Materials of Conferences

ANALYSIS OF SYNERGIC EFFECT IN COMPOSITIONAL COATINGS WITH TAKING INTO CONSIDERATION THE SOLID COMPONENT OF THE COUNTER-BODY AND THE LIQUID LUBRICANT

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In simple case the tribologic system from two materials may be presented by following scheme M1//M2, where the symbol is denotes the "third body" without liquid lubricant. If the friction velocity V and the specific loading P are fixed, the tribologic characteristics of the M1 surface are dependent on composition and properties of the counter-body, i.e. M2. And what are the true M1 properties?

Let's assume that some friction condition (P, V, stationary regime, identity materials) are the "standard". Then the sets of $(f_i^o, I_{lin,i}^o)$ values, which were received in corresponding systems Mi//Mi, may be presented as a "conventionality values" of the antifrictional property and the firmness for wear of the Mi material, only. In this case the comparative analysis of the materials properties and the prediction of its tribologic characteristics in others systems may be accomplished. Really, for M1//M2 system the properties of the M1 and M2 surface are following:

$$f_1 = f_1^o + (I_{lin,1}^o/(I_{lin,1}^o + I_{lin,2}^o))(f_2^o - f_1^o); I_{lin,1} = I_{lin,1}^o + [(f_1 - f_1^o)/(f_1^o + f_2^o)]I_{lin,2}^o;$$

$$f_2 = f_2^o + (I_{lin,2}^o/(I_{lin,1}^o + I_{lin,2}^o))(f_1^o - f_2^o); I_{lin,2} = I_{lin,2}^o + [(f_2 - f_2^o)/(f_1^o + f_2^o)]I_{lin,1}^o;$$

where the $(f_1^o, I_{lin,1}^o)$ and $(f_2^o, I_{lin,2}^o)$ are the values, which were received in corresponding M1//M1 and M2//M2 systems. Then we have the next correlation:

$$I_1 + I_2 = I_1^o + I_2^o, \quad f_1^o = f_2^o = f = (f_1^o I_1^o + f_2^o I_2^o)/(I_1 + I_2).$$

Thus, in the first place, the summary wear in tribologic system is the wear sum of the system elements, which were received on "conventionality scale", and secondly, the wear-friction of tribosystem $f(I_1 + I_2)$ is the wear-frictional sum of the system elements, which may be calculated on "standard scale". By this thesis the prediction of the tribologic characteristics of materials surface in any systems Mi//Mj may be realized if the experimental dates for systems Mi//Mi and Mj//Mj are determined.

1. The velocity of linear wear I^o and the friction coefficient f^o of the compositional covers (CC) may be presented in following form:

$$I^o = \alpha\langle I^o_{sol}\rangle + (1-\alpha)\langle I^o_{lub}\rangle + \delta_I(\langle I^o_{sol}\rangle - \langle I^o_{lub}\rangle),$$
$$f^o = \alpha\langle f^o_{sol}\rangle + (1-\alpha)\langle f^o_{lub}\rangle - \delta_f(\langle f^o_{sol}\rangle - \langle f^o_{lub}\rangle),$$

where the values $\delta_I = \delta_f = \delta = 4(1-\alpha)\alpha^2\,[1-k(1-k_n)]$ is the relative synergic effect of the corresponding properties, the symbol α is denotes the volume share of solid CC component in two-component (solid + lubricant) approach, and the parameters k and k_n are the dimensional and nano-structural factors, accordingly [1–4].

If the values I^o_{CB} and f^o_{CB} are the counter-body (CB) tribologic properties according to "standard scale" (by conditions $I^o_{CB} > I^o$ and $f^o_{CB} > f^o$), then we have

$$I = \alpha'\langle I^{o'}_{sol}\rangle + (1-\alpha')\langle I^o_{lub}\rangle + \delta'(\langle I^{o'}_{sol}\rangle - \langle I^o_{lub}\rangle),$$
$$f = \alpha'\langle f^{o'}_{sol}\rangle + (1-\alpha')\langle f^o_{lub}\rangle - \delta'(\langle f^{o'}_{sol}\rangle - \langle f^o_{lub}\rangle),$$

where $\alpha' = \alpha + \Delta\alpha$, $\langle I^{o'}_{sol}\rangle = \langle I^o_{sol}\rangle - \Delta I_{sol}\rangle$, $\langle f^{o'}_{sol}\rangle = \langle f^{o'}_{sol}\rangle + \Delta f_{sol}$.

