Wear Properties of Some W/Cu Materials Prepared by Powder Metallurgy

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Abstract: *The aim of the paper is to present experimental research in the field of W/Cu materials processed by Powder Metallurgy (PM) technologies. In order to fabricate W/Cu materials, mechanical alloying (MA) technique was used to obtain nanocomposite powders with the following compositions (85W/Cu, 80W/Cu and 75W/Cu). For the MA process was used a high energy vario planetary ball mill, Pulverisette 4 made by Fritsch and the milling times were between 2 and 8 hours. Green billets were obtained by die pressing at 600 MPa and then were sintered at 1180 ^{o}C for two hours. Scanning electron microscopy (SEM), ball on disk tribometer, profilometer were used in order to study the morphology and wear behaviour of the samples.*

Keywords*: mechanical alloying, nanocomposite powders, sintering, wear*

1. Introduction

Materials based W/Cu present particular interest especially because their fields of applicability as following: electrical contacts, welding electrodes, heat sinks, etc. [1, 2]. Electrical contacts play an important role in the electrical circuit in the way that, if a contact not working properly it lead to the damage of all circuit and also all the circuit take fire. To ensure a good functionality of these parts, W/Cu materials are suitable because their good thermal and electrical properties provided by copper combined with lower thermal expansion coefficient, wear and arc resistance properties provided by tungsten [3]. Due to the lack of solubility between W and Cu it's difficult to prepare these types of materials by classical method like casting. However, there are some methods to produce materials based on W/Cu with higher concentration of W, namely: infiltration method which consists in the infiltration of molten copper in tungsten skeleton which is difficult to use at higher copper content (>20%) [4]; method of sintering of the mixed powders. In the liquid sintering process of mixed powders the final product presents lower density and non-homogeneous structure [5]. Another technique to synthesis of nanocrystalline 80W/Cu composite powders with good sintering ability is sol-spray drying and hydrogen reduction [6, 7]. W/Cu alloys with 5, 8 and 20% copper content can quickly synthesized by microwave infiltration sintering [8]. Microwave sintering attracts attention especially in the field of ceramic, magnetic and hard materials [9-13]. High energy ball milling is a process which assures homogeneity and densities close to the theoretical one. Ball milling has different meaning as following: Mechanical Alloying (MA) and Reactive Milling (RM) which involves the synthesis of a new phase in materials by solid state reaction; Mechanical Milling (MM) refers to the process of milling of pure metals or compounds without solid state reaction [14].
The present work is focused on the MA and MM process of tungsten and copper powders in order to synthesize of parts obtained by W/Cu nanocomposite powders and to study their tribological behaviour. Friction coefficient and wear rate are very important properties for a lot of materials used in the field of electrical applications, automotive, biomedical etc. For example a human joint has a friction coefficient between 0.01-0.1 and for an endoprosthesis is almost 0.3 [15].

2. Raw Materials

Tungsten nanopowders obtained by MM process and copper micron powders type SE from Pometon were used in order to prepare the mixtures used for the experimental work. Copper characteristics are presented in table 1 and SEM images of the initial powders are presented in fig. 1 and 2. Three types of mixtures with the following composition (% weight) were prepared as following: 85W/Cu, 80W/Cu and 75W/Cu. All the three mixture were subjected to MA process using a Pulverisette 4 vario planetary ball mill made by Fritsch. The parameters for the MA were: grinding vials volume: 250 ml; grinding vials material: stainless steels; balls diameter: 10 mm; number of balls: 50; material of balls: stainless steel; ball/powder ratio: 5/1 (40 grams powder and 200 grams balls); alloying medium: air; alloying times: 2, 4, 6 and 8 hours (samples were taken at each interval).

