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SELECTIVE TRANSFER OF MATERIALS IN THE ASPECT OF GREEN TRIBOLOGY

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Abstract: *One of green tribology's principles touches the environmental implication of coatings and lubricants, development, optimization and implementation of ecology friendly manufacturing and implementation of coatings.The paper deals with green tribology in the aspect of wear reducing frictional coatings and regeneration of worn surfaces without joint dismantling. Copper frictional coatings in the case of nonabrasive treatment of steel or cast iron surfaces, their production with the assistance of selective transfer of materials between the friction surfaces are considered. In the example of frictional coating deposition, this phenomenon is supported by the rubbing of brass stick on steel cylinder surface under particular conditions of selective transfer in the presence of a special lubricant. Important is the extremely low wear of components coated under condition of selective material transfer mode with wide practical application. The interdisciplinary character of the study and application of technologies for coating formation, layer growth techniques, surface texturing, etc. involves studies by specialists of different sciences.*

Keywords: *green tribology, frictional coatings, surface design, selective transfer.*

1. INTRODUCTION

1.1 Tribology and Green Tribology

Natural resources have been cruelly consumed in the last three centuries and the earth is seriously damaged and polluted. Humanity has to survive fighting with the pollution and the deficiency of material, energy and cleanness. Generally speaking, this problem is mainly the result of the misuse of our contact with nature. So, it is contact deficiency and a way out could be sought in the science of contacts, i.e. in tribology. Radical knowledge and technologies of sustainability are needed to establish new human way of thinking.

Tribology is supposed to assist the knowledge and technologies in the purpose to meet the expectations of quality, reliability and environment sustainability. Tribology comprises the knowledge of friction, lubrication, wear, hermeticity and other process between contacting surfaces. The modern concept observes tribology problems as essentially interdisciplinary. Typical tribological studies involve the efforts of mechanical engineers, material scientists, chemists, physicists, and so forth. New areas of tribological studies have been developed at the interface of various scientific disciplines, for example, nanotribology, biotribology, geotribology, ecotribology, etc.

Recently, the new concept of '**green tribology**' has been defined as 'the science and technology of the tribological aspects of ecological balance and of environmental and biological impacts' by H. P. Jost [1,2]. The former notion was eco-tribology and stressed the interaction of contact systems with the environment [3,4]. Green Tribology means saving materials, energy, improving the environment and the quality of life. The area of Green Tribology will directly affect the economy by reducing waste and extending equipment life, improve the technological and environmental balance, and improve the sustainability and safety in the human society. Green Tribology reflects in fact the tribological aspects of ecological balance and of environmental impacts, and is expected to directly affect the reducing of waste and thermal pollution, and extending equipment quality, reliability and life, which are some of the key challenges facing the societies today [5], [6], [7].

1.2. Wear prevention

Tribological knowledge helps to reveal and heal wear related problems. So, it is possible to improve quality significantly by measures preventing the reasons for failures related to wear of contacting surfaces. What is wear? Wear is a process of tribological interaction resulting in physico-chemical loss of material (weight, size or shape) from the surfaces in contact. Most important forms of wear are abrasion, corrosion, erosion, attrition, fretting, thermal destruction, scuffing, pitting, etching, etc. [8]

The specific field of green or environment-friendly tribology emphasizes the aspects of interacting bodies, which are of importance for material, and energy sustainability and safety, and which have huge impact upon today's environment. This includes essentially the control of friction and wear, being of importance for energy, resources and cleanness conservation [5]. One of the most important tasks of Green Tribology is ***Minimization of wear***. Wear limits the lifetime of components and creates the problem of their recycling. Wear can lead to high consumption of the natural resources. Wear creates debris and particles that contaminate the environment and can be even hazardous for humans. Moreover, the large amount of heat generated in the contact joints, also leads to its thermal distortion and failure, and to pollution of the environment with material waste and heat.

Measures for minimizing wear are related to surface processing, namely optimal material selection and surface texturing, and/or **coating the surfaces**. It leads to good health and preservation of performance quality of machines, equipment and production systems, and hence, material, energy and environment saving as a whole.

1.3. Surface coatings

There are various methods for surface coatings deposition, a diversity of approaches to study the behavior of the coatings, and numerous areas of their application.

Wear prevention coatings are applied in many areas: production industry and power industry, marine, automotive and transportation industry, aerospace techniques, agriculture, food processing, mining and metallurgy, sporting equipment industry, electronics, packaging, robotics, renewable energy sources, waste treatment and more. A great variety of parameters influences the quality of the coating, depending also on the application. Important characteristics are: thickness, porosity, microstructure, inclusions, cracks, microhardnes and adhesion and cohesion bond strength [9]. Control is realized using various standardized test methods by means of tensile test machines, scratch testers, etc.

