The study of the temperature distribution in the driving device material during high-speed acceleration

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Abstract. Driving device (DD) provides functional interaction of the product with the slot profile of the guide pipe during high-speed acceleration. During the sliding period, the DD material provides contact with the slideway pipe and is heated to high temperatures, which change the mechanical properties of the DD material. In this paper, a study of the temperature distribution in the copper and steel leading devices, numerical simulation of the temperature distribution deep into the device materials were held. The distributions are presented in the graphical form.

1. Introduction

During operation, the DD material is subjected to intense influences, one of which is heating of the contact layer of material by friction on the steel surface of the slideway. Heating changes both physical-mechanical and friction properties of the DD material [1,2,3].

It is important to determine how the temperature distribution in the material changes when it moves. To do this, it is necessary to solve the problem of thermal conductivity. In turn, to solve this problem, an initial condition is required: the temperature of the surface layer of DD, which can be determined by the theory of H. Block [4,5,6]. This temperature changes as the DD moves along the slideway because of the heat accumulated from friction.

2. Theory and numerical simulation

The theory of H. Block allows calculate the temperature of local heat sources when moving rubbing bodies depending on the path traveled, it refers to a heat source with specific power $Q$ (W/m²), continuously moving at speed $V$ on the surface of the half-space:

$$T_{max} = 2\mu P \left( \frac{BV}{nk\rho c} \right)^{1/2},$$

where:

- $\mu$ is experimentally determined coefficient of friction,
- $P$ is average contact pressure of copper (steel) DD;
- $k$ is thermal conductivity of copper (steel);
- $\rho$ is density of copper (steel);
- $c$ is specific heat of copper (steel);
- $B$ is length along the sliding (length of the way passed DD);
- $V$ is sliding velocity of DD.
Based on the theory, the flash point for metals is determined by the melting point. For the material DD "copper" it is equal to 1053°C (melting point 1083°C minus ambient temperature 30°C). For steel, the flash point is 1420°C (melting point 1450°C minus the ambient temperature of 30°C).

In order to determine the effect of permissible deviations in the manufacture of DD on the temperature during operation, average contact pressure $P$ was used, depending on the accuracy of manufacturing DD.

According to the results of calculations, the dependences of temperature distribution $T$ °C on the length of guide $l$, m, were derived. The following conclusions can be drawn based on these dependences:

- there is a sharp increase in temperature at a distance of 0.5 m for both DD;
- copper DD reaches the melting temperature at a distance of 1.5 m, and steel reaches the melting temperature at a distance of 2 m;
- the recrystallization temperature of steel DD is reached at 0.4 m.
- the temperature difference at contact loads, depending on the accuracy of manufacturing the material DD, can be neglected.

The results of the calculation in the form of temperature dependences of the surface layer on the traveled path are presented in figures 1 and 2.

![Figure 1](image-url)  
**Figure 1.** Dependence of the temperature on the copper DD surface on the movement time.
To determine the distribution of the temperature field in the DD material when sliding on the slideway, numerical mathematical modeling is carried out. In the formulation of the problem, the following assumptions are made: the material is homogeneous and isotropic, the physical parameters are constant, deformation of the investigated volume is very small compared to the volume itself. Heat dissipation is determined by the theory of H. Block.

To determine the material of DD heating during acceleration, the previously obtained dependences were used (Figures 1 and 2).

The software PascalABCNET was used for calculating the heat conduction problem. Also materials [7] were used. The results of calculations for the movement time of 0.0252 s are shown in figures 3 and 4. The figures represent cross sections of DD, and also listed the temperature field in them. In addition to the melting temperature of the materials, the recrystallization temperature is also distinguished, which is the boundary between the hardening of the material and its softening.

Figure 2. Dependence of the temperature on the steel DD surface on the movement time.
Figure 3. The temperature distribution of the copper DD in time $t = 0.0252 \, s$.

Figure 4. The temperature distribution of the steel DD in time $t = 0.0252 \, s$.

**Conclusion**

As a result of this work, the following conclusions can be drawn:

- the dependences of the temperature distribution on the slideway length are determined. Two fundamental ways of heating the DD material were marked: for copper $T_{rec} = 180 \, ^{\circ}C$, and $T_{mel} = 1082 \, ^{\circ}C$, for steel $T_{rec} = 720 \, ^{\circ}C$, and $T_{mel} = 1450 \, ^{\circ}C$;
- temperature distributions in copper and steel DD are calculated for $t = 0.006 \, s$, $t = 0.0133 \, s$, and $t = 0.0252 \, s$, the boundaries of the temperature distribution layers for both DD are also determined.
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