IOP Conference Series: Materials Science and Engineering

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To cite this article: R Caliman 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **591** 012036

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IOP Conf. Series: Materials Science and Engineering **591** (2019) 012036 doi:10.1088/1757-899X/591/1/012036

Experimental researches on the tribological analysis of composite materials sintered with iron matrix

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Abstract. In this paper a study is conducted on the abrasion wear behavior of iron matrix composite materials, testing of samples obtained by sintering was made for different values of the applied load as for the relative speed of sliding. Starting from the studied literature, recipes of sintered sintered metal composite materials having iron matrix have been developed which have been tested for their physico-chemical and tribological properties. The prepared powders were dosed according to the formulations (Fe 68%, Cu 13%, Ni 5-7%, Graphite 6%, SiC 8%, SiO 2 8%), and the resulting mixtures were homogenized to achieve homogeneous mixtures to ensure, finally, a good reproducibility of the physico-mechanical properties of the sintered material. For forming, a cylindrical die having a surface area of 2cm^2 was used. Working pressures ranged from 5000 ÷ 6000daN/cm^2. The densities obtained for the compressed samples were determined by weighing the METTLER analytical balance and measured with the micrometer for the volume calculation. The values of „raw" densities range from 5.12 to 6.3g/cm^3.

1. Introduction

Many of our modern technologies require materials with unusual combinations of properties that cannot be met by the conventional metal alloys, ceramics and polymeric materials. This is especially true for materials that are needed for aerospace, underwater and transportation applications. For example, aircraft engineers are increasingly searching for structural materials that have low densities, are strong, stiff and abrasion and impact resistant, and are not easily corroded. This is a rather formidable combination of characteristics. Frequently, strong materials are relatively dense; also, increasing the strength or stiffness generally results in a decrease in impact strength [1-5].

Material property combinations and ranges have been and are yet being, extended by the development of composite materials. Generally speaking, a composite is considered to be any multiphase material that exhibits a significant proportion of the properties of both constituent phases such that a better combination of properties is realized. According to this principle of combined action, better property combinations are fashioned by the judicious combination of two or more distinct materials. Property trade-offs are also made for many composites [6, 7].

A composite, in the present context, is a multiphase material that is artificially made, as opposed to one that occurs or forms naturally. In addition, the constituent phases must be chemically dissimilar and separated by a distinct interface. Thus, most metallic alloys and many ceramics do not fit this definition because their multiple phases are formed as a consequence of natural phenomena [8-12].

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In designing composite materials, scientists and engineers have ingeniously combined various metals, ceramics and polymers to produce a new generation of extraordinary materials. Most composites have been created to improve combinations of mechanical characteristics such as stiffness, toughness, and ambient and high-temperature strength [13-16].

One simple scheme for the classification of composite materials is shown in figure 1, which consists of three main divisions: particle-reinforced, fiber-reinforced and structural composites; also, at least two subdivisions exist for each. The dispersed phase for particle-reinforced composites is equiaxed (i.e., particle dimensions are approximately the same in all directions); for fiber-reinforced composites, the dispersed phase has the geometry of a fiber (i.e.,a large length-to-diameter ratio) [17].

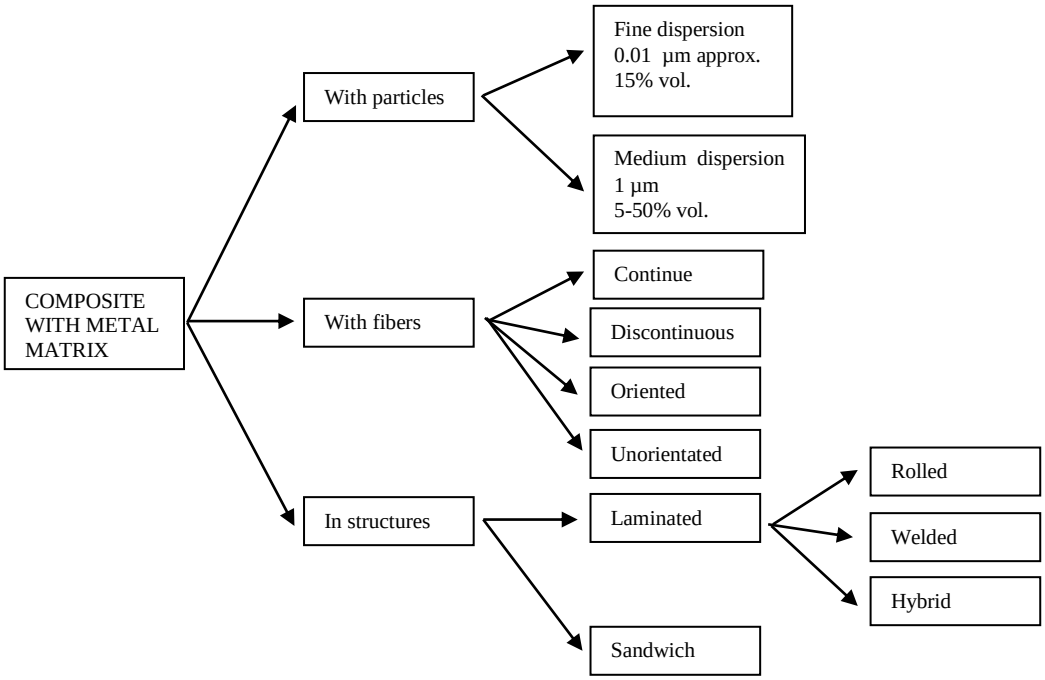


Figure 1. Classification of composite materials with metal matrix.

