FEATURES BEARING LAYERS OBTAINED BY THERMAL SPRAYING AND REQUIREMENTS IN SERVICE IMPOSED TO MATERIALS FOR FRICTION COUPLINGS

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Abstract*: The paper presents the main characteristics required antifriction materials used in friction couplings and technological factors contributing to these requirements. It also presents the criteria for choosing the bearing material.*
Keywords*: anti-layer characteristics, influencing factors, classification*

1. INTRODUCTION

Progress of engineering and transport is linked to increased speeds and loads in friction couplings. Bearing material requirements are determined by specific operating conditions and widely varying couplings. In aeronautical engineering and automotive, the use of bearing materials capable to operate in conditions of dry friction is a problem of current interest, its resolution providing for a substantial simplification of friction couplings construction and exploitation, to reduce weight and increase safety in operation. For the chemical, nuclear, textile, food, etc. industries, bearing materials are required to operate stable in hostile environments (water, acids, bases, metals melt, superheated gas). Also, techniques for spacecraft and low temperatures are necessary bearing material capable of operating efficiently under vacuum and temperature (sometimes) close to absolute zero. In siderurgy are needed materials capable of operating in high temperatures, etc.. Related all above, appear the requirements imposed to antifriction materials designed to operate under specifically determined conditions. In addition to well-defined properties that determine their functional capacity in concrete terms, these materials must have other properties necessary and common to all materials used. These properties relate to:

- Low value of coefficient of friction and high wear resistance;
- Optimum surface resistance and volume, combined with appropriate surface machinability items accidentally;
- Toughness sufficient to eliminate the risk of brittle fracture;
- High resistance to fatigue;
- Ability to form secondary structure with a layer of surface protective role against seizure tendency;
- Sufficient thermal conductivity and optimum value of coefficient of linear thermal expansion;
- Presence of a reserve material, solid or liquid lubricant (optional) ;
- Accessibility (technical and economic).

Along with these, for categories of materials with specified destination, are required special features. Thus, for example, heavy materials for friction torque required must possess strength (volume) large enough, materials for operation at high temperatures without lubricants must be resistant to oxidation and stability in the physical and mechanical properties temperature range, bearing characteristics associated oxidation products, materials designed to operate in a vacuum or inert gas must have high resistance to seizure because this feature actually determine the allowable working pressure values between elements of torque, maximum permissible speed that slip, etc .
It follows that there is no material bearing universally acceptable to all operating conditions of friction couplings, and therefore, choosing a particular material will be made bearing in strict correlation with the stresses to which is subject to friction torque which is intended.

2. INFLUENCE FACTORS BEARING CHARACTERISTICS

a)The role of chemistry in providing bearing characteristics.
Pure metals typically do not possess complex characteristics antifriction. To create antifriction materials by specific methods of powder metallurgy is used as a basis, usually readily available metals, with relatively low price, mainly iron, copper and aluminum recently.Bearing characteristics are obtained by adding the basic alloying elements or the introduction of anti-added.Alloying leads to changes in base of material's structure, physical-mechanical and antifriction qualities. Noting that frequently between these groups of features are not recorded interdependence: high bearing capacity is ensured by using materials with high strength characteristics and low coefficient of friction by adding special additives which usually bearing leads to a decrease resistance characteristics.Increased resistance characteristics of iron-based materials are often to ensure the introduction of alloying elements such as chromium, nickel, copper, phosphorus, manganese, molybdenum, carbon, etc., in various combinations. Improved bearing characteristics of this group of alloys is determined by the presence of graphite, sulfur, sulfides, fluorides, etc. Increased resistance

