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RESEARCH

Wear Behavior of Materials Based on Cu/Cr and Cu/Cr/W used for Welding Electrodes

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A B S T R A C T

The paper presents experimental research regarding the wear behavior of some composite materials based on Cu/Cr and Cu/Cr/W prepared by Powder Metallurgy (PM) route. Because of low solubility between Cu and Cr is very difficult to elaborate these types of materials by classical technologies and because of that, in this research was used Mechanical Alloying (MA) technique to prepare Cu/Cr materials. In order to obtain good refractory was introduced 5% of W in the mass of materials. There were made studies regarding the wear behavior of these materials function the Cr content.

1. INTRODUCTION

Proper functioning of the welding electrodes involves the necessity of materials with higher wear resistance and higher electrical and thermal properties.

Materials based on Cu/Cr presents excellent electrical properties, high mechanical strength and because of these properties are widely used as materials for plasma facing components, divertor plates of Internal Thermonuclear experimental Reactor, railway contact wires, integrated circuit lead frame and electrode of resistance welding [1-4]. The solid solubility of Cr in Cu is very low and because of this, PM by MA improves the solubility and reduces the particle size which improves the electrical and mechanical properties of the Cu/Cr alloys [5-8]. Because the MA is a process to produce solid state materials the limitations of equilibrium diagrams doesn't apply in this process. There are five stages that occur in the MA process as presented in Fig. 1.

In the stage 1 the particles are flatten due to the energy resulting from the impact of balls and grinding bowl.

In the second stage increases the surface area of the powder particles as a result of cold welding processes that occurs inside the bowls.

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In the stages 3, 4 and 5 increase the hardness of the particles due to accumulation of internal stresses because of collisions between the balls and the powder particles. In the end it is obtained the desired material as a fine powder which depends on the milling time.

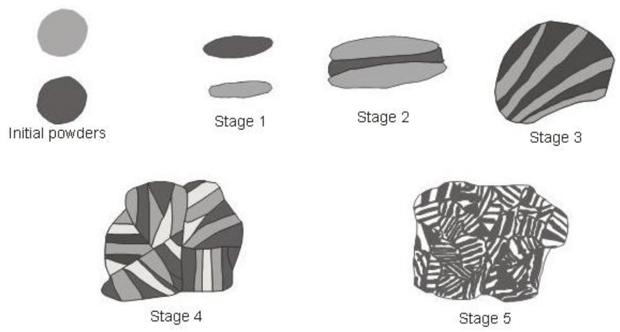


Fig. 1. The 5 stages of Mechanical Alloying [9,10].

By controlling the MA parameters (speed, ball to powder ratio, milling atmosphere, ball diameters and so on) it can be achieve Cu/Cr alloys with notable performances. The addition of Cr in copper matrix increases the mechanical properties especially after the aging heat treatment.

2. MATERIALS AND EXPERIMENTAL PROCEDURE

2.1. Raw materials

For the experiments were used Cu, Cr and W powders with the properties presented in Tables 1-3 and Fig. 2.

Table 1. Characteristics of Cu powders.

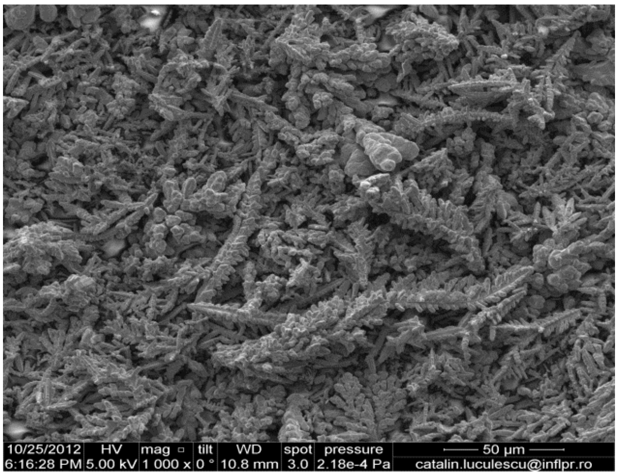
Physical properties		
Properties	Admitted values	Standard
Apparent density [g/cm^3]	2.30 – 2.50	SR EN 23923-1/98
Flow time [sec/50g]	Max 40	SR ISO 4490:2000
Chemical composition		
Element	Admitted values	Standard
Cu	Min. 99,7	IL-08-0-98
O_2	Max. 0,15	SREN 24491-4:1994

Table 2. Characteristics of Cr powders.