The paper concerns the method of coating deposition during friction process. It aims and focuses on the procedures of obtaining and the study of copper frictional coatings under selective transfer mode in the case of nonabrasive treatment of steel and cast iron surfaces.

2. FRICTIONAL COATINGS UNDER CONDITIONS OF SELECTIVE TRANSFER

2.1. Background

Tribologists have the task to keep the destruction as small as possible or to stop it, in order that the system comes to the equilibrium process between destruction and regeneration. Exactly this happens in the process of selective transfer of material between friction surfaces. In the case of frictional coatings production, this phenomenon is assisted by rubbing of brass against steel under the special conditions of selective transfer.

D. N. Garkunov and G. Polzer are of the first researchers in theory and practice of selective transfer of material during friction coating deposition [10], [11], [12], [13]. Common works were carried out connecting the Tribology Center in Sofia and the Tribology Group of Prof. Polzer in Zwickau, and recently in Schoenfels, Germany. What is friction coating deposition? A steel element (e.g. a shaft) to be coated is both subjected to rotation and to the pressure of a brass stick in the presence of a special lubricant, forming a bronze-steel tribocouple (See the principle in Fig. 1).

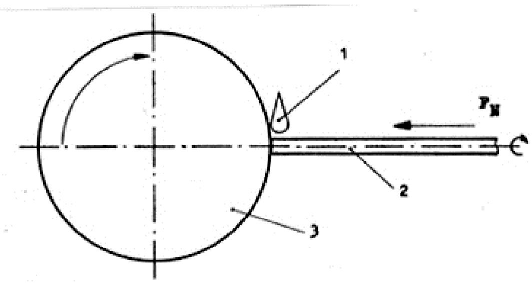

Figure 1. Principle assembly for brass deposition on shaft (1 - surface active liquid; 2 - brass rod; 3 - shaft to be coated)

The film forms on the friction surfaces in the bronze-steel tribocouple with glycerin lubrication passing firstly through dissolution of the bronze surface, where the glycerin acts as a weak acid. The atoms of the elements (tin, zinc, iron, aluminum) absorbed in bronze outgo into the lubricant, as result the bronze surface is enriched with copper.

Friction deformation of the bronze surface causes new passing of elements into the lubricant, so the bronze layer is purified and it nearly contains only copper. Its pores fill with glycerin. Glycerin is reducer for copper oxides, hence the copper film is free form oxides; it is very active with free ions and is highly adhesive for the steel surface. The steel surface is covered by thin copper layer. Self-organization and selective transfer of copper to steel take place. Before the stabilized selective transfer, the process goes on until steel and bronze are coated by 2 μm copper layers [12]. Mechanical and chemical transformations take place; e.g. formation of surface active substances on the friction surfaces; they interact chemically with the surfaces and form chemisorbed layers (see Fig. 2).

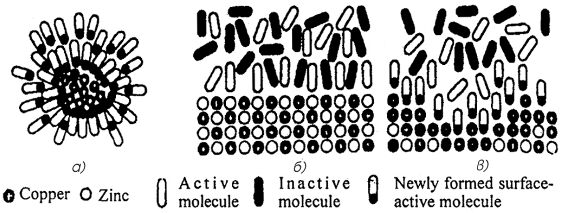

Figure 2. Formation of micelles and interaction of surface-active substances with bronze (as per [12])

Some results of the basic studies and application in the area of copper frictional coatings are presented below. Based on equation of the theoretical physics, G. Polzer [11] had formerly derived equations of self-organization at friction. Always when destruction problems are available in nature, there is either a simultaneous growth process which involves equilibrium between destruction and regeneration or destruction leads to exponential destroying of the whole system, in our case the tribological couple.

A self-organization in the system brass-glycerol-steel is observed and the obtained film – a coat with significant change of wear-resistance. Major result is the low wear of components coated under condition of selective material transfer mode. Important is also the reduction of the concentration of hydrogen at the frictional surface and, respectively, the lower hydrogen wear. It is highly important for practical applications that the inclination for welding and seizure [13] between the friction surfaces is significantly lowered under conditions of selective transfer. A considerable practical result is the possibility for dismantling-free restoration of worn units/couples.

2.2. Experimental work

The phenomenon of direct coating deposition is assisted by the rubbing/deposition of brass under the special conditions of selective transfer of material. Different processes result. In the contact zones emerges reactive coating deposition with special properties: Copper is rubbed on the steel friction surfaces with totally different electro-chemical potential, and secondly, not only the content but also the structure in the friction surfaces is being changed [13].