characteristics of the copper bearing material is ensured by placing tin, nickel, aluminum, iron, etc.
Anti-growth characteristics of this group of alloys are usually ensured by placing graphite, lead, silver, etc. Changing the chemical composition of these groups allows the adjustment characteristics of materials in very large limits.
In each case choosing the basis and character is determined by alloying destination of the material and therefore its expected operating conditions. Thus, bearing materials for operation at high temperatures and aggressive media must have a basic stainless and refractory, with high content of chromium and nickel. For operation in water type bases are chosen mainly bronzes and nickel-copper alloys, nickel-iron, with high concentrations of nickel, etc.
b) The influence of micro structural parameters (including porosity) on the bearing characteristics
Structural components of bearing materials, very different, can be grouped into two categories:
• hardening effects in iron base alloys: pearlite, carbides, martensite, drinking, the basic non-ferrous alloys: solid solutions, eutecticele, intermetallic phases;
• the effect of softening: pores, inclusions of graphite, sulphides, lead and other easily fusible.
The occurrence of one or other structural components is determined by the chemical composition of raw material and processing system. The final structure shows a large bearing material impact on physical and mechanical characteristics.
However, the complexity of correlations between physical-mechanical characteristics, bearing and others, the direct influence of each structural component of these features is often extremely difficult to establish, very experimental conditions (presence or absence of friction lubricants under at low values or high sliding speeds and loads, etc.) manifested may change substantially influence the character of a particular structural component of the operating characteristics of the materials.
As a general rule it should be noted that the highest level and while bearing characteristics of the physical and mechanical possesses heterogeneous structures.
For iron-based antifriction materials are possible such structures: ferrite, ferrite + graphite, pearlite + ferrite + graphite, ferrite + pearlite + cementite + graphite, graphite + pearlite + cementite. These main types of structures contain higher or lower proportions of pores and also inclusions of sulfur, sulfides, nitrides and other structural components. In case of complex alloy steels are structural features such as: austenite, austenite with different types of inclusions (borides, sulfides, carbides, etc.), martensite (if requested hard couplings), with varying degrees of porosity.
Anti-based alloys of copper or aluminum structures may have single phase (solid solution) or multi phases containing well defined chemical compounds (Cu_4Sn; $CuAl_2$; Mg_2Si etc.), pores and inevitable.
The presence of a certain phase in the material structure has an influence on the characteristics of its bearing. However, in exploitation, in the presence of lubricants the influence of the structure is showing in a lesser degree because interaction of rubbing surfaces is influenced by the presence of lubricant film.
Porosity strongly influences the physical-mechanical characteristics of powder products, a phenomenon very clearly highlighted, in particular in the case of single component materials. Increasing porosity from 5-30% (upper limit representing the maximum permissible proportion of pores in self-lubricating bearing material) leads to a reduction in strength and plasticity characteristics of more than three times (Table 1). Porosity increase is accompanied by worsening thermal conductivity and electrical conductivity.
Changing porosity of bearing materials affects their bearing characteristics, respective the coefficient of friction, the wear, etc. The general trend is to reduce the coefficient of friction and wear values with increasing material density.
Structure and properties of basic course bearing material determine its tribological behavior.

Table 1. Influence of porosity on strength characteristics of sintered iron

Porosity %	Rm Kgf/mm^2	A_5 %	HB Kgf/mm^2	KCU Kgf*m/cm^2	Rc Kgf/mm^2
5	-	-	119	3.4	-
10	23.6	15.8	-	-	-
10.6	-	-	96	1.4	-
13.8	-	-	-	-	72
15	19.7	12.2	-	-	-
15.1	-	-	80	1.0	-
19.8	-	-	-	-	67
20	15.8	9.0	-	-	-
20.9	-	-	66	0.7	-
25	12.6	6.4	-	-	-
25.7	-	-	54	0.6	-
26.3	-	-	-	-	65
30	10.2	5.0	-	-	-
30.3	-	-	42	0.3	-

Clearly the best tribological behavior is dependent on the mass ratio proportions existing basic phases and is correlated with the actual working conditions. Thus:
- Board pearlite base antifriction materials ensure high wear resistance under a regime of friction limit;
- To increase the speed of sliding, increasing the proportion of pearlite instead provide a reduction coefficient of friction.
For example, increasing the proportion of pearlite from 50-90% provide a coefficient of friction decreased from 0.12 to 0.08 [3];
- Ferritic structure provides a lowered resistance to wear and thus result in lower wear of the spindle (the second element of the friction torque was Class lll: camp-axis). The presences of ferrite in proportions of up to 50% call for a greater quantity of lubricant and allow a softer axle;
- Free cementite presence with pearlite core mass increases resistance to wear, allowing a higher load bearing, particularly in terms of limit friction without

lubricant supply and high speed bearings. It appears, however, in this case an increase in the intensity of wear of the axles. To limit escalation cementite wear is recommended that proportion does not exceed 5-10% and material shaft have up to 45-50 HRC hardness.