Particle size [μm]	Max 50
Purity [%]	99,8
Density [g/cm^3]	7,18
Thermal conductivity [W/(m·K)]	93,7
Electrical conductivity [1/Ω·m)]	$7.9 \cdot 10^6$

Table 3. Characteristics of W powders.

Particle size [μm]	Max 50
Density [g/cm^3]	18,5
Tapped density [g/cm^3]	11,25
Flow time [sec/50g]	8



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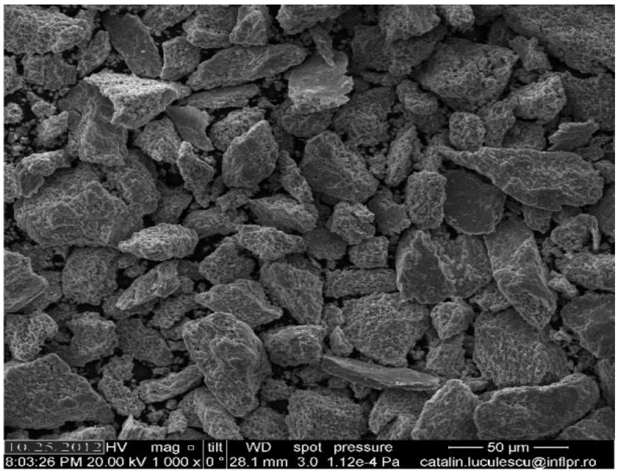

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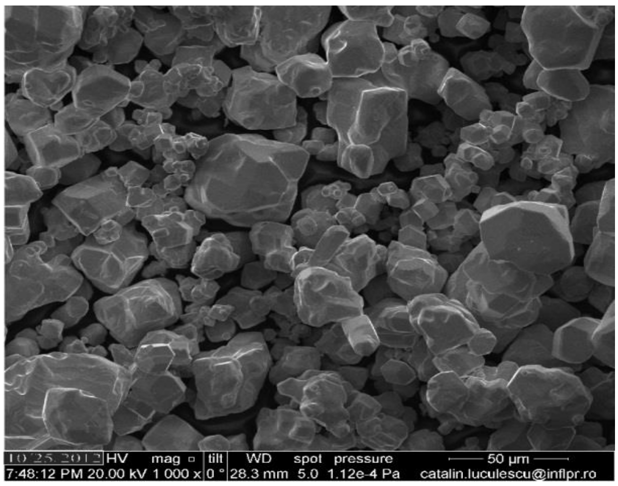

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Fig.2. SEM images of elemental powders: a) Cu; b) Cr; c) W.

Copper powder was obtained by electrolytic process and has dendritic shape (Fig. 2 a). Chromium (Fig. 2b) and tungsten (Fig. 2c) powders have irregular shape and aren't so agglomerated as copper powder.

Four mixtures were prepared as presented in Table 4.

Table 4. Chemical composition of the mixtures.

No.	Sample code	Chemical composition [%]			MA time [hours]
		Cu	Cr	W	
1.	A1	99	1	-	6
2.	A2	98	2		6
3.	B1	94	1	5	6
4.	B2	93	2	5	6

2.2. Elaboration of electrodes

All the mixtures were pressed at 650 MPa in order to obtain green billets with Φ=12 mm and were subjected to the sintering treatment, Fig. 3.

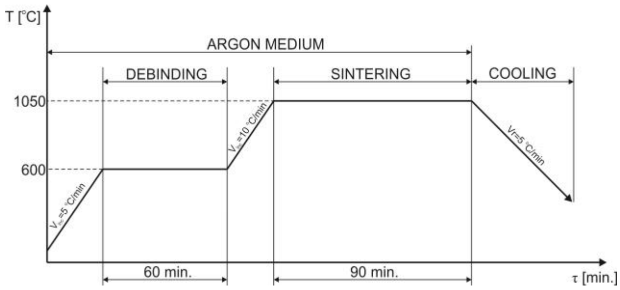


Fig. 3. Sintering chart.