TABLE 1: Properties of Cu powder

Physical properties					
Properties	Admitted Values			Standard	
Apparent density [g/cm^3]	2.30-2.50			SR EN 23923-1/98	
Flow time [sec/50g]	Max 40			SR ISO 4490:2000	
Chemical composition					
Element	Admitted Values			Standard	
Cu	Min. 99.7			IL-08-0-94	
O_2	Max 0.15			SREN 24491-4:1994	
Particle size distribution					
Average grain size[µm]	>212	180-212	180-106	106-45	<45
Cu	Min. 99.7	Max 2	25	45-65	rest

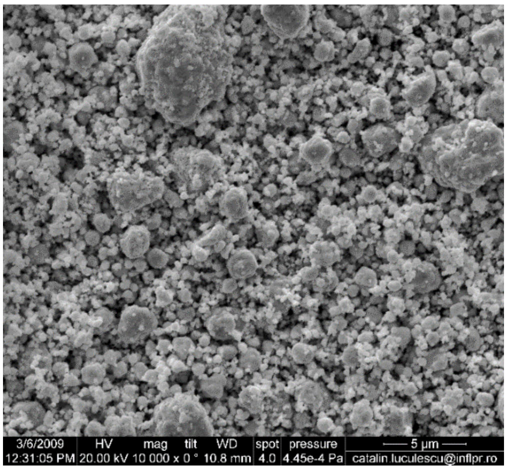


Fig. 1. SEM image of W nanopowders

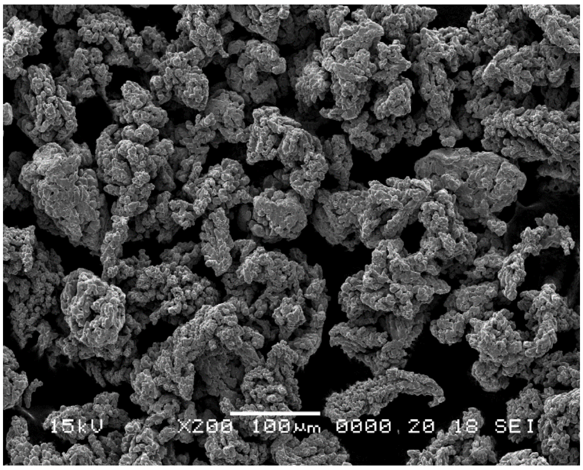
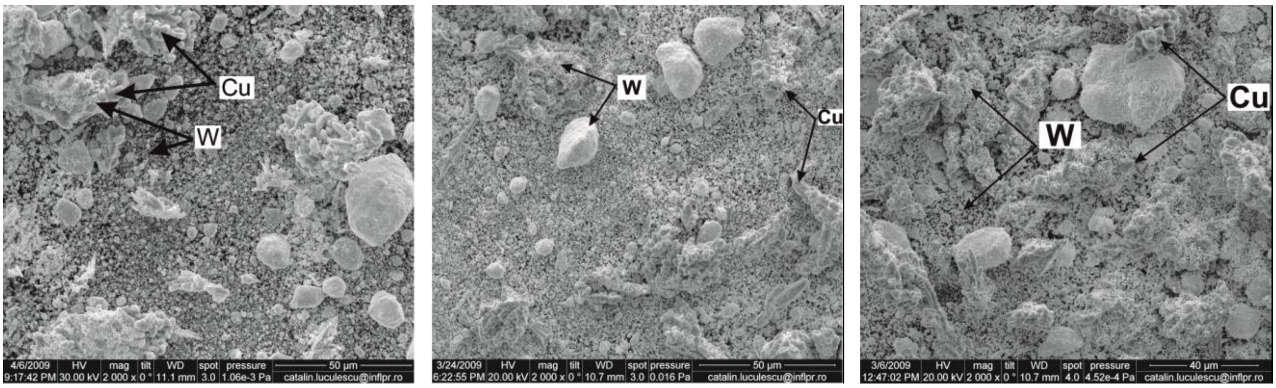


