Study on modernization processes in the coating metal surfaces (plain bearings) by thermal spraying

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Abstract: *Knowledge accumulated within the metal coating through thermal spraying allows the understanding of aspects related to the coat structure phenomena, in this case of the routs that need to be followed in order to create strong and stabile connections between the coats subsided through thermal spraying, between the particles that compose those coats, respectively. However, all this knowledge does not ensure the understanding of some practical situations that are apparently paradoxes, as for instance the absence of tin bronze adherence to ignobly steel holders, the perfect adherence of bronze to the aluminum on the same types of holders, in the context in which both elements, tin and aluminum, respectively are found in equal quantity in the two type of bonze that maintain them in solid solutions (below 10%).*
The parallel study in the sinter antifriction domain has offered information regarding the optimal correlation between the composition of antifriction material and the required type of application, the optimal pinches level and the way that this morphological characteristic may be influenced. By experimental research it is necessary to determine the conditions under which such coverage can be obtained by thermal spraying of the metal coatings.

Key Words: *the optimization of the experimental module, optimal adherence, optimal structure of antifriction holders.*

1. INTRODUCTION

The research made in the metal coating domain through thermal spraying and one of the main applications of these technologies – coating creation with antifriction characteristics has shown a series of aspects regarding the kinetic formation of these coats, their adherence, cohesion and possible performances.

In the metal coating literature, the thermal spraying does not offer sufficient information regarding the adherence nature of the holder's coats such as to make possible the anticipation of behaviour of some types of subsidence in contact with the holders, namely the operative determination of technological that will allow the achievement of maximum adherent holder coats with a minimum effort.

Moreover, the literature of specialty contains few data regarding the concrete effect of the variation of different influential factors over the adherence, cohesion and tribological performance of the achieved coats.

When they are encountered, the data is referring to the effect of singular variation of the influential parameters without offering information under the form of process models regarding the effect of simultaneous variation of many influential factors. The research has shown the advantages of metal coating using a flame arc; this technique is increasingly used on the global scale.

All the information in the domain of metal coating through thermal spraying lead to the conclusion linked to the existent similarity between the morphology of this coats and of the coats obtained through the process of synthesizing: pinches, respectively pinches represent the common feature of the coats composed through the two processing versions, controlling their dimension and respectively the volume proportions making possible their use in tribological application series.

The documentation study made on the synthesized antifriction material has shown apart from the importance of choosing a base and alloying elements (manufacturing networks), the major role of micro structural components, including pinches, over the resistance and antifriction characteristics.

In this context, the conditions in which such coats may be obtained through metal spraying (thermal spraying) techniques will be determined by experimental research. In order to answer the following theoretical and practical issues of high importance related to metal coating through thermal spraying, that study underlined the need for general and specific approach to the versions of thermal spraying using a flame arc:

> Foundation of the adherence nature of the subsided coats through thermal spraying;

> Model the influences of the electrical, geometrical and gas dynamic parameters of the thermal spraying process using a flame arc;

> Optimization of objective functions.

The subject has awakened the interest among foreign scientists (Dr. Prof. Mustapha Khadhraoui – Provence University – France and Dr. Georg Jarczyk – Frankfurt – Germany), which have asked for details regarding the research stage.

The results of the trial applied to the Bz pseudo alloy with aluminum on steel support covering bearing has shown the following:

- Resistance to contact pressure has assured functioning without modification of the bearing’s active surface form;
- The attrition of the covering coat has been done within the admissible limits (no significant dimensional differences of the baking active surface diameter between the beginning and the end of the trial have been recorded), so no difference in the balance of the bearing has appeared;
- The conformable antifriction coat has been sufficient in the operation conditions with an offsetting of maximum 0.025°(1.5’-within the balance limit of the bearing);
- Thermal behaviour was good in conditions of gradually increasing the temperature of the oil at the exit up to 60°C;
- The good compatibility between the covering coat (pseudo alloy bronze and steel) and the axle material.

Good results have been obtained regarding the behaviour of the bearing (jamming has not appeared) even in conditions of poor greasing (low pressure of the oil at the entrance of the bearing) at a failure stop.

