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TRIBOLOGICAL RESEARCHES ON COMPOSITE MATERIALS

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Abstract: The paper presents tribological researches on some composite materials TiC_x-(Fe-C), which are obtained from hard powder of TiC, bounded in a steel or special alloy matrix. In this study, there were tested the static friction coefficients for infiltrated cermets, based on titanium carbide, TiC_x (where x varied from 0.70 to 1.00), infiltrated with a Fe-0.8% C. There were used cermets, based on titanium carbide phase, incorporated in carbon steel. The static friction coefficients were measured in two different cases: before and after a thermal treatment was applied.

1. INTRODUCTION

This type of composite materials belongs to the category of MMC materials (Metal-Matrix-Composites). The tested composite materials TiC-(Fe-C) are obtained from hard powder of TiC, bounded in a steel matrix (carbon or alloyed steel) or super alloy; the metallic component contributes to the improvement of the composite material tenacity. The primary phase of obtaining pieces/components is the Powder Metallurgy. The composite materials TiC-(Fe-C) have the unique characteristics:

- processing capability by using conventional procedures;
- extreme high hardness after the thermal treatment.

The composite materials of TiC-(Fe-C) type, obtained from titanium carbide TiC_x with metallic alloy Fe-C represent a new category of materials. The chemical interaction between titanium carbide TiC_x with alloys Fe-C constitutes the theoretical basis of practical achievements of the new category of cermets composite materials.

2. THE CHARACTERISTICS OF COMPOSITE MATERIALS

The composite materials realized of titanium carbide with metallic matrix (Fe-C), mentioned in the specialized literature under the name of Ferro-TiC, represent reference points for composite materials realized on titanium carbide TiC_x with metallic matrix ($Fe-C_x$).

These materials have specific technological characteristics, some of these are remarkable and they cannot be found at any other commercial known alloys:

- **Processing.** Very easily to be processed though they have significant hardness.
- **Wear resistance.** They are 2-3 times more using resistant than the tool steel, alloyed steel or the super alloy. Sometimes they have a higher wear resistance than materials like Stellite or the composite materials like WC-CO.
- **Microstructure.** The smooth and rounded TiC particles are uniformly distributed in the metallic matrix. They have not corners or sharp shapes.
- **Hardness.** The hardness considerably decreases the inertia and the wear of the turning on and translating pieces. Therefore, they can be used in the construction of the supersonic aircrafts, rockets or armament.
- **Metallic characteristics.** The hardness, the compression strength and the elasticity module have the highest values from the hardening and processing materials. The significant hardness of the TiC compared with the matrix hardness contributes to the increasing of the plastic deflection strength, which allows the using of these materials at high temperatures.

- **The vibration damping capacity.** The annealed composite materials of Ferro-TiC type present a significant capacity of vibrations damping.
- **Oxidation resistance.** This characteristic appears due to a thin layer of Titanium monoxide which actions as a protective shield against a supplementary oxidation.
- **Corrosion resistance.** The presence of TiC in the composite material reduces the metallic material (Fe-C) exposed to the corrosive attack to almost 50%.
- **Nuclear effectiveness.** It doesn't contain elements to be undesirable in nuclear applications, being suitable to the reactor components, which require a significant wear resistance.

Due to the favorite combination between mechanical resistance and friction resistance at high temperatures and corrosion resistance and also because of favorable proportion between mechanical resistance and weight, these composite materials are used in high responsibility applications used in both common industries and high tech.

3. RESEARCHES ON FRICTION COEFFICIENT FOR COMPOSITE MATERIALS TiC - (Fe-C)

3.1. Generalities

In specialty literature for composite materials, the known results are completely insufficient – researches being at beginning – both theoretical and experimental point of view. In specialty literature there are also no references about tribological behavior of the new materials TiC(Fe-C).

