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The tribology of the car: Research methodology and evaluation criteria

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Abstract: From a position on structural and power theory of friction and wear, it is possible to apply the method of Contact Electrical Resistance (CER) for a complex research the processes in a-zone of frictional contact. The original construction of friction node and drive mechanism of friction machine is developed. The regularities of changes the CER and tribomechanical indices for non-metal friction couples in dependence on loading parameters and lubricating media were received. The method of determination the range and level of normal wear and critical points of transmission to damage in accordance with kinetics of wear changes is proposed. The interrelation between geometrical, physical and mechanical properties, processes of formation, transformation and destruction of secondary structures, tribotechnical indices and CER in dependence on operation regimes of friction couples.

Keywords: friction, wear, adaptability, secondary structures, electric resistance.

1. Introduction

The range of normal mechanochemical wear characterized by dynamic equilibrium of the processes of secondary structures (SS) formation and destruction - the range of structural adaptability (SA) - is the most important for the theory and practice of friction and wear. SS appearance is the thermodynamic basis of fundamental regularities of friction, lubricating action and wear, and the formation of a great SS gamma - the Science of Materials basis [1].

As the investigations [2] have shown, the criterion of contact electrical resistance of friction couple (CER) meets such demands. As the physical basis of the given criterion for the estimation of friction and wear processes served that, as investigations have shown, the SS films forming on the friction surface are non-conducting and minimize the surface destruction Values of resistance and wear depend on their type, structure and properties. The distinctive feature of friction geo modifiers from other additives consists in adding some substances to the samples tribomating which launch the self-organization processes [3-6]. Different types of additives of synthetic and natural origin change the oil physical thermal-oxidative ability due to the formation of materials surface layers enabling to decrease the friction coefficient and additional dissipation of friction energy [7-9], resulted in increased oil lubrication ability but wear resistance does not change greatly. That why it is necessary to seek for some new compositions with more positive characteristics for tribomating. A wide range of tribological characteristics and repairing compositions with additives of natural origin which are based on serpentinite-based powder properties have been studied in the papers [10-12].

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The aim of this work was to examine CER criterion application to study surface destruction (wear, damage) mechanisms, to reveal correlative dependence between structural state of friction surfaces (SS type and properties) and tribotechnical indices and CER. For the purpose, an electrical scheme for CER measuring has been developed which makes it possible to measure its value in the range 0-1,0 K Ω with the solving capability of 0,1 Ω.

2. Materials and Methods

Materials and Methods should be described with sufficient details to allow others to replicate and build on published results. Please note that publication of your manuscript implicates that you must make all materials, data, computer code, and protocols associated with the publication available to readers. Please disclose at the submission stage any restrictions on the availability of materials or information. New methods and protocols should be described in detail while well-established methods can be briefly described and appropriately cited.

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Interventionary studies involving animals or humans, and other studies require ethical approval must list the authority that provided approval and the corresponding ethical approval code.

3. Results

The measuring of wear intensity (№) was being carried out by a traditional means. As a control value of given parameters, their stabilized value after each loading stage of friction node were taken. The structure of friction surfaces of specimens was investigated on a scanning electronic microscope Cam Scan, SS chemical composition was determined on a microanalyzer of Cam Scan system and an attachment Link 860.

The experiments were carried out on serial machines and specially created friction machine [13-15] with the different schemes of contact in the ranges of sliding velocity V=0,2 –12 m/s. On the specially created friction machines sliding velocity and unit load were changed fluently (see Figure 1) with a help of hydraulically driven (it is shown in Figure 1).