Taking into consideration the most possible correlations $k_{CB} \cong k \cong 0,5$; $k_{nCB} \cong k_n \cong 0$ and neglecting of members, which are contained $(\Delta\alpha)^2$ and $(\Delta\alpha)^3$, we have the next relation for relative synergic effect $\delta' \cong 2(1-\alpha)\alpha^2 - 2\alpha(3\alpha-2)\Delta\alpha = \delta - \Delta\delta$, where the value $\Delta\delta$ is the change of the synergic effect amplitude. Then the changes of the CC tribologic properties are following:

$$I - I^o = (\Delta\alpha - \Delta\delta)(\langle I^o_{sol}\rangle - \langle I^o_{lub}\rangle) + (\alpha + \delta)\Delta I_{sol},$$
$$f - f^o = (\Delta\alpha + \Delta\delta)(\langle f^o_{sol}\rangle - \langle f^o_{lub}\rangle) + (\alpha - \delta)\Delta f_{sol.}$$

In these correlations the members contained of little values $\Delta\delta\Delta f_{sol}$, $\Delta\alpha\Delta f_{sol}$, $\Delta\delta\Delta I_{sol}$ and $\Delta\alpha\Delta I_{sol}$ were neglected.

It's determined, by fixed α the relation for $(f - f^o)$ is increase when the $\Delta\alpha$, $(\langle f^o_{sol}\rangle - \langle f^o_{lub}\rangle)$ and Δf_{sol} are increase. The dependences $(I - I^o)$ are contains maximum with coordinates $[(I - I^o), \alpha]_{max}$. By increasing the values $\Delta\alpha$, $(\langle I^o_{sol}\rangle - \langle I^o_{lub}\rangle)$, and ΔI_{sol} the coordinate $(I - I^o)$ is increase, too, but second coordinate α_{max} is decrease.

It's note, this qualitative dates are may be used for prediction of LL substances for with necessary CC tribologic properties [5, 6].

2. In accordance with "concentration wave" model the velocity of linear wear I^o and the friction coefficient f^o of the compositional covers (CC) may be presented in following form:

$$I^o = \alpha\langle I^o_{sol}\rangle + (1-\alpha)\langle I^o_{lub}\rangle + \delta_I(\langle I^o_{sol}\rangle - \langle I^o_{lub}\rangle),$$
$$f^o = \alpha\langle f^o_{sol}\rangle + (1-\alpha)\langle f^o_{lub}\rangle - \delta_f(\langle f^o_{sol}\rangle - \langle f^o_{lub}\rangle),$$

where the values $\delta_I = \delta_f = \delta = 4(1-\alpha)\alpha^2\,[1-k(1-k_n)]$ is the relative synergic effect of the corresponding properties, the symbol α is denotes the volume share of solid CC component in two-component (solid + lubricant) approach, and the parameters k and k_n are the dimensional and nano-structural factors.

If the values $(I^o_{l.lub}, f^o_{l.lub})$ are the conventional characteristics of the liquid lubricant (LL) according to "conventionality scale" (by conditions $I^o_{l.lub} < I^o$ and $f^o_{l.lub} > f^o$), then we have

$$I = \alpha'\langle I^o_{sol}\rangle + (1-\alpha')\langle I^{o'}_{lub}\rangle + \delta'(\langle I^o_{sol}\rangle - \langle I^{o'}_{lub}\rangle),$$
$$f = \alpha'\langle f^o_{sol}\rangle + (1-\alpha')\langle f^{o'}_{lub}\rangle - \delta'(\langle f^o_{sol}\rangle - \langle f^{o'}_{lub}\rangle),$$

where: $\alpha' = \alpha - \Delta\alpha$, $\langle I^{o'}_{lub}\rangle = \langle I^o_{lub}\rangle + \Delta I_{lub}\rangle$, and $\langle f^{o'}_{lub}\rangle = \langle f^{o'}_{lub}\rangle - \Delta f_{lub}$.

Taking into consideration the most possible correlations $k \cong 0,5$; $k_n \cong 0$ and neglecting of members, which are contained the $(\Delta\alpha)^2$ and $(\Delta\alpha)^3$ fragments, we have the next relation for relative synergic effect $\delta' \cong 2(1-\alpha)\alpha^2 + 2\alpha(3\alpha-2)\Delta\alpha = \delta + \Delta\delta$, where the value $\Delta\delta$ is the change of the synergic effect amplitude. Then the changes of the CC properties are following:

$$I-I^o = -(\Delta\alpha + \Delta\delta)(\langle I^o_{sol}\rangle-\langle I^o_{lub}\rangle)-(1-\alpha-\delta)\Delta I_{sol},$$
$$f-f^o = -(\Delta\alpha-\Delta\delta)(\langle f^o_{sol}\rangle-\langle f^o_{lub}\rangle)-(1-\alpha+\delta)\Delta f_{sol}.$$

It's note, that in these correlations the members contained of little values $\Delta\delta\Delta f_{sol}$, $\Delta\alpha\Delta f_{sol}$, $\Delta\delta\Delta I_{sol}$ and $\Delta\alpha\Delta I_{sol}$ were neglected.

