of cars are operated in difficult weather conditions, in humid and dusty air [2]. In contrast to general-purpose electric motors TMs operate in a variety of modes (short-term, re-short-term with frequent starts), accompanied by a wide change in rotor speed and current load (starting from the place can be 2 times higher than nominal). During the operation of traction motors there are frequent mechanical, thermal and electrical overloads, shaking and shocks. Therefore at development of their design provide the increased electric and mechanical durability of details and knots, heat-resistant and moisture-resistant isolation of current-carrying parts and windings, steady switching of motors. In addition, the TM of mining electric locomotives must meet the requirements for explosion-proof electrical equipment.

The aim of the work. To analyze the advantages of using DC motors of suspended-axial design for freight electric locomotives, in particular by performing the ventilation calculation of the engine for electric train ER9T-747 which was created at Darnytsya car repair plant.

Materials of research. Research is made with use of drawings of the engine [3] on the basis of which the areas of section of channels of movement of cooling air are defined.

Total air duct resistance

$$z = z_{input} + z_1 \cdot z_2 / (\sqrt{z_1} + \sqrt{z_2})^2 + z_{output} = 34 + 582 \cdot 2650 / (\sqrt{532} + \sqrt{2650})^2 + 50{,}5 = 354\ N \cdot s/m^5.$$

Necessary air consumption

$$Q = \sum P / 1100 \cdot \theta_d = 46071{,}3 / 1100 \cdot 24{,}5 = 1{,}71\ m^3/s.$$

The ratio between the amount of air passing inside the armature Q_2 and between the coils Q_1

$$Q_2 / Q_1 = \sqrt{(z_1/z_2)} = \sqrt{(78087667)} = 0{,}47.$$

The ratio of the amount of air passing inside the armature Q_2 to the total air flow Q

$$Q_2 / Q = 0{,}47/(0{,}47 + 1) = 0{,}32,$$

$$Q_2 = 0{,}32 \cdot Q; \quad Q_1 = (1/(1+0{,}47)) \cdot Q = 0{,}68 \cdot Q.$$

Suppose that with a long flow of hourly (nominal) current 532 A overheating of the armature winding will be 140 °C. In this case, the losses in the armature winding will be equal

$$P'_{Cu} = I_н^2 \cdot R_{a20} \cdot [1+0.004 \cdot (165-20)] = 551^2 \cdot 0{,}0318 \cdot 1{,}58 = 15254W.$$

When calculating the additional losses in steel, half of them, estimated by the kFe coefficient, refers to steel, and half to copper. Steel losses

$$P_{Fe} = P'_{Fe} \cdot (1+1/2 \cdot 0{,}3) = 5671 \cdot 1{,}15 = 6521{,}65\ W.$$

Estimated losses in copper

$$P_{Cu} = P'_{Cu} + 0.15 \cdot P'_{Fe} = 15254 + 0{,}15 \cdot 5671 = 16104{,}65\ W.$$

The thermal resistances of the armature replacement circuit are determined taking into account the air velocity (Table 1) relative to the heat-releasing surfaces at an air flow rate $Q = 1{,}71\ m^3/s$ and its heating coefficient $a = 0{,}3$.

Table 1− Calculating Air Velocity Over Engine Surfaces

Surface	***Formula for determining of air velocity***	***Air velocity, m/s***
The surface of the coils	$V_m = 0{,}68 \cdot Q / 0{,}04 = 0{,}68 \cdot 1{,}71/0{,}04$	29,07
The outer surface of the anchor	$V_{ob} = \sqrt{(V_a^2 + V_m^2)} = \sqrt{(32.3^2 + 34^2)}$	47
Manifold bushings	$V_{к\,в} = 0{,}32 \cdot Q / 0{,}022 = 0{,}32 \cdot 1{,}71/0{,}022$	24,87
Winding holder channels	$V_{о\,к} = 0{,}32 \cdot Q / 0{,}08 = 0{,}32 \cdot 1{,}71/0{,}08$	6,84
Ventilation channels of the anchor	$V_{ак} = 0{,}32 \cdot Q / 0{,}031 = 0{,}32 \cdot 1{,}71/0{,}031$	17,6