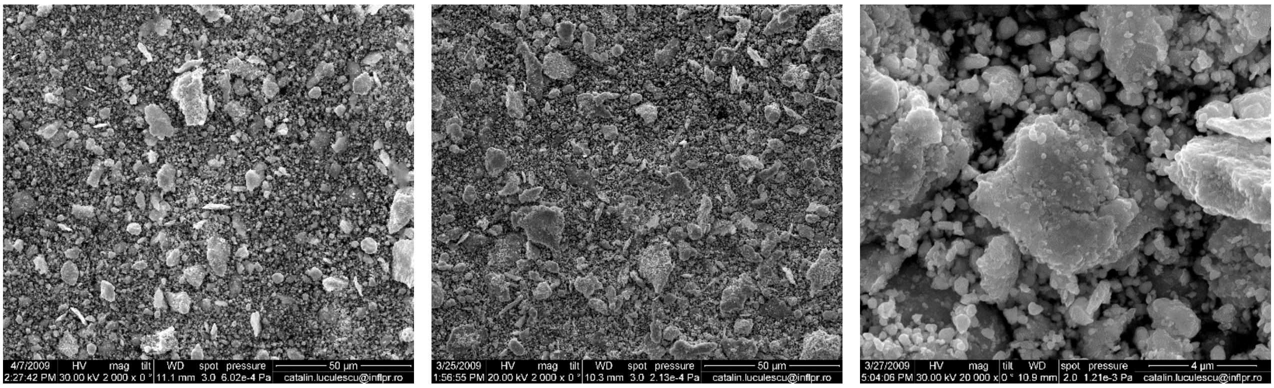
Fig. 2. SEM image of copper micronic powders

As it can be seen from fig. 1, the W nanoparticles [73-90] nm are agglomerated and from fig. 2 copper particles are dendritically which correspond to the electrolytic process by which are made.
In fig. 3 are presented SEM images of the three homogenous mixtures and in fig. 4 are presented SEM images of the mixtures MA for 8 hours.



a) b) c)

Fig.3. SEM images of homogenous mixtures: a) 85W/Cu; b) 80W/Cu; c) 75W/Cu



a) b) c)

Fig. 4. SEM images of MA mixture: a) 85W/Cu; b) 80W/Cu; c) 75W/Cu

A lot of W nanoparticles are placed between the dendrites of Cu powders in the case of homogenous mixtures, fig. 3. The dendritically shape of the copper particles isn’t observed after 8 hours of MA, fig. 4. The particle size distribution of the mixtures after 8 hours MA is in the range of [100-500] nm. The presence of nanoparticles (<100nm) it’s observed especially in the case of mixtures MA 8 hours with 15 and 20% copper. This is possible due to the presence of lower content of ductile phase (copper).

3. Experimental work

The samples were made in accordance with the operations presented in fig. 5.

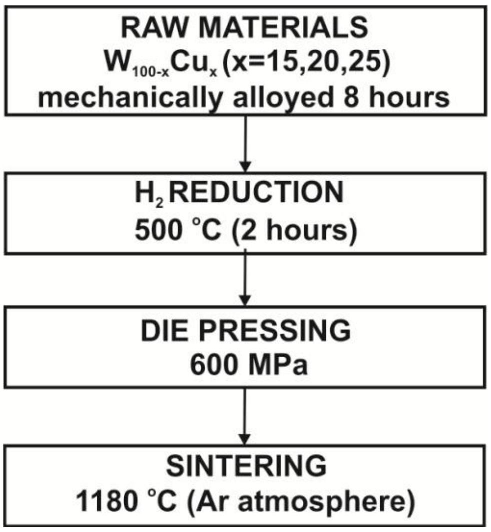


Fig. 5. Flow chart of operations made in order to elaborate the sintered parts

In order to eliminate the oxygen from the powders, they were subjected to a reduction treatment in H_2. By this process, the tensions that were accumulated in the powders during the MA process were eliminated too.

Due to lower dimensions of the particles it is very difficult to die pressing the powders without any binder, so, in this case 2% (weight) of paraffin was added. For die pressing to types of dies were used (cylindrical with Φ=12mm and rectangular with dimensions of 50x7x10 mm). The sintering treatment was carried out in a resistive furnace at 1180 ^{o}C using inert atmosphere (Ar). The samples were cut and prepared in order to study the microstructural aspects. The wear behaviour was performed using a CSM Instruments tribometer and a Surtronic 25+ profilometer, fig. 6.The parameters for wear testing were: load – 2N; testing method - circular; radius - 2mm; speed - 1cm/s; distance – 1500 mm; ball material – 100Cr6; temperature - 25 ^{o}C.