2. OPTIMIZATION OF THE EXPERIMENTAL MODEL

The experimental research has followed among solving some unclear aspects of the metal covering through thermal spraying, solved in practice but not theoretical substantiated, quantification of influences of the electrical, geometrical and baric parameters of the thermal spraying using a flame arc process over the adherence, cohesion and pinches of the coats and the optimal tribological characteristics associated to these, respectively:

- Verifying the absence of tin bronze adherence on unalloyed carbon steel holders; the phenomenon was detected in practice and the existence of this characteristic in the presence of some attachment steel coatings that contain chrome;
- Confirmation and quantification of the adherence and cohesion level and the level of tribological characteristics of the aluminium bronze coats subsided through thermal spraying on unalloyed carbon steel holders.

In general the technological process of subsiding through thermal spraying is achieved within the following stages:

- degreasing (carbon dichloride, westrosol, etc.);
- sandblasting the surface that is to be covered, in under pressure sandblasting installation, using corundum 125;
- subsiding adherence coat of 0, 2 – 0, 3 mm thickness;
- subsiding to proper coat, the covering coat, with thickness up to 2, 5 - 3, 0 mm.

It is intended to establish a complex technology in order to achieve some high reliability, high mechanic resistance bearings with an optimized transitory operation regime of friction behaviour by using a composed bearing with a steel body, subsided materials and with good tribological characteristics an increase of the mechanical and tribological characteristics has been achieved.

Considering the follow up effects, the material subassembly support/coat subsided must ensure a multitude of properties that will enable the functioning in specific operational conditions: surface properties; volume properties; interface properties; technical-financial characteristics.

Bronze with aluminum are used as part materials because they are the strongest and complex base alloys of copper. Aluminum offers resistance and also the capacity of being hardened through thermal treatment. The disadvantage of bronze is its low ductility that affects the conformability. Therefore, the bearings made from these bronzes work with high hardness axles, which must have a very low roughness (1520 microns RMS). These bronzes have a very good corrosion and high temperature resistance.

The adherence levels of the coats subsided through thermal spraying, in different processing conditions, has been checked by traction testing (STAS 11684/3-83) and detrusion (STAS 11684/4-83), respectively. An essential aspect of this verification must be noticed:

- Their results do not indicate the real value of the coat resistance link made by the holder (adherence) but the resistance link of the particles within the coat (cohesion), if the tear takes place in this area;

- The traction tests or detrusion give information of a qualitative nature regarding the presence or absence of the coat adherence to the holder; in which case the tear takes place through the subsided coat (regardless of the trial type or the testing equipment used) on the holder observing the partial presence of the coat. It is considered that the adherence of the coat on the holder is assured, another way not;

- There is no method in the world which will allow the experimental assessment of the coat-holder link resistance; this is done, when needed, analytically through connections with empiric character.

The test was done in the following conditions:

$V_a = \omega/R = 10$ m/s;

N = 16 daN; t = 120 s.

The friction force was done with the help of a strain gauge bridge coupled to the bounded strain gauge attached to the loading device. Graduation of the effort, namely the pressure on the testing demonstration is done by attaching stamp masses on the rod representing the loading device of the mounting. Measuring the thermal effect of the friction was done with the help of a mill volt meter, thermocouple; the Cromel-Alumel type was used. The measurements were done on the opposite surface of friction.

Verifying the tribological behavior of the coats subsided through thermic/thermal spraying in fluid friction conditions were done with the help of a Timken friction couple, on a Timken at a speed of n = 700÷l390 rot/minute, (depending on the nature of subsiding) using as a lubricant the TIN125EP oil.

The tribologic tests made in accordance with STAS 12877-91 have to follow up the determination of the sticking assignment, of the friction coefficient, the degree of wear in the sticking bench, respectively.

Regarding the coats achieved through thermal spraying, in order to understand the phenomena that takes place during their configuration, in the coat, at the coat-holder interface and in the adjacent areas of the coat-holder interface within the holder, investigations have been conducted with the help of an electronically microprobe SEM JEOL JXA 5A regarding the remediation of the chemical elements contained in the coat on that section. The coats' pinches subsided in different versions of metal coating through thermal spraying used in this research, were estimated by using a new computerized analysis line of images composed from an efficient microscope, a surveillance camera and a computer equipped with a specialized software for the imagine data capture made by the Media Cybernetics Image PRO-PLUS-MATERIALS PRO 95 company.

