GENERALIZATIONAL INFORMATIOLOGICAL THEORY OF THERMAL DYNAMICS OF FRICTION AND WEAR OF TRIBOSYSTEMS WHICH INCLUDE SLIDING ELECTRICAL CONTACTS

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SUMMARY
A new scientific trend – generalization thermal dynamics of friction and wear of tribosystems (GTDFWT) – is now set basing on the achievements of thermal dynamics of friction and wear for brakes and muffls (founded by prof. A.V.Chichinadze), spread on to the class of current-collecting frictional mechanisms. This new theory can be applied to all kinds of friction knots and wide range of regimes and conditions of exploitation.

Keywords: electrofriction, thermal dynamics of friction and wear (TDFW), sliding electric contact (SEC), unsteady (UMF or HPT) and steady-stated mode of friction (SSMF or UYPT).

1 INTRODUCTION
At present GTDFWT is an elaborated theory of electric-friction interaction (EFI) of frictional couples and is aimed at its being put into practice. Besides that we have constructed a developing polylevelled model considering geometric, thermal, power and electric levels for each frictional couple. The critical points disposition peculiarity that defines the architecture of the frictional contact was studied for each level. This fact provides optimal wear resistance and the least losses caused by friction Informational-mathematical record of EFI picture as a system of functional is represented at page 4.

The best discussion of scientific researches outcomes which have an applied directedness is their concrete practical realization. Therefore we shall consider generalized thermal dynamics of friction and wear of tribosystems using the example of account with the help of GTDFWT set of equations. An example of account represented below is one of a support of sliding on a fresh contact was studied for each level. This fact provides optimal wear resistance and the least losses caused by friction Informational-mathematical record of EFI picture as a system of functional is represented at page 4.

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In the further descriptions the following main designations are used: \( f \) – friction coefficient; \( R_e \) – contact electrical resistance; \( h_e \) – linear wear intensity; \( I \) – weight wear for the whole period of friction; \( t \) – friction time; \( t \) – time of entering the steady-stated mode of friction (SSFM or UYPT) zone; \( P \) – load; \( V \) – sliding velocity; \( J \) – current strength; \( N \) – electro friction interaction power; \( \alpha_{\text{sn}} \) – thermal currents distribution coefficient; \( MPKT \) – parameters of macrosizes of contact skew fields; \( A, l \); \( l_2 \), b – nominal contact area, linear nominal sizes of a friction couple contact and size of a friction couple element in perpendicular direction to a contact; \( A, l_2, a \) – actual area of contact (frictional and electrical); \( d_{\text{sp}}, d_{\text{p.sx}} \) – diameter of a single spot of contact (frictional and electrical); \( m_{\text{sn}} \) – probable number of contacts on the actual area of contact; \( \eta \) – friction couple element material densities; \( v \) – factor of kinematic viscosity; \( K_{\text{sn}}, \mu \) – mutual overlapping coefficient; \( \Gamma \) – geometrical characteristics of friction surface quality; \( \Phi \) – physicochemical characteristics; \( \Theta \) – thermal-physical characteristics; \( \Theta \) – electrophysical characteristics; Index “1, 2” shows that parameter takes two significances: “1” for a one friction surface and “2” for another friction surface; Index “1” for opposite skew field; Index “2” for movable skew field; Index “a” for air; Index “SSMF or UYPT” for the parameter corresponding the steady-stated mode of friction; \( \text{grad} \theta_{\text{max}} \) – maximum surface temperatures gradient on normal in the contact; \( \theta_e \) – mean surface temperature; \( \theta_{\text{max}} \) – maximum friction surface temperature; \( \theta_{\text{in}} \) – initial temperature; \( \theta_{\text{v0}} \) – current volumetrical temperature; Temperatures (increment) of each friction pair element: \( \theta_e \) – mean volumetrical temperature increment; \( \theta_e \) – mean surface temperature (increment) – mean surface temperature increment caused by EFI; \( \theta_{\text{v0}} \) – volumetrical temperature increment caused by joule heat; \( \theta_{\text{scn}} \) – temperature flash on the contact.
2 BASIC DATA OF ACCOUNT:

\[ P = 147N, J = 500A, V = 50m/s; \]
\[ \Delta x = 0.5 \times 10^{-3} m^2, l_1 = 0.00417m, l_2 = 0.12m, b_1 = 0.01m; \]

materials of a contact pair: copper M1 + baked material on an iron basis MK15-C05, impregnated with fusible alloy Pb - Sn;

\[ \lambda_1 = 381.2 \text{ W/m°C}, \lambda_2 = 104.1 \text{ W/m°C}, T_0 = 293 \text{ K} , \]
\[ \alpha_1 = 111 \times 10^{-6} \text{ m²/c}, \alpha_2 = 37 \times 10^{-6} \text{ m²/s} , g = 9.81 \text{ m/s²}, \]
\[ \gamma_1 = 8.9 \times 10^4 \text{ kg/m²}, \gamma_2 = 7.8 \times 10^4 \text{ kg/m²}, \rho_2 = 30 \times 10^{-8} \text{ Ohm} \cdot \text{m}, \]
\[ \lambda_n = 2.58 \times 10^7 \text{ W/m°C}, v_B = 15.06 \times 10^{-6} \text{ m/s}. \]

The set of equations GTDFWT for the given case of frictional pair of «a contact wire – pantograph slice through which current is transmitted» type on the base of EFI functional system will be noted as at p.4:

variable information of laboratory researches of a friction couple materials: copper M1 (index of parameters «1») and MK15-C05 (index of parameters «2») on ΦMX, ΦSX, ΦθX as functions of temperature J, and also on electrofrictional performance and temperature performances as functions from time \( \tau \) of entering a zone of steady-stated mode of friction (SSMF or YPT) and time \( t \) of friction (work) of frictional pair.

The initial information is taken from the reference literature and our experimental researches.

In an outcome of the set of GTDFWT equations solution the following information about considered sliding electrical contact of a type «the contact wire - pantograph slice through which current is transmitted» is received (it is partly represented on the pictures):
wear of both contact wire \( I_w \) (at each chosen site of the total length of contact wire) and slice \( I_{w2} \); performances of actual contact squares (mechanical and electrical) sizes: \( A_1, A_{3x}, m_{nw}, d_{sp,3x} \); a specific electroresistance of a film on actual square of contact \( \sigma_{3x} \); distribution of heat flows in contact \( \sigma_{mt} \); performances of sliding electrical contact of both elements temperatures: \( \vartheta_{\text{max}}, \vartheta_{\text{max}2}, \vartheta^*, \vartheta_1, \vartheta_2, \vartheta_{\text{ob, x1}}, \vartheta_{\text{ben}} \).

Let's evaluate a level of forecastability of operational parameters by the stated settlement method. For example, let slice by operational mode of the indicated here account works 25 minutes, passing accordingly 75 km. And such work is multiply repeated before limiting allowable wear \( \Delta = 5 \text{ mm} \). Square of a slice (package of slices of a pantograph): \( l_d \cdot l_{sh} = 1,2 \cdot 0,12 = 0,144 \text{ m}^2 \). A denseness of a material \( \gamma_{m2} = 7,8 \cdot 10^3 \text{ kg/m}^3 \). Under the schedule \( I_{w2}(t) \) the wear will make \( 22 \cdot 10^{-5} \text{kg} \). Then the wear for one 75-kilometer run will make

\[
h_2 = \frac{22 \cdot 10^{-3}}{0,144 \cdot 7,8 \cdot 10^{-3}} = 2 \cdot 10^{-5} \text{ m}
\]
The total gone way up to a replacement of a slice (package of slices) is

\[ L_{\text{rep}} = \frac{5 \times 10^{-3} \times 75}{2 \times 10^{-3}} = 18750 \text{ km} \]