Fig. 6. Tribometer mechanism (left) and profilometer (right)

4. Results and discussions

After die pressing the green density was measured according to relation 1 and the results are plotted in the graph from fig. 7.

$$\rho = \frac{m}{V} [g/cm^3] \quad (1)$$

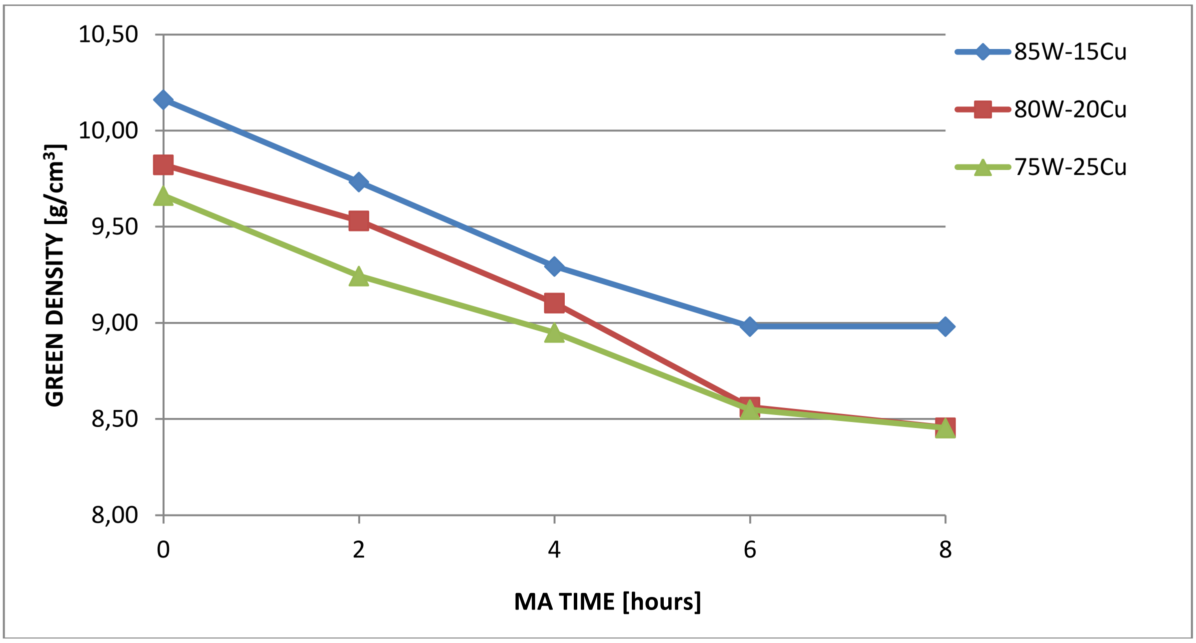


Fig. 7. Evolution of green density

The green density is influenced by the composition, the highest values being attained for the mixture 85W/Cu. The green density decreases with the increasing of MA time, which is normal, because at higher MA times the particles are smaller and lead to a reduction of compressibility of powders.

The evolution of density after the sintering treatment is presented in fig. 8.