2. Obtaining and testing samples of composite materials with iron metal matrix

On the basis of the above, as well as taking into account the concrete possibilities of providing the raw materials required for the experiments, it has been chosen to obtain the sintered composite materials from the powders of the component elements, which method has the following advantages [18]:

• Raw materials can be purchased relatively easily.

• Using the same raw materials and their proportions in the composition, by varying the parameters of the pressing operations (pressing force) and sintering (temperature and duration) different physico-mechanical properties can be obtained.

• Mixtures made from the powders of the component parts have a very good compressibility, resulting in dense semi-products with high physical-mechanical and tribological characteristics.

The sequence of operations for the experimental program is as follows:

Experimental program for iron matrix sintered metal composites

a. Composition elaboration: iron base material

b. Material preparation: drying of non-metallic powders (graphite, SiO_2, SiC) to remove moisture - metal and non-metal powders

c. Dosage: composite iron base material

d. Homogenisation: iron base composite material

e. Pressing: compaction pressure: (5:6) x103 daN/cm^2 - for composite iron base

f. Sintering: temperature 1100˚C - for Fe Composites Fe

g. Determination of physico - mechanical and tribological characteristics of sintered metal composite materials: Density, Brinell hardness, average friction coefficient and wear material.

3. Preparation of metallographic samples for structural characterization

Stages of metallographic sample preparation are essentially the same as for any metallic sample: choice of sample type; sampling; polishing; dry grinding; final polishing; attack with specialized metalographic reagents. In recent years, by performing cutting-edge cutting machines that use very fine abrasive discs, the dry sanding step is almost eliminated, the surfaces being cut at the cutting are extremely fine [19-20].

Metalographic samples were prepared on the Buehler apparatus. Thus, sample debiting was performed on a specialized apparatus "Buehler-ABRASIMET 2" type (figure 2) having the following general characteristics: engine power - 0.8KW; speed - 2400rpm; power of the recirculating pump cooling emulsion - 75W; cooling tank capacity - 27 liters; abrasive disc diameter - 254mm.

Sample embedding was done in a BAKELITE powder on an automatic hydraulic press "Buehler-SIMPLIMET 2000", the working parameters being:

- Working pressure: 300bar;
- Preloading pressure: 10bar;
- Working temperature: 60°C
- Heating time (cooling): 8min.

After incorporation the samples were subjected to the polishing process on a "BuehlerVECTOR" automatic machine with a platter (figure 3).



Figure 2. Cutting machine type "Buehler-ABRASIMET 2".



Figure 3. The "Buehler-VECTOR" sanding machine.

In order to highlight the shape, size and distribution of the constituents from the experimental samples, qualitative optical microscopy studies and researches were carried out on the samples, using for this purpose an optical metallographic microscope. Recipes chosen for sintered materials with iron matrix are shown in table 1.

Table 1. Recipes of metallic materials sintered with the iron matrix.

	Chemical composition (% gravimetric)					
Type of material	Fe	Cu	Ni	Graphite	SiO_2	SiC
Fe-1	68	13	7	6	8	-
Fe-2	68	13	5	6	-	8

The sintering of Fe-1 and Fe-2 samples was performed in the SAFED tunnel furnace with exo-type protection under the following conditions: Sintering temperature: 1100°C, "Exo" gas flow: 4Nm^3/h and Furnace speed: 0.6m/h.

4. Tribological tests

The sintered samples of copper-based metallic materials have been subjected to complete friction tests at speeds between 8m/s and 23m/s and pressures between 4daN and 12daN using an IFTM type friction test machine.

For each recipe, three samples were tested, corresponding to their pressing forces. Given that the test results of the three samples had close values, the arithmetic mean of the results was calculated for the material characterization. Also, each determination was repeated at least 2 times.

To wear evaluation, the gravimetric method was used, the samples being weighed, on each METTLER analytical balance, after each determination.

Table 2 shows the mean friction coefficients for each recipe and test variant. For the rapid evaluation of the friction material resource, the wear intensity is expressed by the mass of dislodged material / dissipated energy ratio, also presented in table 2.

Table 2. Variation of friction coefficient and wear intensity for iron matrix sintered metal.

Type of material	Friction speed (m/s)	Compaction pressure (daN/cm^2)	Sintering temperature (°C)	Test pressure (daN/cm^2)	Average friction coefficient	Mass / Energy (g/J)
0	1	2	3	4	5	6
Fe-1	8	5000	1100	4	0.55	0
Fe-1	14	5000	1100	8	0.40	4.65
Fe-1	23	6000	1100	12	0.33	13.07
Fe-2	8	5000	1100	4	0.46	0.37
Fe-2	14	5000	1100	8	0.41	0.53
Fe-2	23	6000	1100	12	0.43	2.63

The evolution of the coefficient of friction, according to the speed at constant pressure and, respectively, according to the pressure applied to the sample, at constant speed, is shown graphically in figures 4 to 7.