Now we shall define how the contact wire on 15th kilometer will be worn out if interval of movement of trains (i.e. slices on a place of account of a contact wire) is 5 minutes and total time of operation is 25 min. Under trains (i.e. slices) on a place of account of a contact wire kilometer will be worn out if interval of movement of trains to take into account wear of each element of friction (i.e. because of the wear of a contact wire needs to be substituted because of the operational mode of the indicated example of account of friction). The operational datas. Thereby basing on such accounts it is possible to go further, i.e. by drawing up of the schedule of trains to take into account wear of each element of friction couple of sliding electrical contact, for the economies from increase of intensity of the railway traffic not to be liquidated by losses on wear and repair of a contact web.

The represented outcome of an wear process account was got through the elaborated by us in GTDFWT theory of electrofrictional interaction (EFI). The dynamics of this electrofrictional interaction in time is conditioned by availability of a gradient of temperatures on normal in contact (\( \text{grad} \theta_{\text{max}} \)), which, in turn, is caused by difference in temperatures of conjugate surfaces of friction, i.e. jump of temperatures in contact. This way it is possible to explain an availability of two zones of friction by electrofrictional interaction fixed in experiment. Namely, while the electrofrictional interaction is being carried out in a zone of the unsteady mode of friction (HPT), i.e. when \( \text{grad} \theta_{\text{max}} > 0 \), electrofrictional wear performance are continuously and mutually changing. By entering a zone of a steady-stated mode of friction (YPT), when there is \( \text{grad} \theta_{\text{max}} = 0 \), electrofrictional wear performance are stabilized at the certain level of periodical oscillation process adequate to a reached temperature mode of a fatigue process of destruction of friction surfaces by their wear. Entering the zone of steady-stated mode of friction according to experimental data happens simultaneously for all electrofrictional wear performances and the equality of total magnitude of friction surfaces linear wear intensity for any specific modes of electrofrictional interaction is observed:

\[ \text{I}_{\text{rep}} = \text{I}_{\text{rep}} + \text{I}_{\text{rep}} = \text{const} \]

and this magnitude is inherent in the strictly certain frictional pair, i.e. it is informatiological oil a frictional constant (IFC) of this friction couple and it reflects the generalization law of an information conservation by friction and wear process in tribosystems. Thus time factor is exhibited only through a gradient of temperatures on the normal in contact (\( \text{grad} \theta_{\text{max}} \)) which is an argument in the mathematical descriptions of EFI GTDFWT theory that models wear and its dynamics from the thermic point.

Thus usually used hypothesis of temperatures jump absence (i.e. the maximum temperatures of both surfaces of friction are equal) and the settlement evaluations on its basis are applicable only for a zone of a steady-stated mode of friction.

The considered IN model of electrofrictional interaction that reflects its time dynamics is exhibited of the available certain ratio and functional associations that form a closed system of mutual changes by electrofrictional interaction, analytically noted as follows:

\[
\begin{align*}
\theta_{1,2} - \theta_{2,2} : \theta_{\text{min}1,2} - \theta_{2,2} : \theta_{\text{min}2} = 0 \\
\theta_{\text{min}1} & = \frac{5 \times 10^{-3} \times 75}{2 \times 10^{-3}} = 18750 \text{ km} \\
\theta_{\text{max}} & = \frac{4 \times 10^8}{0.5 \times 10^2 \times 8.9 \times 10^4} = 9.10^8 \text{ m} \\
\text{m} & = \frac{\Delta \theta}{60 \times 0.9 \times 10^{-3}} = 2.3 \times 10^5 \text{ hour} = 26.25 \text{ year} \\
\text{It is known, that run of slices up to a replacement by their work in various modes (i.e. as a whole less intense, than in our account, when there is one and a heavy mode of work) is on the average up to 40 thousand km, average period of service of a wire makes 25 years, i.e. we have the good correspondence of settlement and operational datas.}
\end{align*}
\]

Mathematical realization of this system made it possible to get theoretical researches of wear process practically useful outcomes.