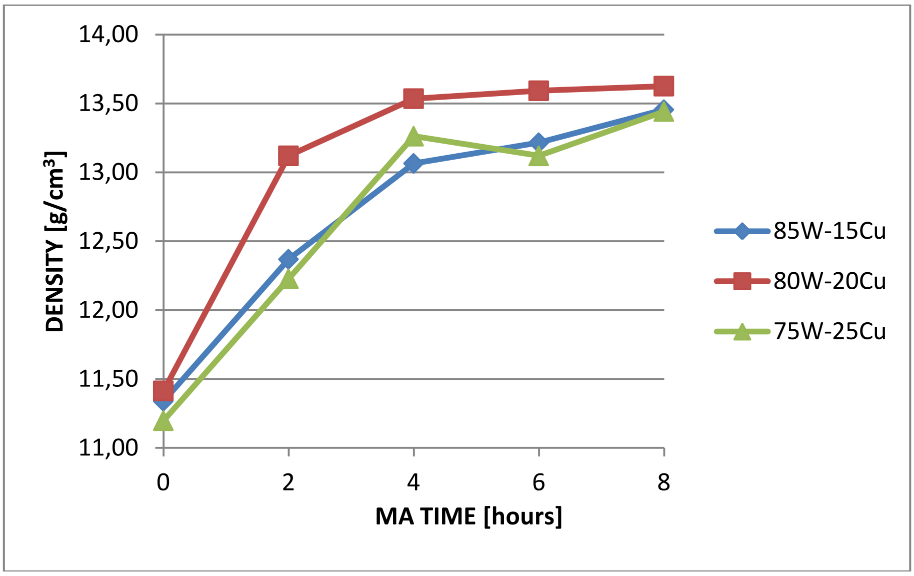
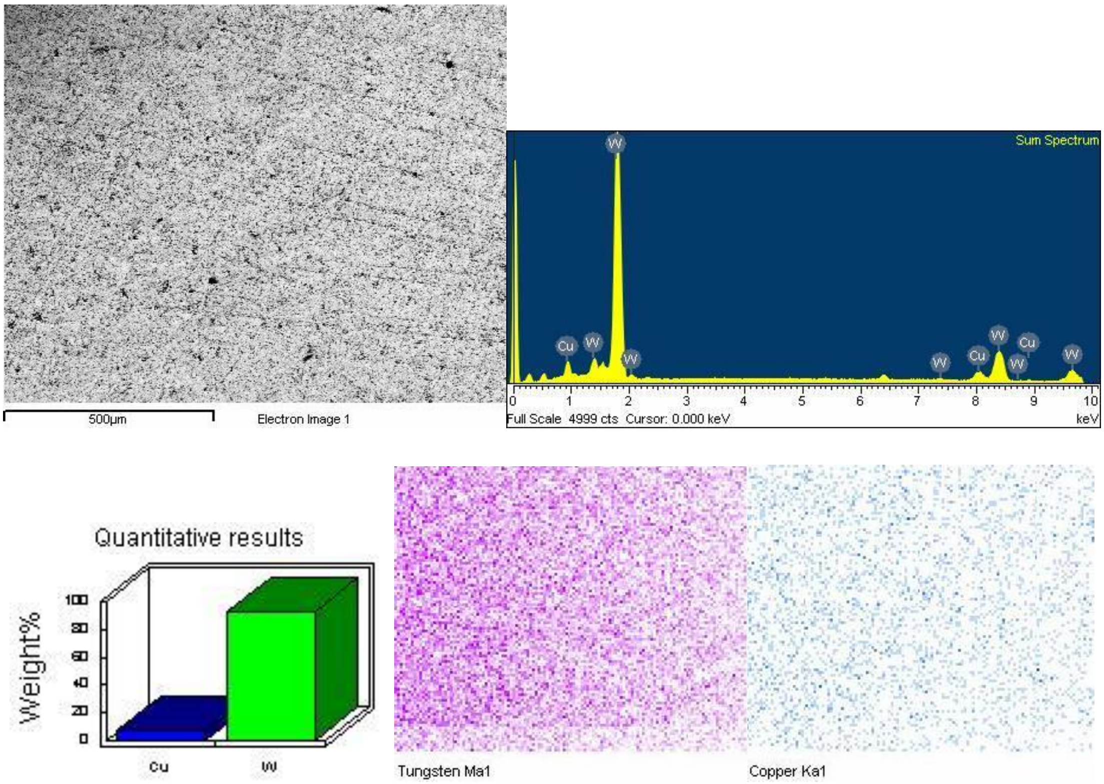
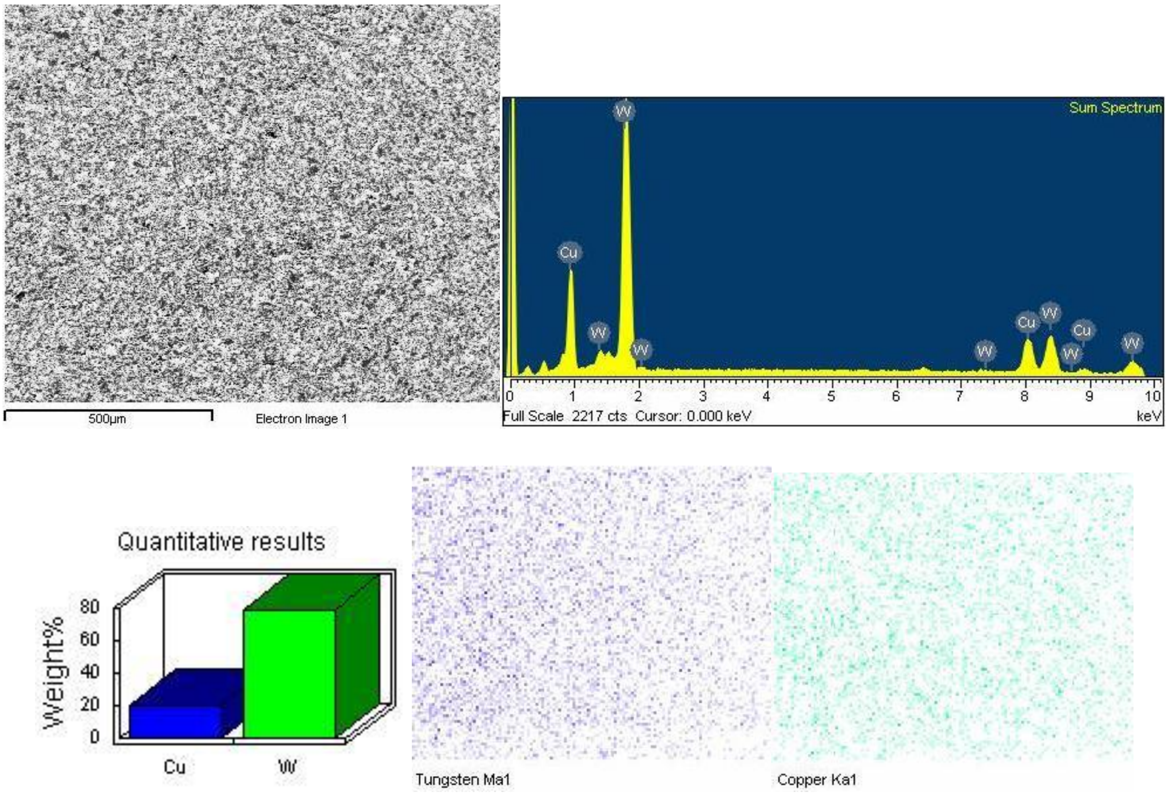