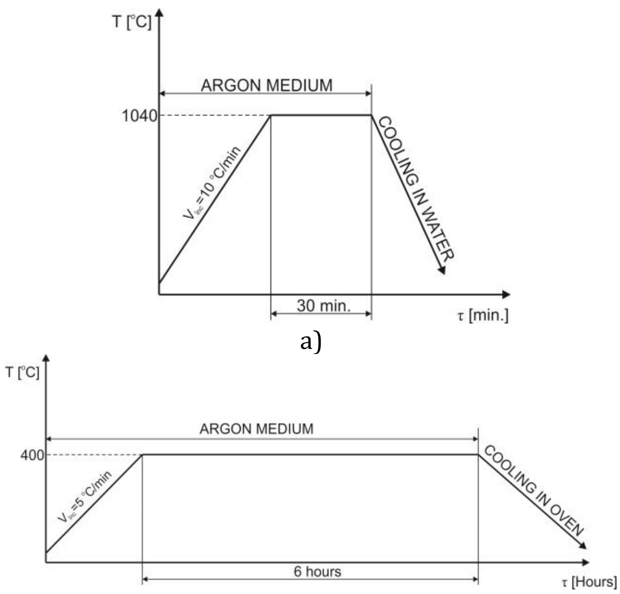


Fig. 4. Hardening (a) and aging (b) treatment charts

To study the possibilities of improving wear resistance and hardness characteristics of electrodes and maintaining the thermal resistivity and conductivity at higher values, hardening followed by aging heat treatments of sintered electrodes were made, Fig. 4.

3. RESULTS AND DISCUSSIONS

For all the samples were determined the densities as green and sintered state and the results are presented in Table 5.

Table 5. Evolution of green and sintered densities.

No	Sample code	Green density [g/cm^3]	Sintered density [g/cm^3]
1.	A1	7,75	7,86
2.	A2	7,61	7,69
3.	B1	8,01	8,15
4.	B2	7,89	8,00

Due to higher density of W (19.25 g/cm^3) the samples which have W in their composition presents higher values of densities as green and as sintered state.

The samples were polished in order to analyze them by micro hardness and wear behavior point of view. For micro hardness tests a Namicon apparatus were used. The results are presented in Table 6.

Table 6. Microhardness of the samples.

No	Sample code	Composition	Micro hardness HV01		
			As sintered	As hardened	As aged
1.	A1	Cu99Cr1	60	32	72
2.	A2	Cu98Cr2	69	61	84
3.	B1	Cu94Cr1W5	65	58	75
4.	B2	Cu93Cr2W5	70	60	76

Due to low values of micro hardness after hardening treatment, the wear behavior was performed only for the sintered and aged samples. The tests were made using a CSM Instruments tribometer and a Surtronic 25+ profilometer.

The parameters for wear testing were: Load: 2 N; Testing method: linear; Amplitude: 6 mm; Speed: 7 cm/s; Distance: 20 m; Ball material: 100Cr6; Temperature: 25 ^{o}C.

The results regarding tribological behavior are presented in Tables 7-9 respectively in Figs. 5 and 6.

Table 7. Evolution of friction coefficient.

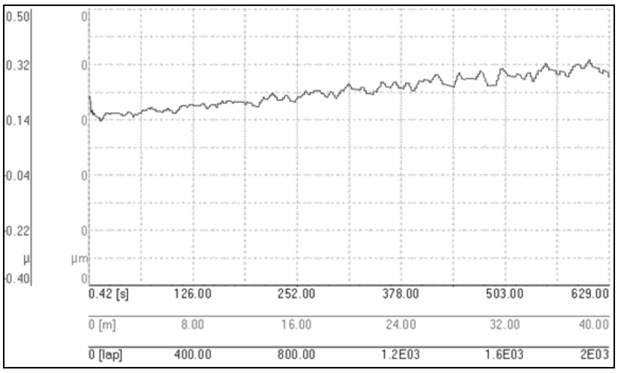
No	Sample code	Composition	Friction coefficient	
			As sintered	**As aged**
1.	A1	Cu99Cr1	0,233	0,178
2.	A2	Cu98Cr2	0,161	0,160
3.	B1	Cu94Cr1W5	0,158	0,152
4.	B2	Cu93Cr2W5	0,150	0,145

Table 8. Evolution of worn track section.

No	Sample code	Composition	Worn track section [μm²]	
			As sintered	**As aged**
5.	A1	Cu99Cr1	595	570
6.	A2	Cu98Cr2	266	189
7.	B1	Cu94Cr1W5	158	158
8.	B2	Cu93Cr2W5	147	139

Table 9. Evolution of wear rate.