It results that influence in the material structure on bearing properties change substantially depending on the specific operating conditions of the household.

Porosity, structural components with impact on bearing characteristics clearly influence the strength characteristics of the material (Table 1).

Operating mode of friction torque, i.e. the absence or presence of lubricant (dry friction or fluid), mutual speed of its elements, load applied, coupled with the nature of the material elements of their micro structural features, and determines the tribological behavior of them.

That influence bearing structure material properties change significantly depending on actual operating conditions of the household. Thus, research carried out under conditions of fluid friction (constant supply lubricant from the outside - 8 drops per minute) and working parameters: loads applied up to 200 kgf/cm^2 and sliding speeds in the 0.5 to 12 m / s have concluded that the friction coefficient varies from 0.006 to 0.018 within, is strongly affected by structural changes (including changes in porosity).

Increased the amount of pearlite from 20% to 100% operating capacity of the material is increased by 1.5 times, raising the general phenomenon of resistance and in particular the hardness of the material. For example, for rolling bearing with 30% porosity, possessing structure ferritic - pearlite or pearlite ferrite pressure limit is permissible and clearly correlated with increasing sliding speed.

Thus, the speed of 4 m / s limit pressure increases from 75 to 90 and 120 kgf/cm^2 to change that structure in ferrite-pearlite and pearlite respectively increased significantly decreasing sliding speed (10m / s pressure limit is 75, 75 and 60 kgf/cm^2). In the case of structures characterized by high plasticity, or ferritic-perlite, pressure is growing and that the temperature coefficient of friction is lower than for pure structures aborting.

With increasing sliding speed permissible load friction decreases for all types of materials (i.e. basic structure mass). However, in the presence of oil (lubricant), the effect of changes induced mass change is phased basis.

The dry friction behavior of the same material conditions change significantly. Thus, with the iron bearing material, the porosity is 10% and the proportion of 20-30% ferrite subjected to friction, increased wear and recorded an increase of the coefficient of sliding friction to increase speed.

The basic materials of mass pearlite is also recorded an increase in intensity to increase the speed of sliding wear, friction coefficient but suffers a slight decrease.

Mass base material containing 12-15% pearlite cementite as a network staple features bearing steady load and speed range examined.

Increasing sliding speed, the lowest values of the coefficient of friction, wear and that the temperature on friction surfaces have a minimum porosity materials (dry friction conditions).

By increasing the material porosity camps for couplings operating under fluid friction, increase the amount of lubricant transferred friction zone, a phenomenon that provides an increase in lifetime of the camp, the allowable load limit and a temperature drop in the friction.However, the implications of increasing material porosity on the level of resistance limit the maximum allowable level of 25-30% porosity material.As such, it becomes necessary to determine the optimal porosity of materials for each specific application in hand.

c) *Choosing antifriction material composition*

c.1. *Classification of metals and alloys by their resistance to wear*

Complex practical problems related to creating advertising materials bearing the different destinations processing principles to allow a priori estimation of correct choice of a particular metal or alloy to form the basis for future bearing material. An attempt was also made by Kostețki and Nosovski and targeted one of the main features of interest bearing materials, namely their resistance to wear.