Fig. 8. Evolution of sintered density

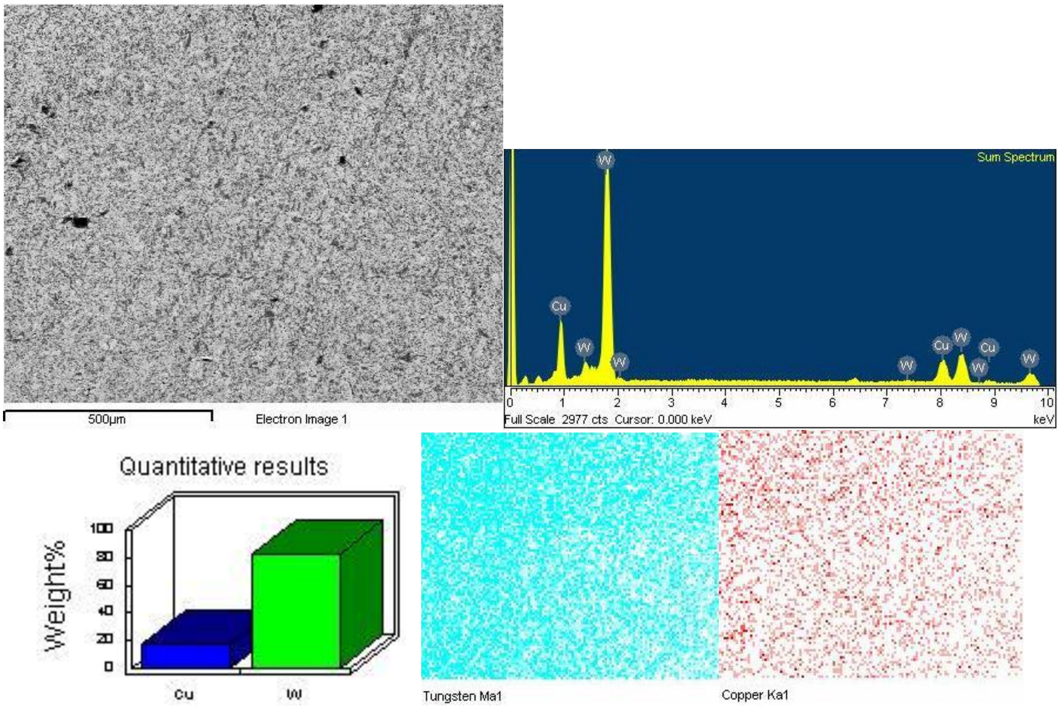
Comparative with the green density, in the case of sintered density it is observed that it increase with the increasing of MA time. The highest value of the sintered density was attained for the sample 80W/Cu. The relative density is almost 80% from theoretical density.
The microstructures of the sintered samples obtained by nanocomposite powders processed 8 hours by MA are presented in fig. 9.