Thermal resistance of groove insulation at thermal conductivity

$$R_\beta = \beta / S_\beta \cdot \lambda = 0{,}155 \cdot 10^{-2} / 1{,}63 \cdot 0{,}26 = 3{,}6 \cdot 10^{-3}\ \text{degrees/W},$$

$$S_\beta = z \cdot (2 \cdot h_z + b_п) \cdot l_a = 96 \cdot (2 \cdot 3{,}56 + 1{,}0) \cdot 21{,}0 = 16370\ см^2 = 1{,}63\ m^2;$$

$$\beta = 1/2 \cdot (b_п - b_N) = ½ \cdot (1{,}0 - 0{,}69) = 0{,}155\ см = 0{,}155 \cdot 10^{-2}\ m.$$

Total thermal resistance of resistors connected in parallel R_3 and R_4

$$R_{II} = R_3 \cdot R_4 / (R_3 + R_4) = 13{,}6 \cdot 10^{-3} \cdot 8{,}0 \cdot 10^{-3} / (13{,}6 + 8.0) \cdot 10^{-3} = 5{,}0 \cdot 10^{-3}\ \text{degrees/W}.$$

The calculation of the overheating of the armature winding is performed according to the thermal schemes (Fig. 1) by the method of overlay. The overheating of the armature winding is equal to the product of the heat flux passing through the resistance R I on this resistance

$$Q = \sum P_{R\,I} \cdot R_{I.}$$

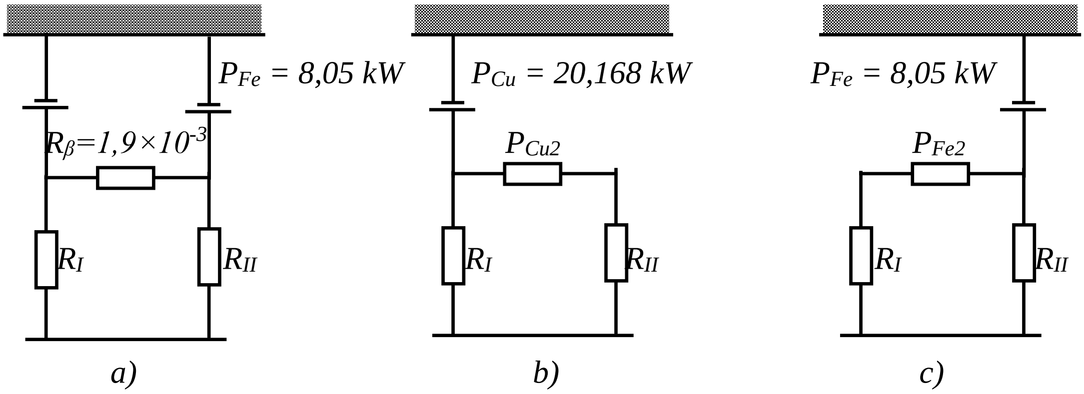

Figure 1 – Thermal diagrams for calculating the overheating of the armature winding above the ambient temperature

The total heat flux passing through the resistance

$$\sum P_{R\,I} = P_{Cu1} + P_{Fe2} = 3{,}69 + 1{,}05 = 4{,}74 \text{ kW}.$$

Overheating with steady thermal equilibrium and losses corresponding to the hourly mode

$$\theta_{\infty} = (P_{Cu1} + P_{Fe2}) \cdot R_{I} = 4{,}74 \cdot 10^{3} \cdot 30{,}77 \cdot 10^{-3} = 146\ °C.$$

Conclusions. Comparing the obtained specific indicators with those of the best examples of rectified current traction motors, it can be concluded that the mass of the designed engine is at the level of average values. Weight reduction can be achieved by using magnetic materials with higher magnetic permeability, as well as by increasing the homogeneity and improving the insulation design.

The resulting overheating of the armature winding in hourly and long-term modes indicate the possibility of some increase in the current density in the armature winding in proportion to the product of the current density adopted in the calculation per square root of the ratio of the permissible overheating to the calculated one. With insulation class H and an ambient temperature of 25°C, the permissible overheating of the armature winding is 160°C.

It is also possible to reduce the flow rate of air cooling the armature at the initial current density.

Reactive EMF less than permissible, therefore, normal commutation of the motor is ensured.

In general, we can conclude that a sufficiently efficient traction motor has been designed with some optimization possibilities in terms of material consumption. An increase in overheating of the armature winding is possible due to a decrease in the amount of cooling air.

References

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