Regarding to this, this paper analyses the tribologic behavior for these materials: the determination of the static friction coefficient for different friction couples, in witch one of the materials is made of composite material TiC(Fe-%C). The static friction coefficient μ_s appears at the limit between stop and go movement, it means at start. It is influenced by an important of factors; among witch the type of the material has an essential importance.

3.2. Apparatus used for static friction coefficient determination

For determination of static friction coefficient we used the following tribometer, based on the principle of measuring the angular dimensions [Figure 3.1] [1].

The apparatus is made on the principle of the inclined plane. This apparatus can be seen in the Tribological Laboratory of "Transilvania" University of Brasov.

For that type of apparatus, the friction couple is resting and it will be inclined slowly with a plane with variable inclement (inclined plan = mobile table), until the sliding appears between the mobile semi-couple and the fixed semi-couple. The angle α_{limit} = α_e, at which the sliding appears, is in correlation with the static friction coefficient μ_s, according to the following relation:

$$\mu_s = tg\alpha_l \qquad \textbf{(1)}$$

The inclining of the tribosystem driving plate is achieved with a motion screw that is seated up in a nut, having the screw thread axis inclined under 60° given the horizontal [2].

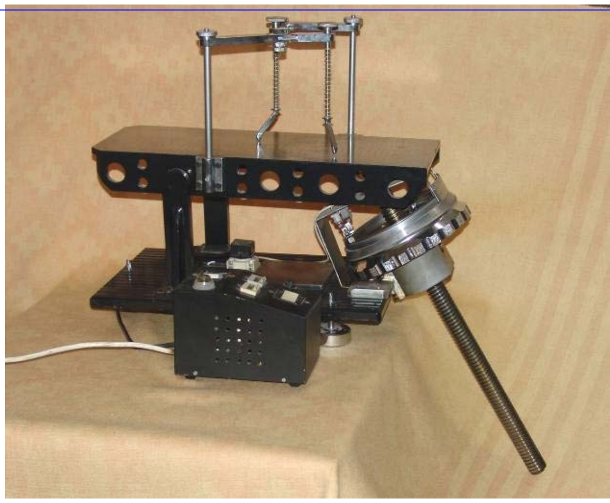


Figure 3.1 Tribometer based on angular measurements

The computation of the plate inclining is made by the determination of the fractional number "*n*" of the rotations of the screw which have the distance between two consecutive fillets of the screw "*p*" until the moment of appearing the sliding of the mobile semi couple, obtaining a non linear function, like $\alpha_e = \alpha_e(n)$. The fractional number of rotations of the screw is composed of an integer number of rotations n_i, plus a fraction of a rotation (made by a number of degrees δ and a number of minutes ε). The values δ and ε are read on the indicators of the apparatus, and "*n*" is determined with the following relation:

$$n = n_i + \frac{\delta}{360} + \frac{\varepsilon}{21600} \qquad \textbf{(2)}$$

This function is also tabled by help of computer, for all fractional number of the rotation of the barrel which rotate the screw. The working methodology is described in [1].

3.3. TYPES OF SAMPLES FOR SEMI COUPLES

There are two semi couples, a fixed semi couple and a mobile one, in contact on a plane surface, compound the friction couple. The mobile semi couple is obtained from composite material TiC_x (Fe - 0.8%C), realized for 5 different values of *x*, *x*=0.70; 0.80; 0.90; 0.95 and 1.00.