Metallographic analysis made in the aluminium bronze holder-coat interface adjacent areas subsided through thermal spraying, characterized below, emphasizes the distribution of the two elements of the sprayed material, copper and aluminum in the coat and holder. Without emphasizing the increase (x300) of the aluminum atoms' concentration in the superficial coatings of the support, respectively in the areas in which probably redox type reactions took place, the atoms of this element have substituted the iron atoms in his oxide network.

3. OPTIMAL ADHERENCE. FOUNDATION OF OPTIMAL ADHERENCE OBTAINENED FOR THE COATING SUBSIDED THROUGH THERMIC/THERMAL SPRAYING

The coat made through thermal spraying represents a layer structure, composed of strong distorted particles and linked between them through contact surfaces, welded among them on portions with Dx diameter and Fx surface = $\pi D^2/4$.

The welded particles do not cover the whole contact surface between them; this generates the mechanical resistance difference between the resistance of the sprayed coat and the materials in a compact state.

The resistance of the achieved thermal sprayed coats depends on the number of link elements between the particles, formed during the clashing, distorting and solidifying process and it is determined by the course of chemical interaction in the contact areas.

The separation limit between coat and holder dictates the resistance of the link between these structural elements and the resistance characteristics of the coat are determined by the resistance of the particle links that composes it.

The Link between particles in a coat and in the holder respectively appears as an effect of low interaction forces of Van der Waals type, chemical interaction, and the effects of mechanical "hanging respectively".

The effect of Van der Waals type, and the link resistance generated by the mutual, mechanic type, “hanging” between particles or coat and holder particles determines a reduced value of the coat-holder link resistance.

The maximum value of this does not exceed the level of 10÷15 Mpa (10 ÷ 15 N/mm^2). Theoretically, the result indicates that chemical interaction is the main responsible for the level of adherence to the holder, to the cohesion of particles in the coat resulted through thermal spraying, respectively.

By using a specialized software to estimate the thermodynamic functions: “Chemical Reaction and Equilibrium Software with Extensive Thermo chemical Database” the main thermodynamic sizes were determined, corresponding to the probable reactions between series of materials usually used in the thermic/thermal spraying practice, the bronzes and ignobly carbon steel holders → free enthalpy of reaction and respectively their thermal effects. The obtained results have been verified and confirmed in practice: special specimens intended to adherence testing by traction/detrusion trials have been covered through thermal spraying using a flame arc on an INCERTRANS type.

The analysis of the thermodynamic data regarding to oxidation of iron matrices, emphasizes the fact that the oxidation of this element is possible even in conditions of low temperature ($\Delta rG^T<<0$) and the thermal effect of the oxidation reactions is notable ($\Delta rH^T<<0$), can you can see in figure 1.