The compress forces at the rotation of the brass stick involve great pressure in the contact zone between stick and basic material due to the relative small contact surface, hence a positive gradient of the shear strength in depth direction of the friction surface according to I. V. Kragelsky [8].

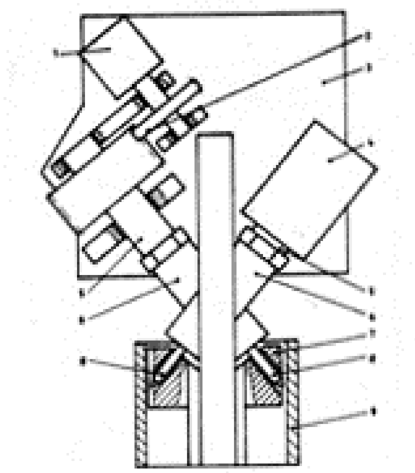

Figure 3. MBZ 3A Brass-coating device for sliding bushes (application in lathes)

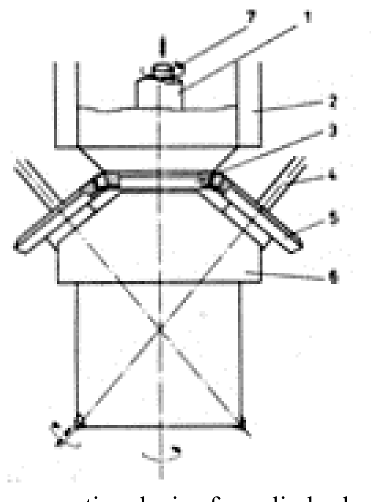

Figure 4. Brass-coating device for cylinder-bushing by boring machine

As a result, a tribological system appears which can bear higher loads at the influence of various processes. Different machines were designed and constructed at the Department Tribotechnik in Zwickau' Higher Technical School, corresponding to the principles of the frictional deposition and the ideas of the selective transfer. Many pieces of the devices „MBZ 1" for shaft coatings and „MBZ 3 A" for application in rotating machines were manufactured (see Figs.3, 4, 5, 6), e.g. the „MBZ 3 A" for engine cylinders was produced in 30 items. Unfortunately there is not sufficient use of the advantages of the deposition of copper frictional coatings in the overall practice.

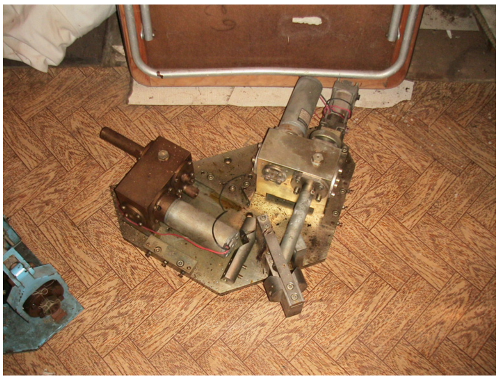

Figure 5. View of the brass-coating device MBZ 3A

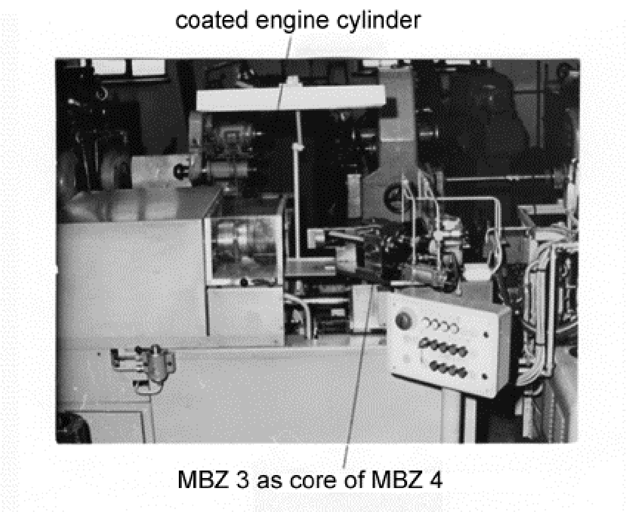

Figure 6. The brass-coating device applied in an automatic machine

Some diagrams referring to a part of the basic new results are presented below. In Fig. 7 is given the variation of hardness in depth; so the strengthening can also be obtained at different rotation speeds.

Fig. 8 shows the reduction of hydrogen concentration of the friction surface in depth. The hydrogen wear results from synergetic interaction of various surface phenomena: exoemission, adsorption, frictional destruction, which provide hydrogen extraction from the frictional surfaces. Thermal gradient is also formed, as well as electrical and magnetic fields; this leads to hydrogen diffusion in the metal, hydrogen concentration in the subsurface layer and rapid wear of this layer [12]. Metal defect formation in the friction deformed layer also increases the H_2 concentration and augments the wear. Frictional coatings, however, improve significantly the wearresistance against hydrogen wear [13].

