BALKANTRIB'O5
5th INTERNATIONAL CONFERENCE ON TRIBOLOGY
JUNE.15-18. 2005
Kragujevac, Serbia and Montenegro

ON SELF-ORGANIZATION AND SELECTIVE TRANSFER IN TRIBOLOGICAL SYSTEMS

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Abstract

*The paper reveals how tribology reflects the broader sense of science in general and its ability to regard things in their wholeness. We have often to deal with the so-called "immersed systems", i. e. the behavior of these systems becomes informative if only they are regarded as imbedded into their milieu. Accordingly, these systems are accentuated "**contact** systems", because of the unfeasibility to consider them as isolated objects, separately of their contact with all other elements of their environment, and are subject of tribology.*

Self-organization (spontaneous creation of highly ordered structures arising from lower degree of order, even from chaos), i.e. purposefulness and spontaneity along with relative independence from the interaction environment-system not only for living systems is regarded as mechanism of the exceptional ability of systems to subsist.

The usefulness of tribological investigations in the scope of self-organization resides in the comprehension that the contact body could be "trained". During self-organization global external impact stimulates the release of internal to the system mechanisms, due to which the system is able to pass from one equilibrium state to another one, more adequate to the external conditions. In the paper, the problem of the character and extent of the admissible external affect is sought in system ability to rearrange its structure and homogenize its elements in a manner to become most adaptive to the modified external circumstances. Concrete examples of self-organization and selective material transfer between the contacting surfaces are illustrated in the expose.

Keywords: *tribosystems, self-organization, selective material transfer*

1. INTRODUCTION

In the last 30 years scientists' attention was attracted by the non-equilibrium open systems, their interaction with the environment and the exchanged mass-, energy- and information flows. At this point we have often to deal with open systems, and with the so-called "immersed systems" [1], i. e. the behavior of these systems becomes informative if only they are regarded as imbedded into their milieu. Accordingly, these systems are accentuated "contact systems", because of the unfeasibility to consider them as isolated objects, separately of their contact with all other elements of their environment.

2. SELF-ORGANIZATION CONCEPT AND TRIBOLOGY

Viewed in the larger sense, **tribology** as a science of contact, is anchored in the deep essence of things. Tribosystems viewed as systems for the behavior of which contact has the most crucial importance, are considered as open non-equilibrium systems. They may exist only due to their embedding in the environment. Friction, a typical contact process, can be seen as resistance/opposition of environment against system behavior. In these systems the ability to forget (to extinguish) external disturbance is due to dissipation and, under given conditions, relies to a specific organization of the system called

self-organization. Far from equilibrium, as a result of energy and mass flows towards and from the system, non-equilibrium becomes a source of ordering: a new space-time organization of the system, or new structures (the so-called dissipative structures) may appear. The state of tribosystems is determined by external conditions (surrounding medium – elements, pressure, temperature; motion velocity; contact pressure, etc.), and by internal conditions (properties and specifics of the contact body) [2]. Impact on the system and changes in the external conditions, could improve output parameters, i.e. improve effectiveness. At the same time for unchanged external situation each non-equilibrium system attempts towards self-organization on the account of internal options, choosing for process progression ways with minimum loss of energy (the price is sometimes recompensed by feasible entropy production).

The notion self-regulation is also used, it keeps to the principle of Le Chatelier-Prigogine and exposes the ambition of the system to preserve a stable structure in a given interval of external perturbations by means of creation of internal forces, which decrease the impact of the external factors. Self-organization will be a highest degree of self-preservation of system structure (incl. self-reproduction) resulting from the modification and decrease of the external influences.

According to H. Haken the spontaneous growth of highly ordered structures born of lower degree of order (i. e. higher degree of symmetry) is related to self-organization processes. Self-organization is a process of purposefulness and spontaneity along with relative independence of the interaction environment-system. The external impact of medium is of general, global character, e. g. pressure, temperature, matter gradient, etc. This impact does not contain instructions (program) for the realization of self-organization process, like by some organization process. During self-organization global external impact stimulates the release of internal to the system mechanisms, due to which arise specific structures.