No	Sample code	Composition	Wear rate [mm³/N/m]*10⁻⁵	
			As sintered	**As aged**
9.	A1	Cu99Cr1	8,923	8,548
10.	A2	Cu98Cr2	3,989	2,834
11.	B1	Cu94Cr1W5	1,975	1,975
12.	B2	Cu93Cr2W5	1,837	1,738



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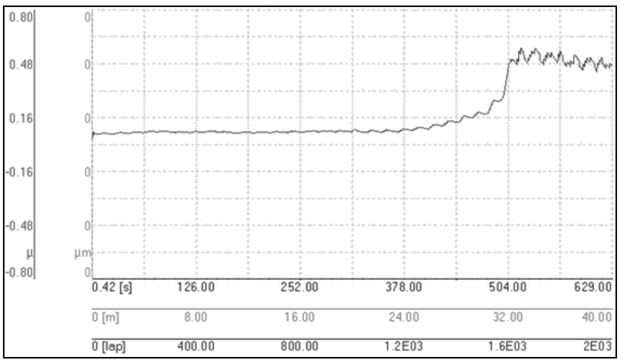

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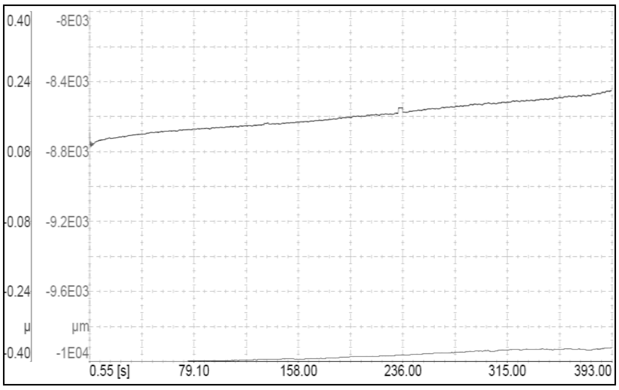

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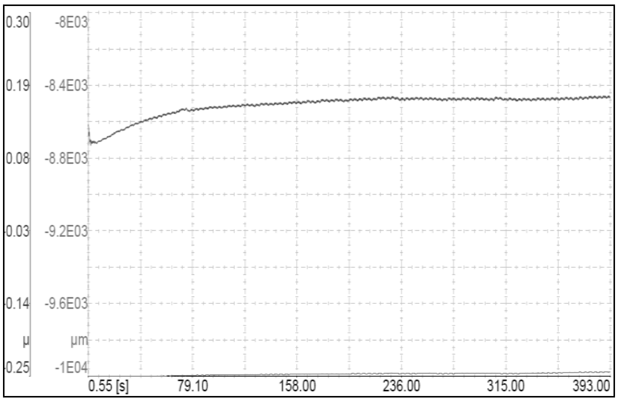

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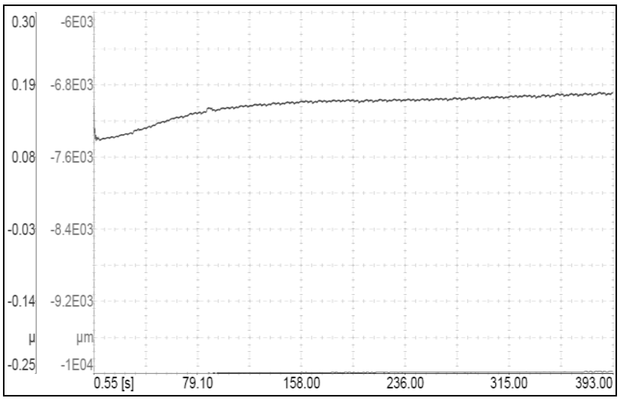

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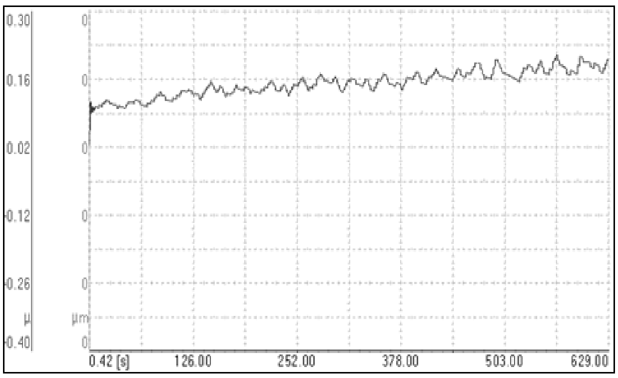