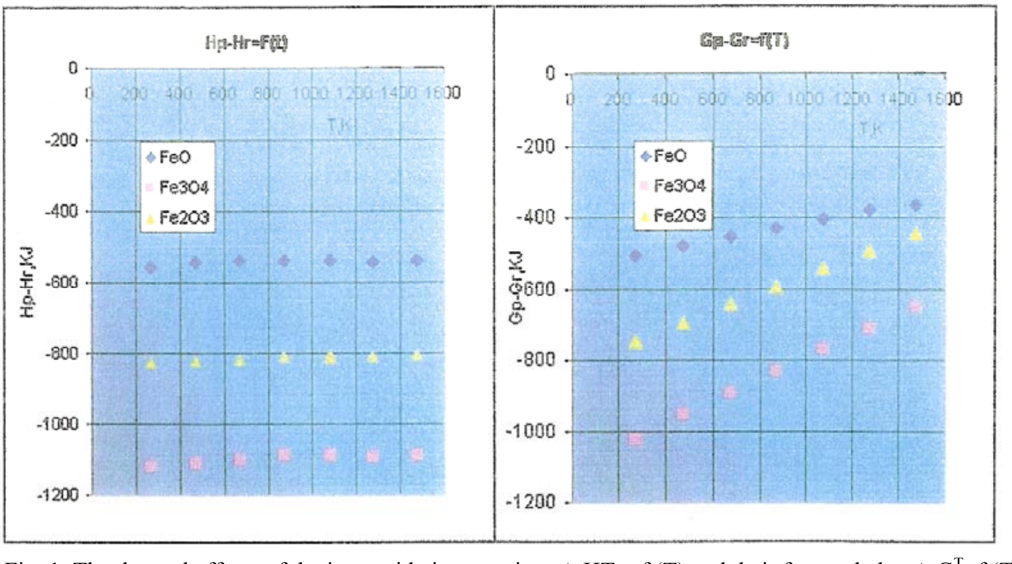

Fig. 1. The thermal effects of the iron oxidation reactions ΔrHT = f (T) and their free enthalpy ΔrG^T=f (T)

4. LABORATORY TRIALS

The results of the laboratory experiments on the aluminium bronze behaviour when subsided with thermal spraying, changing the subsiding parameters (U, p, h) and the effects manifested by the electrical, baric, geometrical and gas dynamic of the thermal spraying variation over the link resistance between the sprayed particles and holder (adherence), respectively, the level of tribologic characteristics (antifriction characteristics) and the optimization of objective functions. Based on these experiments, the previous conclusions have been drawn.

(a)

(b)