a)



b)

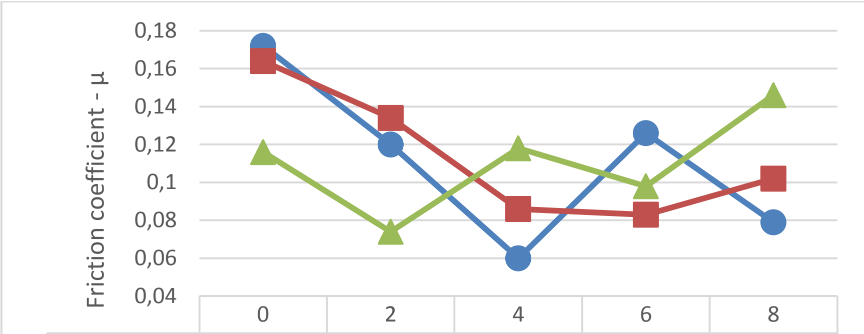


c)

Fig. 9. SEM images and EDS analysis of the sintered samples

From SEM images it is observed the presence of the pores for all the samples. According to EDS analysis the samples present homogenous distribution of elements.

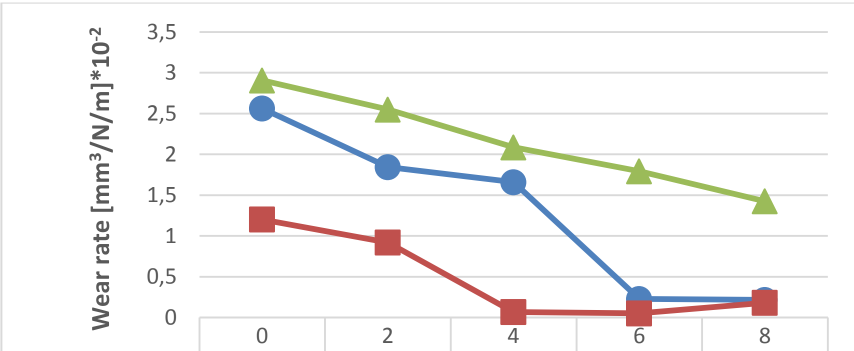
Evolution of friction coefficients is presented in fig. 10.



	0	2	4	6	8
85W/Cu	0,172	0,12	0,06	0,126	0,079
80W/Cu	0,164	0,134	0,086	0,083	0,102
75W/Cu	0,116	0,074	0,118	0,098	0,146

Fig. 10. Evolution of friction coefficient

From fig. 10, it is observed that friction coefficient hasn't a linear evolution. This is due to the fact that comparative with bulk materials, sintered materials are characterised by the presence of the porosity. The pores on the surface of the materials are filled with material of the counter piece and because of that is very difficult to obtain a linear variation of friction coefficients.
The wear rate evolution of the samples is plotted in fig. 11.



	0	2	4	6	8
85W/Cu	2,562	1,843	1,658	0,2267	0,2154
80W/Cu	1,202	0,9196	0,0675	0,05058	0,1807
75W/Cu	2,905	2,548	2,085	1,792	1,425

Fig. 11. Evolution of wear rates

The wear rate decrease with the increasing of MA times and the lower value of 0.05 $[mm^3/N/m]*10^{-2}$was attained for the sample 80W/Cu obtained by mixture MA 6 hours.

3. Conclusions

According to the experimental results there can be underline some conclusions:
- Nanocomposite powders based on W/Cu with the particle size in the range of [100-500] nm can be achieve by MA process;
- Due to lower dimensions of the particles it is hard to attained relative densities above 80% by die pressing;
- Corroborating the values of the densities with the microstructures it is observed the presence of the pores in the structure of obtained materials;
- The materials present homogenous microstructures as it can be seen from EDS analysis;
- Wear parameters are influenced by MA times and composition and the wear rates obtained make these materials suitable for friction parts.

Acknowledgement

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