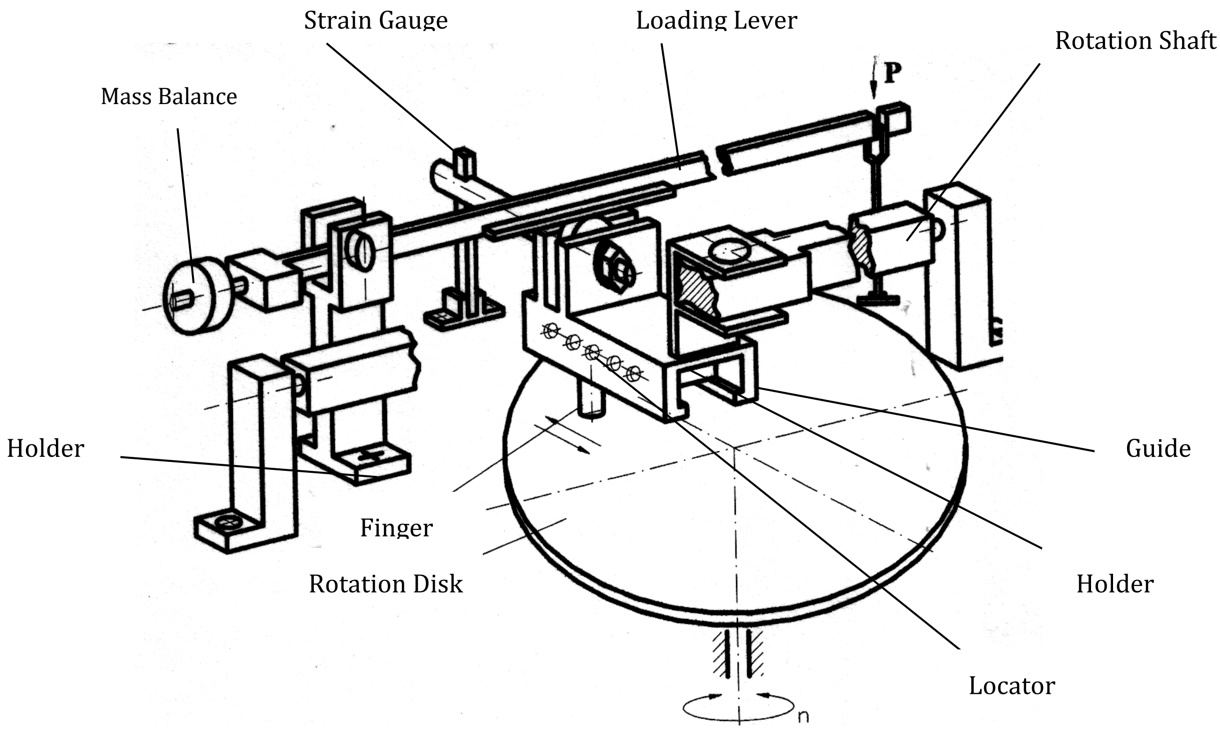

Figure 1. General appearance of friction node and loading mechanism.

The specimens made of steel 45 (42...45 HRC, Ra -0,125μm) were investigated. The specimen diameter - 6 mm. The disk material - steel 40H (48...50HRC, Ra - 0,125μm). Disk diameter 250 mm. The chemical composition of researched steels are shown in Table 1 and Table 2. As a working medium an inactive lubricant – petroleum jelly with "Anglamol-99" addition (3.2% S; 1.8% P; 0.7% N) of concentration was used.

Table 1. Chemical composition of steel 45, %.

C	Si	Mn	Cr	Cu	Ni	P	S	Fe
0.42…0.45	0.17…0.37	0.50…0.80	0.25	0.3	0.3	0.035	0.040	Rest

4. Discussion

The results of wear and CER measuring are shown in Figure 2. The data of investigation of friction surfaces chemical composition are given in Table 3.

Table 2. Chemical composition of steel 45, %.

C	Si	Mn	Cr	Cu	Ni	P	S	Fe
0.36-0.44	0.17-0.37	0.50-0.80	0.80-1.10	0.30	0.30	0.035	0.035	Rest

Table 3. Elemental analysis of friction surfaces, %.

Element	Investigation section in Figure3					
	1	2	3	4	5	6
		SS-1	SS-2			
	uninstalled processes	mechano-chemical	processes	setting the second type	thermo-chemical processes	destruction
S	1.314	0.111	0.973	0.109	0.474	0.009
P	0.496	0	0.288	0	0.381	0
Mn	0.356	0.264	0.452	0.409	0.412	0.440
Si	0.234	0	0.126	0.063	0.220	0.141
Fe	93.29	99.01	950.06	94.47	960.81	98.02

As Figure 2 reveals, there are the ranges of loading parameters sliding velocity V (SA regime) in which the value W is minimum and stable, R - maximum and stable (sections 2, 3, 5). On reaching the critical loads (damage regime) the wear speeds to maximum, R - to zero (sections 4, 6; W and R unstable value at the transition from mechanochemical processes to thermochemical (section 4) are explained by the intensive destruction of surface films, the deterioration of their mechanical, physical and chemical and geometrical characteristics. In the volumetrical destruction regime (section 6) the layers of the initial metal begin to contact. The received analogical regularities for the other friction couples prove that there is a correlative dependence between W, R parameters and SS type in SA range. This dependence is explained W, R parameters as characteristics of one and the same process (SA), one and the same object (SS).