Choosing parameters for the classification of metals and alloys by their resistance to wear is based, according to two authors, the following reasons:

• sliding friction main types of wear are the order of adhesion wear it, wear phenomena caused by oxidation and wear caused by thermal effects (wear by adhesion of the order II) and abrasive wear (wear by abrasion). These types wear are directly related to the specific characteristics of friction surfaces and the interaction of these surfaces with atmospheric oxygen. These processes take place in conditions of friction or dry friction limit. Abrasive wear occurs in the presence of abrasive particles and not subject to this classification;

• key processes that dictate the level of oxidation resistance and adhesion and wear is therefore to establish the principles underlying the classification is considered appropriate to examine susceptibility metals / alloys to oxidation and adhesion respectively.

Note. To eliminate the influence of other factors shown, experiments were conducted in dry friction conditions in the presence of inert gas or vacuum (the study of adhesions) and air or oxygen (the stage of studying susceptibility to oxidation or to highlight the properties of oxide films) .

Experiments were performed on cylindrical samples, rubbed on the OLC45 part counter at a sliding speed of 6 m / s and a pressure of 7.5 kgf/cm^2. Values were estimated force of friction and wear levels. The results obtained indicate a different trend of metals / alloys was determined by adhesion and oxidation. The effect of oxygen on wear intensity depends on the material accidentally elements: surface oxidation leads to the formation of a layer with a different structure of the matrix and in some cases reduced wear intensity and the other contrary, accelerates.

Depending on metals susceptible to oxidation and adhesion phenomena and properties of oxide films formed by rubbing friction couplings elements, they were divided into four groups:

• the first group within metals and alloys (Fe, Cu, Al, steel, etc.) showing a high tendency to adhesion phenomena of order I and II. They can operate in oxidizing environments because the protective oxide film forms characterized by higher hardness than the base metal hardness appropriate.;

• in the second group (Sn, Pb, etc) shows no tendency toward adhesion formation by oxidation of the protective film, producing a mitigation of wear,

• in the third group fall metal (Mg, Co, Cd) with relatively high stability against the phenomenon of adhesion, but due to the oxidation recorded an escalation of the phenomenon of wear, the oxide film formed is extremely fragile;

• in the fourth group enter bismuth and nickel metal type, which trend shows that the wear and adhesion wear-destruction is caused by development and regeneration of the oxide film.

Metals also recorded a special rate of wear. A breakdown of metals and alloys such groups should be considered as indicative since their behavior to changing conditions of friction may change. However, the classification has practical importance because it allows consideration of the drawbacks associated with these metals and alloys used as bearing materials and determine the measures necessary for their removal. Thus, according to this classification, in terms of pure nickel bearing characteristics ranks last. However, in the world were and are made successful with the base material nickel bearing material with a stable operation in hostile environments. Pure nickel-related shortcomings have been removed by allying it with iron or copper and graphite composition with introduction of solid lubricant role.

c.2. Choice of base and alloying elements

Numerous studies indicate that between the initial mechanical characteristics of materials and their characteristics bearing is no direct dependency. In isolated cases, sometimes there is an increase of wear resistance of materials to increase hardness. Analysis of processes occurring during friction leads to the conclusion that the wear rate of friction surfaces is largely determined by the characteristics of secondary structures and a high degree of oxide films formed characteristics (hardness, strength, fragility and their adhesion to support which have formed). All this greatly complicates the problem of anti-choice base material of the future.

3. CONCLUSIONS

In choosing material bearing, its base and its alloying elements, it is necessary to anticipate all of the processes occurring during friction and lead to the formation of secondary structures optimal in terms of resistance to wear and the coefficient of friction necessary a particular application. Features metal base and alloying elements determine whether secondary structures formed. This problem is still insufficiently studied. Multitude of data on the influence of alloying elements on properties of secondary structures allows creation of theoretical bases to base their choice.

REFERENCES

[1] Butnariu, I. etc. - Integrated Technology for obtaining composites by electric arc metalizing applications to special purpose industrial equipment - acronym MCDS.MEdN - PNCDI - CEEX Program Contract 289/2006 - 2008.

[2] Butnariu, I.ş.a. - Processes and technologies in extractive metallurgy. Technical Publishing House, Bucharest, 1995.

[3] Butnariu, etc. I. - Special technology development and refining of steel. U.P.B. Publishing, Bucharest, 1993.