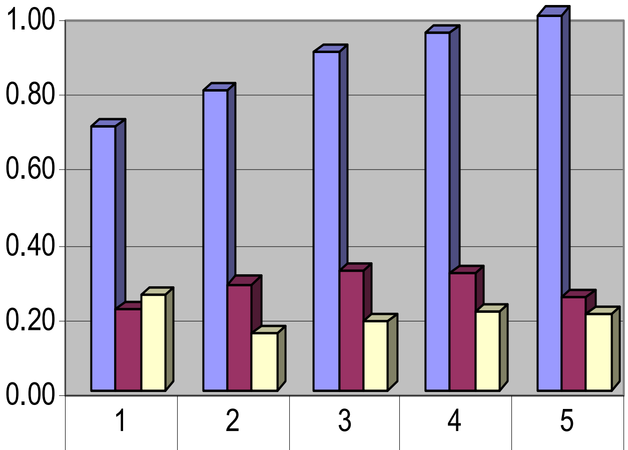
Experimental determinations were made on 10 types of materials: 5 types non-thermal treated (NTT) and the same 5 types with thermal treatment (TT) by hardening and annealing. The harding treatment was made by heating at 900°C (heating speed is 40°C/min.) and cooling in oil; the annealing was made by maintaining for 15 minutes at 200°C and cooling in air.

The fixed semi couple is obtained from different materials: pure technical metallic materials (Cu,Ti), ferrous metallic alloys (01) and non ferrous (Ti-Al-V) and composite material like "sandwich" (BL).

For each friction couple a number of three measurements were carried on using each tribometer in similar conditions.

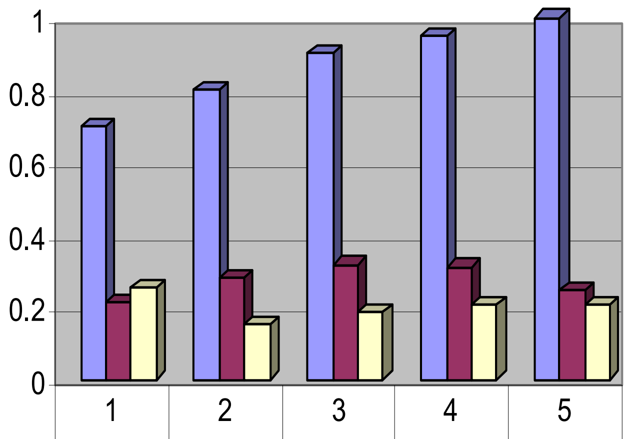
4. EXPERIMENTAL RESULTS

In Figures 4.1-4.5 there are presented the measurements results for static friction coefficient μ_s for different friction couples, regarding to the value of "*x*" in the composite material TiC_x - (Fe - 0.8%C) and the variation chart of the static friction coefficient for the same couples.



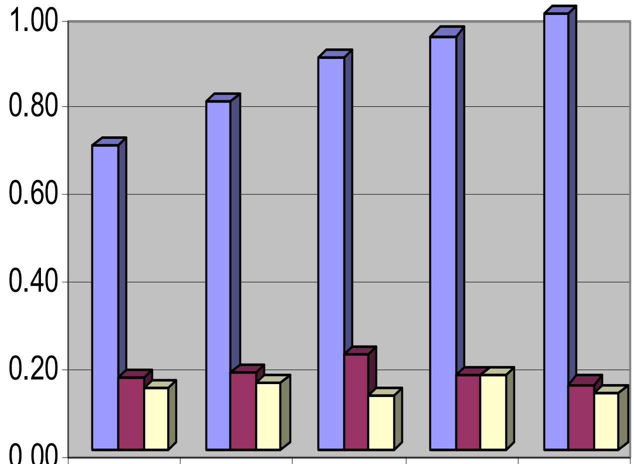
	1	2	3	4	5
x	0.70	0.80	0.90	0.95	1.00
NTT	0.21402	0.28162	0.31602	0.30992	0.24488
TT	0.25201	0.14897	0.18377	0.20703	0.20437

Figure 4.1: The values and variation chart of static friction coefficient μ_s for a couple Cu – TiC_x – (Fe – 0.8%C)