3. OUTLINES OF SELF-ORGANIZATION IN TRIBOSYSTEMS. EXAMPLES

The explicit style of self-organization study in tribological systems was initiated in the beginning of the 1970s with the works of B. I. Kosteckii, L. I. Bershadskii, G. Polzer, D. N. Garkunov, W. Ebeling, etc. Important direction in these efforts is related to the creation of dissipative structures in tribosystems in the presence of sufficient strong energy impact (e.g. effect of self-organization is the phenomenon of abnormal low friction in friction couples under irradiation with intensive flow alpha-particles [3]. Study of the secondary structures becomes main direction in self-organization investigations. The concept of structure-adaptiveness in the abundant research of B. I. Kosteckii and L. I. Bershadskii should be included in the knowledge for adaptive self-regulation.

Similar is the running-in phenomena accompanying the starting process of frictional systems [4]. During running-in phase there is minimum energy dispersion. In the surface layers of contact bodies develop intensive physico-chemical processes building microrelief and surface properties characteristic optimal for system's behavior under given external conditions. After completion of running-in process the system enters the steady state phase characterized by dynamical equilibrium of the contact processes. Well-known example of self-organization in contact processes is the influence of adsorbed layers on surface strength reduction in the effect of Rhebinder.

One of the most important and practically applicable phenomena in tribosystem self-organization is the selective material transfer on contact surfaces [5,6]. The selective transfer is a kind of frictional interaction concerning mainly the molecular component of friction. As a result from the development of chemical and physico-chemical surface processes is obtained auto-compensation of wear and reduction of friction. Characteristic is the system of formation of servovite layer, in which is realized diffusion-vacancies mechanism of deformation without gathering of defects, which would be characteristic for fatigue processes. So, this secondary structure maintains a merciful regime of friction surface destruction and minimal wear (the phenomenon is also known as zero-wear process).

In most cases self-organization effects in the system resulted from purely internal reasons are much smaller than those obtained by dominant external affect. However, such external impact has in a sense limited application: incited selective transfer resulting in frictional coating of the surface and zero-wear

presumes availability of particular copper-containing material and special surface-active substance (additive) in the lubricant; effect of abnormal low friction is manifested in a narrow range of external conditions and low variety of materials; application of fluid or plastic lubricants with high effectiveness becomes impossible for tribosystems functioning under vacuum conditions and low temperatures, etc.

Modern tribological conception about friction, wear and materials give opportunity in many cases to optimize the conditions for introduction the system in operational regime by means of intentional influence in order to form protection properties of the contact body. Normal wear of metal is assured at frictional strengthening originated by local phase transformations in the surface layer along with formation of tempered structures of elevated hardness (martensite due to friction, white zone), and for other metals – as a result of deformation strengthening.

Related to this optimization of the conditions of system initiation in operational mode aims creation and maintenance of normal wear in the period of real contact zone running-in. Optionaly [4] (provided specified sliding velocity corresponding to normal wear), a tribocouple can be loaded following special program of stepwise increment of normal load. The choice is controlled by the assignment for minimum introduced energy, enough for the formation of protection secondary structures in the contact zone. This way of loading gives progressive and homogenous frictional strengthening in a maintained merciful regime of friction surface destruction, along with minimum running-in wear.

Self-organization in contact phenomena have been explicitly observed in the Tribology Center Sofia along with the Space Research Institute and the Institute of Metal Science at the Bulgarian Academy of Sciences [7-11]. One kind of studies concern gas-impenetrability of contact gaps by fluid contact conductance (by reason of a kind of self-regulated contact structure rearrangement, contact gap becomes impermeable for some gases and for specific external conditions, even though the size of gas molecules is incomparably smaller than the reduced contact porosity "channels"). Encouraging series of material examinations under vacuum testing of dry friction of different were carried out. Results related to self-organization have been spotted in several cases of aluminum, borated steels, leaded bronze, etc. Due to spontaneous forming of a hard component of the type Ni_3Al, deposited on the surface like a web, the usual accepted as weak towards wear-resistance aluminum can improve significantly the wear intensity of its frictional surfaces under dry friction conditions. The result was obtained by means of laser treatment of aluminum surface previously coated with thin Ni layer. Self-organization on the surface is possible as a result of the concentrated energy of the laser beam – the formation of the hard coating Ni_3Al is only possible for this type of treatment [11]. So, the way of applying the energy is of utmost importance for the subsequent self-organization processes.

Transient metals (vanadium, zirconium, titanium and molybdenum) help the process of special structure coatings formation on steels with improved wear behavior, e.g. combined coatings of the type "Fe-alloying metal-B" [7,8]. An interesting rearrangement in the contact structure for leaded bronze resulted in important decrease in the friction coefficient and wear intensity.

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