Graphite pellicles, methods of formation and properties

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Abstract. The paper presents the results of experimental investigations aimed at the establishing the composition and the functional properties of the graphite pellicles formed on the metal surfaces by the action of plasma in the air media at normal pressure applying electrical discharges in impulse (EDI). It shows that they have the same behavior characteristics as fullerene, avoiding the stick effect between metal surfaces and between metal and liquid glass at temperatures of the order of 400-1200 °C.

1. Introduction

The formation of nano-scale graphite pellicles on the surfaces of pieces made of different metal alloys causes their diffusion in the surface layer accompanied by the formation of carbides with high hardness and, as a result, it increases wear resistance of this layer [1-5]. The formation of graphite films in all cases leads to the surface roughness decrease.

In accordance with the results obtained by the authors [4], the application of films on the surfaces of the work pieces in the kinematic pairs leads to the reduction of the coefficient of friction by at least 3 times.

The experimental tests on the stick effect of the threaded joints has shown that the stick effect caused by the mutual diffusion of the constituent materials of the joint parts is prevented by the presence of graphite films and even when the couple is maintained in the furnace at temperatures within (400-800)°C it has been showed that for the parts made of construction steel the stick effect in the joint is not present [4].

Film formation on the internal surfaces of pipes allows eliminating the stick effect for paraffin stoppers that are a problem for pipelines of oil transporting.

Experimental investigations and trials come to show that deposits are formed more efficiently when the workpiece is connected in the discharge circuit of the current impulse generator as anode, and the formed films can reach up to 7μm thick, they increase the durability of the glass molding form components by at least 2 times, due to the qualities of solid lubricant and anti-refractory properties that they possess [2, 5].

From those mentioned above it follows that the development of an effective technology of graphite deposit formation on the surfaces of the parts from machine building industry would allow to successfully solve a number of problems such as: ensuring the surface refractoriness, obtaining wear resistant surfaces, reducing the coefficient of friction of parts surfaces functioning in the kinematic couples, buffer film formation at the interface between two surfaces of a couple, partial or total removal of the stick effect between couple parts, etc.

2. Methodology of Experimental Investigations

Experimental investigations on graphite deposition formation on metal surfaces were performed in normal working environment - air. For this purpose electrical discharges in impulse have been applied that interact with electrodes' surfaces in the regime of "cold" electrode spots maintenance to avoid melting, vaporization and removal of material from them. The bars of cylindrical cross-sectional area of (5-7)mm^2 made of technical graphite were used as tool-electrodes. To appropriate to maximum results of interests for production enterprises as workpieces were chosen: nuts and bolts with metric thread M16, plungers applied in molding packaging bottles, component parts of glass molding forms, pipe segments, etc. These pieces were connected in the discharge circuit of the current impulse generator as anode. Materials of which were executed were relative diverse and included group of steels (steel C45, C35), cast iron and bronze alloys. In order to form graphite depositions without melting and vaporization of the machined surface of the workpiece as a source of energy the current impulse generator was applied whose construction and principle of operation is described in [1]. It provides formation current impulses with duration ranging in limits of 10^{-6}-10^{-7} s which corresponds to the life duration of the "cold" electrode spots. Generator offers formation of the current impulses with the following parameters: the energy released in the interstice W_S=0÷4.8J, the energy accumulated in the condenser battery W_C=0÷12J, the charging voltage applied to the condenser battery U_C=(0÷250)V, for its capacity contained within the C=100÷600µF with the step of 100µF. It provides electrical discharge impulses within the interstice values S=0.05÷2.5 mm; discharge frequency f=0÷50Hz. The morphology of the machined surface was studied by means of SEM technique and the chemical composition by means of EDX technique. The adherence of the formed film on the machined surface was achieved by shear tests on a dynamometer type FPZ HECKERT 100. To identify changes in adhesion properties as a result of applying graphite films, it was performed by measuring comparative detachment forces of assemblies made with a strong adhesive - polyurethane - between a set of samples and specimens treated with graphite and without treatment. A set of 3 specimens with graphite treatment and a set of three samples without treatment were supposed to adhesive; the specimens were treated at the end with the graphite film as disclosed in the paper [3]. After adhesive application the specimens overlap an area of 25x25 mm, and after drying of the adhesive they were subjected to the traction.

To measure the wear resistance of graphite films deposited on glass molding plungers the universal microscope of UIM-21 type was used permitting measurement with an error of 1µm as described in [2]. The component parts of glass molding forms (numbered in accordance with the their assembling drawing) were subjected to wear in glassy mass for 44625 cycles (85 hours) for the sample no.19 and for 39900 cycles (75 hours) for the 23 sample. The speed of cycles constitutes v=8.75 cycles/min, the temperature of the glass drop is 1129 °C, the glass of BT-1 type for bottles' molding was used, its chemical composition corresponds to the standard GOST R 52022-2004 SM.

In order to determine the anti-stick properties 6 pairs of bolt joints were selected, of which three pairs of pieces were with deposited on bolt's surface graphite films and another three were kept intact. They were engaged through the action of the same torsion moment. Thus, three pairs were formed for investigations; there were two couples with and without the presence of graphite film in each of them. The studied pairs were placed in the NaCl solution with a concentration of 3% for 24 hours after which they were insert into oven at temperature of 800 ℃ where were maintained for 10 hours, then the measure of the unscrewing moment of the investigated joints was made in accordance with [4].

3. Results of experimental investigations and their interpretation

The morphology analysis of the surface machined by applying EDI with graphite tool-electrodes showed that physic-chemical changes on the surface does not exceed micrometer sizes. Apart from the initial components of the processed material a considerable amount of carbon (about 80%) in atomic