Determination method of range and level of friction couples normal wear became possible due to the strict devision of processes into normal wear processes and damage processes (Figure 3). The method consists in that SA range (Figure 3 CD) is equalled to the range of maximum and stable value CER (Figure 3 AB). The normal wear level (Figure 3 point E) is determined by the measuring of wear value at any value of loading parameters (Px, Vx) from SA range by a traditional means

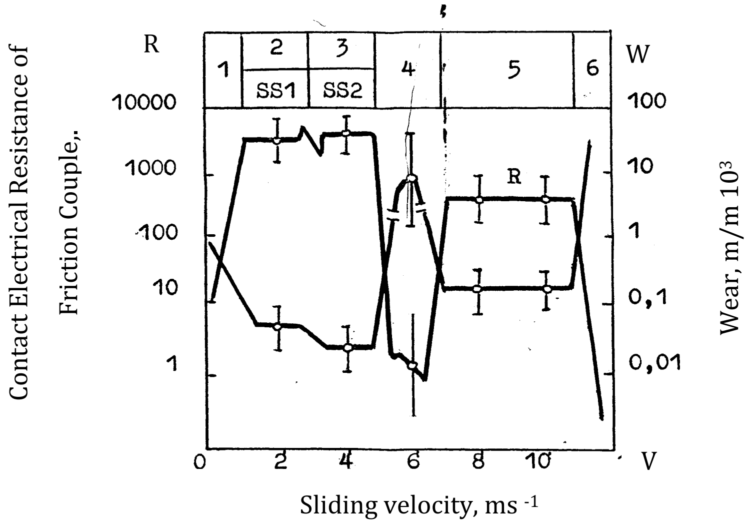

Figure 2. Diagram of dependence of wear and contact electrical resistance of friction couple on sliding velocity in friction of 45 steel specimen over 40H steel disk (P=8MPa, lubricant petroleum jelly with "Anglamol-99" addition).

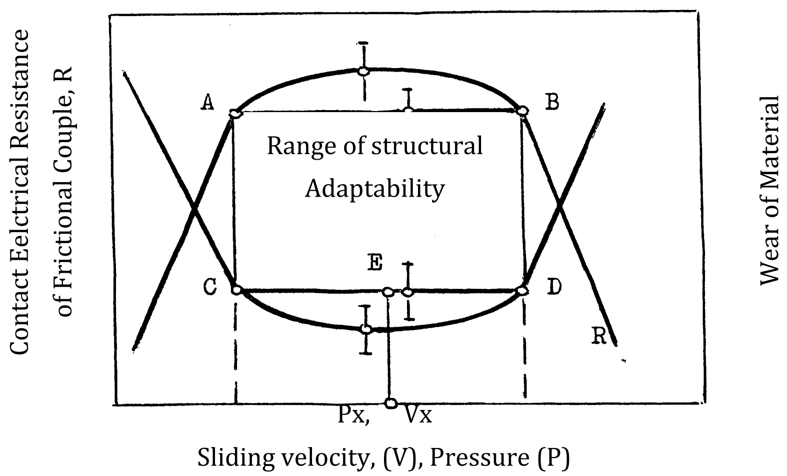

Figure 3. Method of definition the range and level of materials structural adaptability in friction.

Proposed method possesses the high resolving power and sensitivity, permitting in SA range to fix transitional processes from SS the first type to SS the second type and to damage processes. By the CER quantity and nature change the leading type of wear is determined.

In the SA range SS propertied are changed in wide limits under the effect of external parameters. That shows the great possibilities of their internal reconstruction. To estimate SS state and properties, thé criteria R R_{in}^{-1}, *t* are proposed. These criteria are based on the measuring of CER and the time of its stabilization (Fig. 4).

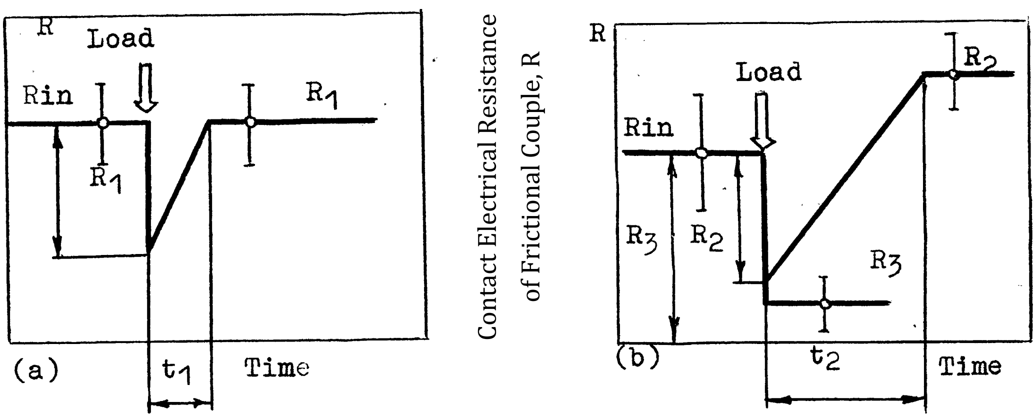

Figure 4. The nature of change of contact electrical resistance initial value (Kin) and the determining of parameters AR R_{in}^{-1} and t in friction in regimes of structural adaptability (a), (b) run-in (R_p) and passage to damage (R_3).