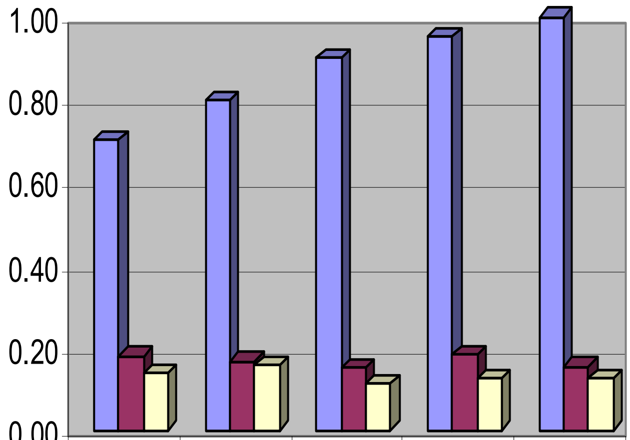
	1	2	3	4	5
x	0.7	0.8	0.9	0.95	1
NTT	0.21492	0.28252	0.31692	0.31081	0.24588
TT	0.25291	0.14987	0.18467	0.20793	0.20537

Figure 4.2: The values and variation chart of static friction coefficient μ_s for a couple Ti – TiC_x – (Fe – 0.8%C)



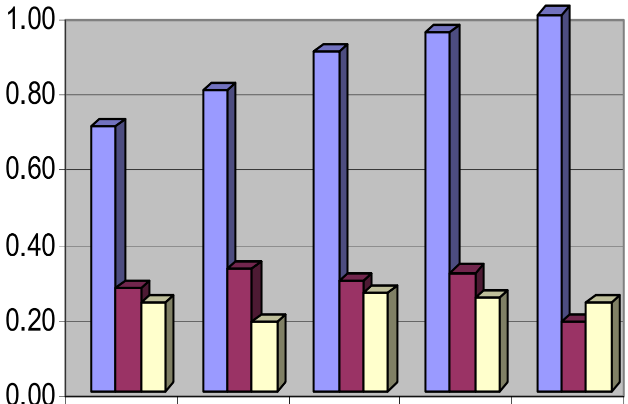
	1	2	3	4	5
x	0.70	0.80	0.90	0.95	1.00
NTT	0.16497	0.17598	0.21958	0.16951	0.15052
TT	0.14393	0.15283	0.12331	0.16951	0.12885

Figure 4.3: The values and the variation chart of the static friction coefficient μ_s for a couple 01 – TiC_x – (Fe – 0.8%C)



	1	2	3	4	5
x	0.70	0.80	0.90	0.95	1.00
NTT	0.17953	0.16705	0.15051	0.18088	0.15397
TT	0.13791	0.15467	0.10977	0.12681	0.12508

Figure 4.4: The values and the variation chart of static friction coefficient μ_s for a couple BL – TiC_x – (Fe – 0.8%C)



	1	2	3	4	5
x	0.70	0.80	0.90	0.95	1.00
NTT	0.27435	0.32137	0.29288	0.31397	0.18518
TT	0.23322	0.18271	0.26145	0.24825	0.23523

Figure 4.5: The values and the variation chart of static friction coefficient μ_s for a couple Ti–Al-V – TiC_x – (Fe – 0.8%C)

The values presented in tables are medium values that they were determined on that tribometer based on angular measurements.

5. CONCLUSIONS

The experimental results that where obtained can be summarized as follows:
(1) Friction couples based on TiC_x - (Fe - C) semi-couples display low static friction coefficient values.
(2) Each friction couple displays individual and specific static friction coefficient behaviour.
For all types of studied couples, it is obviously that it is not a trend of variation of the static friction coefficient. Each friction couple has an individual and specific law of variation of static friction coefficient. The friction couples containing semi couples realized of Ti-C_x-(Fe-C) present low values of static friction coefficient. For the semi couples made of Ti-C_x-(Fe-C) thermal treated, the values of the static friction coefficient are lower.
The low values of the static friction coefficients and also the good wear behavior and other remarkable presented properties confer to these new materials a large application area.

REFERENCES

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