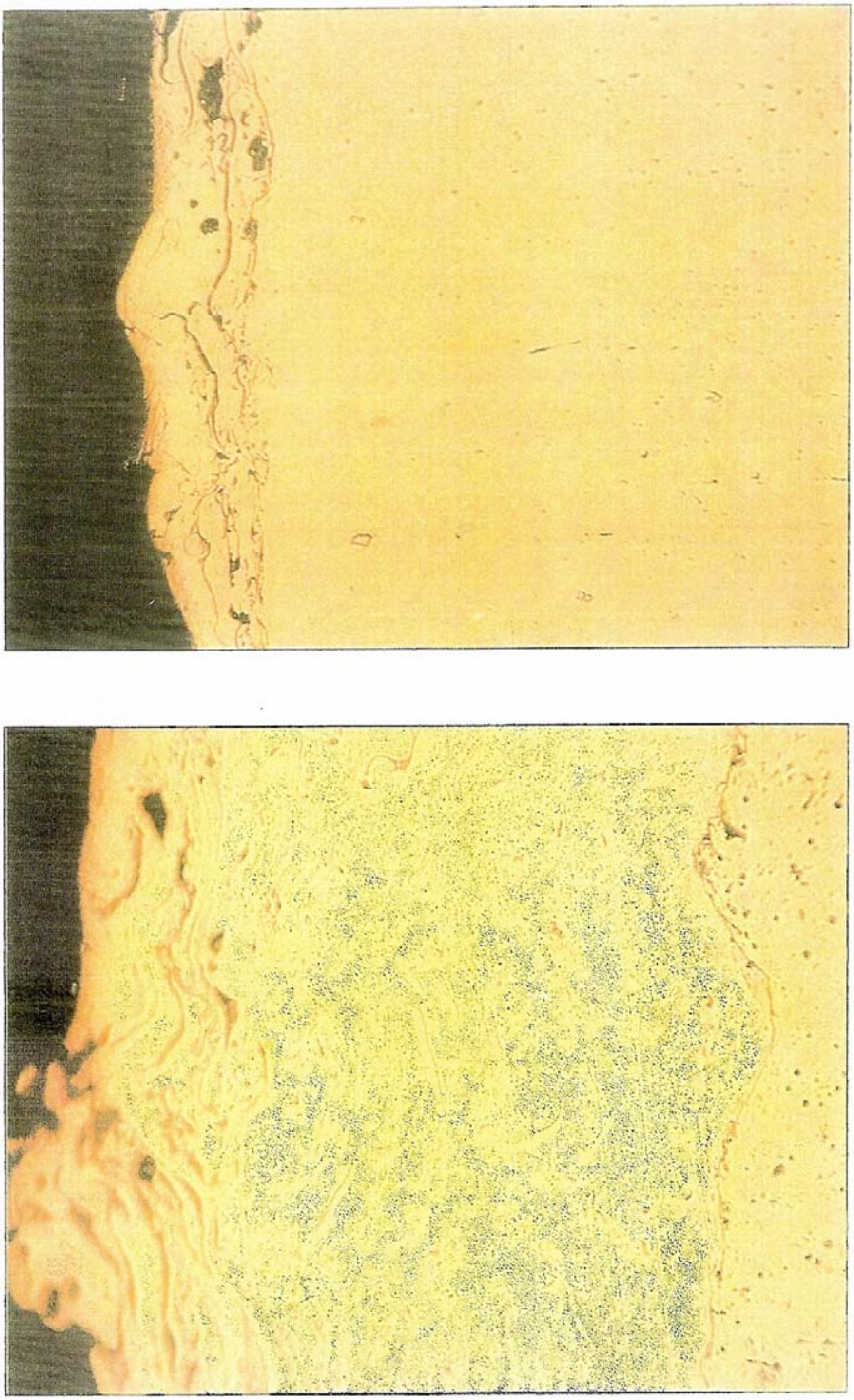

Fig. 2. The microstructure of an aluminum bronze coat subsided through thermal spraying on the holder of OL 60 (a) şi a unui strat de bronz cu nichel (b).

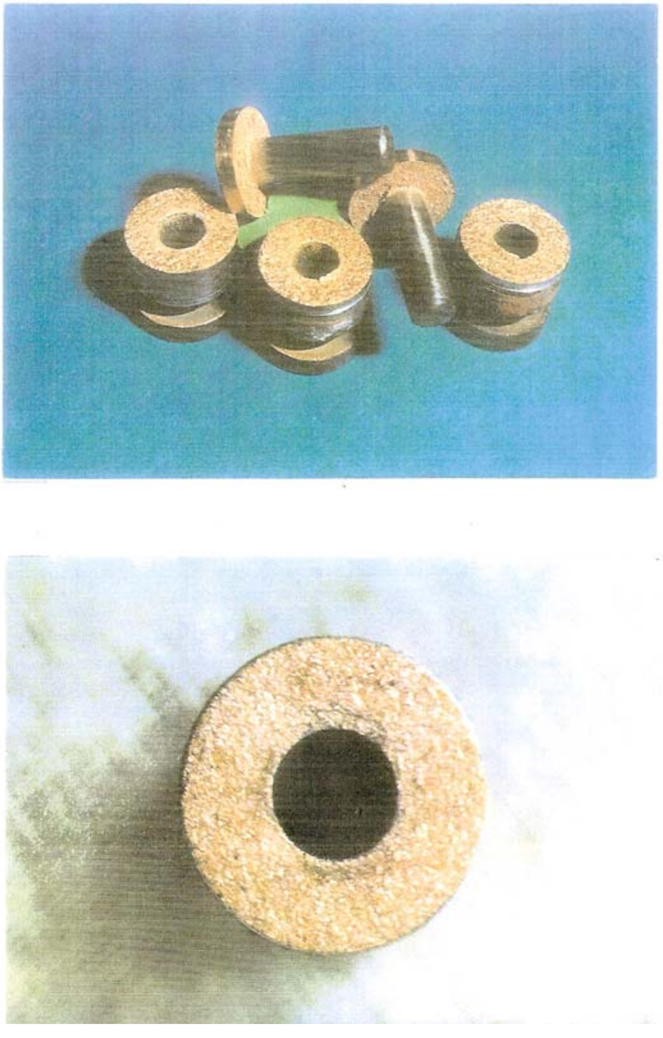

Fig. 3. Specimens used for detrusion trials

5. CONCLUSIONS

The result of the trials applied to the bronze pseudo alloy with aluminum on steel support covering bearing have emphasized the following:

- The resistance to contact pressure has assured functioning without form modifications of the active surface of the bearing;
- The wear of the covering coat has been done within the admissible limits (no significant dimensional differences of the baking active surface diameter between the beginning and the end of the trial have been recorded), so no difference in the balance of the bearing has appeared;
- The conformable antifriction coat has been sufficient in the operation conditions with an offsetting of maximum 0.025°(1.5'-within the balance limit of the bearing);
- Thermal behaviour was good in conditions of gradually increasing the temperature of the oil at the exit up to 60°C;

- Good compatibility between the covering coat (pseudo alloy bronze and steel) and the axel material.

Good results have been obtained regarding the behaviour of the bearing (jamming has not appeared) even in conditions of poor greasing (low pressure of the oil at the entrance of the bearing) at a failure stop.

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