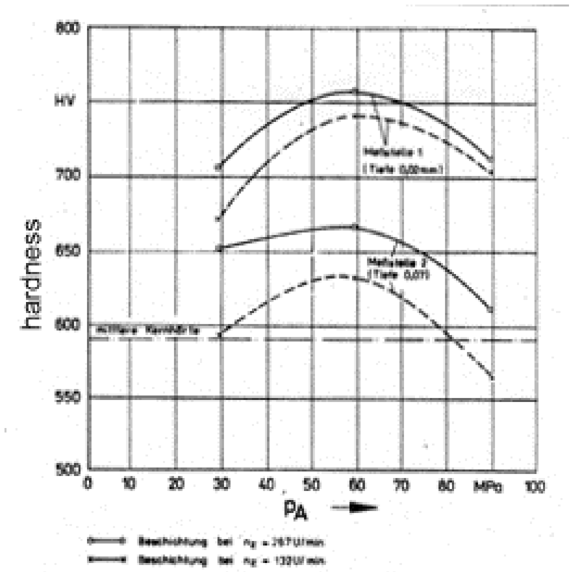

Figure 7. Hardness in different depth after frictional coating deposition on steel

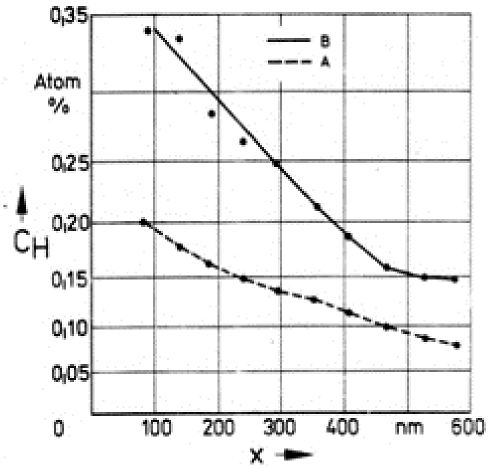

Figure. 8. Reduction of H_2 concentration at the frictional surface in depth

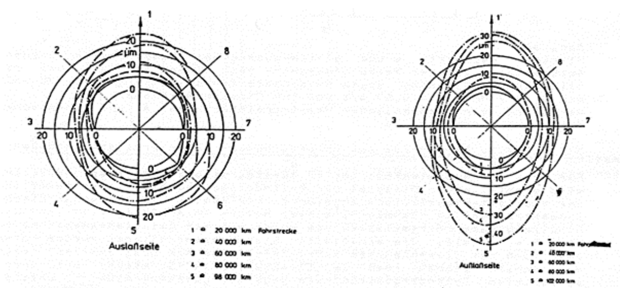

Figure 9. Wear distribution in upper dead point of engine cylinder after different sliding paths: for cylinder with frictional brass coating (left) and uncoated (right)

By means of brass frictional coating in different constructions of steel and cast iron it can be obtained not only the 10 - 20 % lowering of friction force, but also a changed wear distribution, which is to be seen, e.g., for the upper death point in engine cylinders of 2-cylinder-twotact-Ottomotors after various completed paths (see Fig. 9). This was the reason that the brass frictional coatings were successfully applied in the practice of the company Peißig in Zwickau, especially in highly loaded race motors for more than 20 years too.

3. CONCLUSION

Green tribology should be integrated into world science and make its impact on the solutions for worldwide problems. Being a new field, green tribology has a number of challenges. A basic one of them, minimising the wear, is being discussed in above investigation of wear reduction possibilities through frictional coatings.

The study of frictional coatings and their application can be summarized in the following:

- Self-organization in the system brass-glycerol-steel under selective transfer is observed and the obtained film – a designed or controllable coat with significant change of wear-resistance – can be intentionally manipulated to influence its properties during friction.
- Important features of the coating deposited during friction under selective material transfer mode: Low wear of components at nonabrasive treatment of steel/cast iron, and lower hydrogen wear of the coated surfaces; lower inclination for welding and seizure between the friction surfaces; possibility for dismantling-free restoration of worn units/couples.

The practical implementation of brass-copper frictional coating is of extreme importance and was realized in Germany, Russia, Kazakhstan, Poland, etc.

The interdisciplinary character of the study and application of technologies for frictional coating formation, layer growth techniques, surface texturing, etc. involves intervention by specialists of different sciences. The work and collaboration between scientists of Russia, Germany, Poland, Bulgaria, Mongolia and Vietnam in this field was carried out by the International Council for Selective Transfer and Frictional coatings, established in 1990 in London.

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