It's determined, by fixed α the relation for $(f-f^o)$ is increase when the $\Delta\alpha$, $(\langle f^o_{sol}\rangle-\langle f^o_{lub}\rangle)$ and Δf_{sol} are increase. The dependences $(I-I^o)$ are contains maximum with coordinates $[(I-I^o),\ \alpha]_{max}$. By increasing the values $\Delta\alpha$, $(\langle I^o_{sol}\rangle-\langle I^o_{lub}\rangle)$, and ΔI_{sol} the coordinate $(I-I^o)$ is increase, too, but second coordinate α_{max} is decrease.

This qualitative dates are may be used for prediction of new CC with necessary tribologic properties [5, 6].

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NOTABLE ACHIEVEMENTS IN AVIATION AND AEROSPACE TECHNOLOGY

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The cost of a launch the payload into orbit at the present time is still extremely high. This is due to the high cost of the rocket engine, complex control system, expensive materials used in the construction of rocket and their engine, and mainly by their single use.

At the end of XX and beginning of the XXI centuries, the unit cost of a deliver the payload into low earth orbit for non-reusable and reusable carrier of U.S. and Western Europe is approximately 10 000 to 25 000 $/kg. Since 1981, NASA's dream of a reusable spacecraft "Space Shuttle" was realized and has launched more than 100 missions, but the price tag of space shuttle missions has changed not much. For space transportation system "Space Shuttle", the cost of deliver payloads into low earth orbit is 10 416 $/kg (in 2011). Using the new generation expendable launch systems type of "Atlas V", "Delta IV" and "Ariane 5" should lead to some reduction in the unit cost of launch, but, as expected, are not too significant. Due to the peculiarities of the development of space technology in the USSR, the unit cost to deliver payload into orbit by expendable launch system of Russian are noticeably smaller. For example, the cost of a launch by "Soyuz" and "Proton" actually is 2400 and 2100 $/kg, respectively. Nevertheless, further reducing the cost of a launch the payload into orbit associated with reusable hypersonic aircraft.

A new space transportation system being developed could make travel to geostationary earth orbit a daily event and transform the global economy. Theoretically, the most beneficial from an economic point of view, the delivery of payloads and passengers into space is the Russian idea "Space Elevator".

In 1895, the father of astronautics Konstantin Eduardovich Tsiolkovsky in one of his articles described the gigantic structure with a rope stretched to the "Heavenly Palace" where had to climb the elevator, then to fly further into space.

The future "Space Elevator" would be made of a carbon nanotubes composite ribbon anchored to an offshore sea platform would stretch to a small counterweight approximately 100 000 km (62 000 miles) into space. Mechanical lifters attached to the ribbon would then climb the ribbon, carrying cargo and humans into space, at a price of only about 220 to 880 $/kg (100 to 400 $/lb).

At the Department of Aeromechanics and Flight Engineering (DAFE) of Moscow Institute of Physics and Technology (MIPT) was developed the information technology projects "ADANAT" (Aerodynamic Analysis of Ensuring the Establishment of Aviation and Space Techniques) and "TURBO SEARCH" by Professor Yuri Ivanovich Khlopkov. Many research grants from the Russian Foundation for Basic Research (RFBR) and Russian Science Foundation (RSF) supported these projects. The parallel calculation center of DAFE MIPT is equipped with the modern CFD software. DAFE with the famous organizations of Russia "Central Aerohydrodynamic Institute (TsAGI), Central Institute of Aviation Motor Development (TsIAM), Dorodnicyn Computing Centre of the Russian Academy of Sciences, Institute for Problems in Mechanics of the Russian Academy of Sciences, Sukhoi Aviation Holding Company, engineering company "TESIS", etc" was defined many fundamental problems in the field of creation of new generation of aviation and space techniques. Development of the center allowed promoting in the solution of the most complex challenges of computing in aerothermodynamics problems. Some of these are the problems of hypersonic aerothermodynamics, rarefied gas dynamics and task about flows in turbojets, etc.