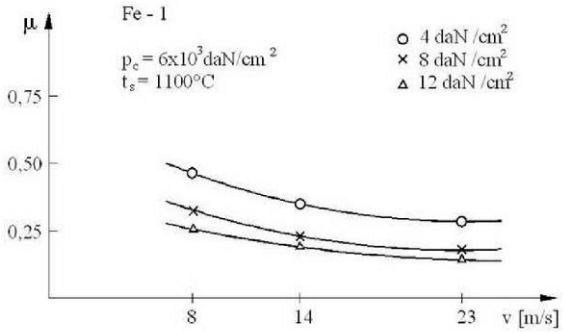


Figure 4. The variation of the friction coefficient, according to the relative friction rate, to the load applied to the constant samples for the Fe-1 material, made by pressing at 6000 daN/cm^2 and sintering at 1100°C.

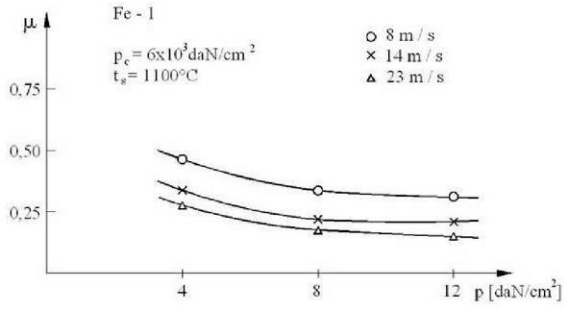


Figure 5. The variation of the friction coefficient, according to the load applied to the samples, to the relative constant friction rate for the Fe-1 material, achieved by pressing at 6000 daN/cm^2 and sintering at 1100°C.

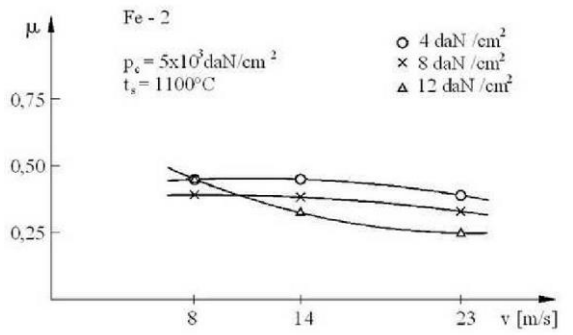


Figure 6. The variation of friction coefficient, relative to the relative friction rate, at the load applied to the constant samples for the Fe-2 material, carried out by pressing at 5000 daN/cm^2 and sintering at 1100°C.

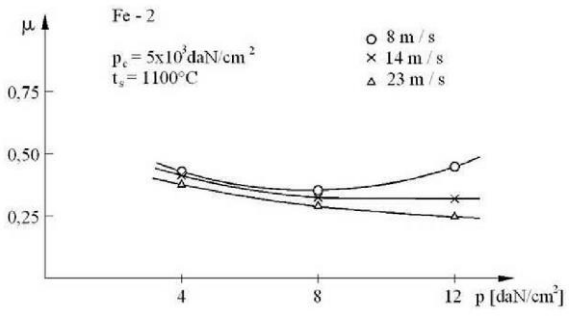


Figure 7. The variation of the friction coefficient, according to the load applied to the samples, to the relative constant friction rate for the Fe-2 material, achieved by pressing at 5000 daN/cm^2 and sintering at 1100°C.

5. Conclusions

In the paper, the documentary study we made has allowed us to highlight a series of factors that influence the physico-mechanical and tribological characteristics of the sintered composite materials. Thus, the factors are generally grouped into two categories: technological parameters (compaction pressure, sintering temperature, sintering time), composition of sintered composite materials.

I mention that we have designed, designed and made original molds for obtaining and testing of composite materials, depending on their type (with metallic iron matrix) and the tests to which they will be subjected (determinations of physical-mechanical characteristics as well as of tribological nature). The experiments we carried out involved the elaboration and testing of a number of six metal composite materials sintered with the iron matrix, grouped into two categories (Fe-1 and Fe-2) differentiated by composition and pressure compaction.

The values of the physical-mechanical and tribological characteristics obtained for the experimental materials having the iron matrix are: sintered compressed density: 4.70÷5.10 g/cm^3, Brinell hardness: 60÷105HB, average friction coefficient: 0.20÷0.55 and mass of dislocated material/dissipated energy: 0÷15.96x10^{-7}g/J.

In Fe matrix compositions, we aimed to produce materials with very high coefficients of friction, at the same time with good absorption capacity and energy dissipation, using fewer constituents in the recipe, so that the technological process is as high as possible simple. At the same time, we studied the influence of friction additions, SiO_2 and SiC.

To quickly and accurately select the composition required for some applications, we plotted the average friction coefficient graphs for different friction rate and sample stresses. Thus, we have concluded that the Fe-1 material has very high friction coefficients, which recommends it for operation in wet environments.

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