After each loading stage (P, V) the fall of CER initial value (R_{in}) on the value ΔR and in a time t its stabilization on a new level occurred (R_1, R_2, R_3). In SA range (Figure 4(a) the criteria ΔR R_{in}^{-1} and *t* are stable and minimum (durable, stable SS), in run-in regimes (Figure 4(b) – R_2) and volumetrical destruction (Figure 4(b) - R_3) their values are maximum and unstable. For the researched friction couple the values of given criteria: SA regime - ΔR_1 R_{in}=0,15…0,40; t_1=7…15 min; run-in regime - ΔR_2 R_{in}^{-1} =0,45…0,85; t_2=20…40 min; volumetrical destruction regime ΔR_3 R_{in}^{-1}≈1; t→∞.

Friction and wear regimes are determined by the relation of velocity of formation V_f and destruction velocity of SS. In SA regime, V_f and V_d are equal and equality of forming time t_f and destructing time td of SS attests about this (Figure 5(a)). In the regime of transition to damage V_f, V_d (t_f, t_d) (Figure 5(b)). t_f, t_d and R_{ss} values are determined while decoding the cyclogram of CER changes through the time in the regime of normal friction to its average value - R_a relatively.

SS lifetime t=t_f + t_d. In SA regime R_{ss} in the function of SS thickness. The revealed dependence allows to determine the parameters V_f and V_d of SS as the relation of R_{ss} to t_f or to t_d in the testing process directly. For SS forming on the friction surface of a specimen made of steel 40 t=40…120 min; SS thickness – 20…100 A; ΔR_{SS}=30…120Ω.

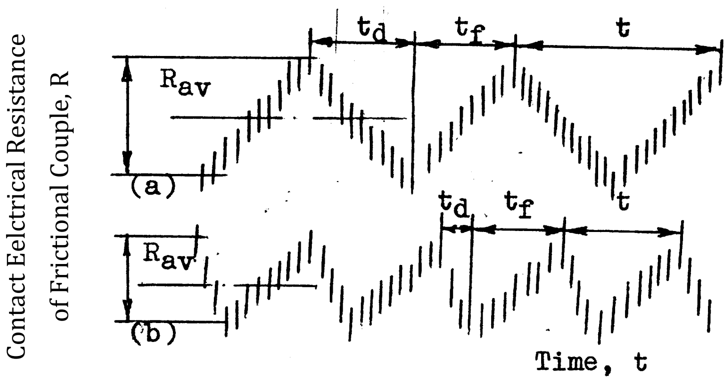

Figure 5. The determining of formation time (t_f), destruction time (t_d), lifetime (t) and geometrical characteristics (R_{ss}) of secondary structure using cyclograms of contact electrical resistance of friction couple change in time in structural adaptability regime (a) and passage to damage (b).

The proposed criteria are the structural-sensitive parameters, that characterized the SS state and properties. The capability to carry out the continuous control on friction and wear processes with the investigation of kinetics of SS formation, transformation in the testing process directly occurred. In community with the metallographycal analysis of friction surface they allow to control the friction and wear processes revealing the nature of tribological interactions.

5. Conclusions

From a position on structural and energy theory of friction and wear, a comprehensive methodology for the study of heavy-loaded friction pairs of the car has been developed and tested.

The universal friction machine has been designed and manufactured, a measuring complex for registration of contact electric resistance of friction pairs, wear intensity and coefficients of friction.

The wide complex has been conducted on the study of processes in the zone of frictional contact for different materials of friction pairs, lubricating media, and power load parameters. The character of relationship between the main tribotechnical showing, the contact electrical resistance and the structural state of the friction surfaces (type of secondary structures) was revealed and substantiated.

An express method for determining the range and level of the process of normal mechanical wear, the nature of the transition processes, kinetics of formation, transformation and destruction of secondary structures is proposed.

The complex for systematic control and analysis of the kinetics of tribological interactions processes, the obtaining of objective data in the process of their synergistic interaction, expansion of the data bank to create a unified theory of friction and wear, was created.

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