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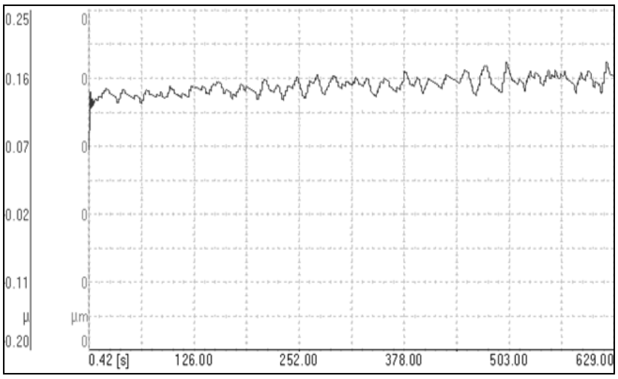

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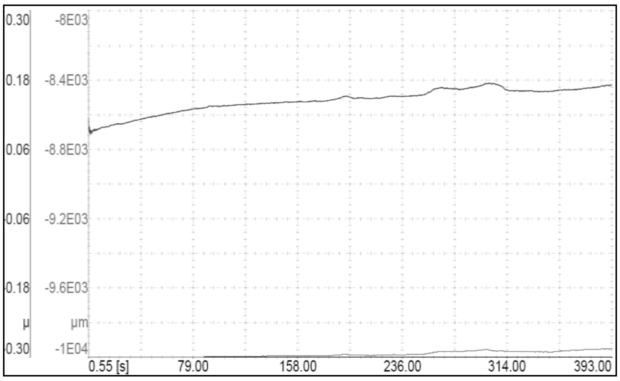

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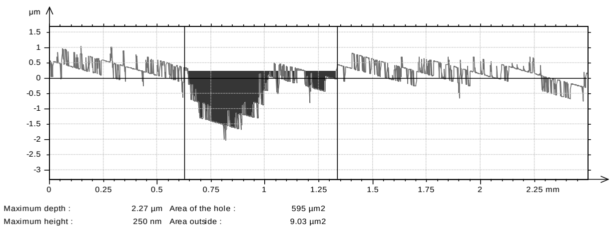
Fig. 5. Friction coefficients of the samples: a) sample A1 as sintered; b) sample A1 as aged; c) sample A2 as sintered; d) sample A2 as aged; e) sample A3 as sintered; f) sample A3 as aged; g) sample A4 as sintered; h) sample A4 as aged.



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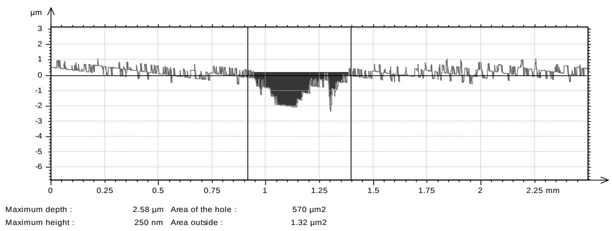

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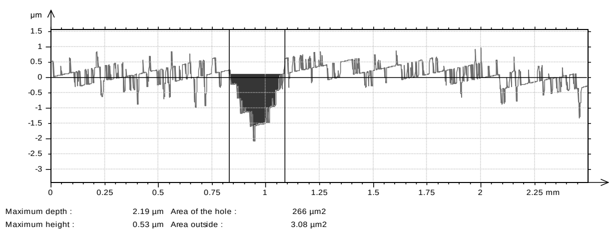

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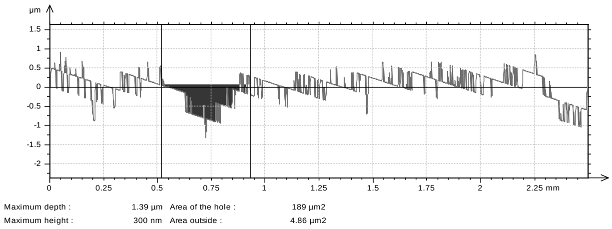

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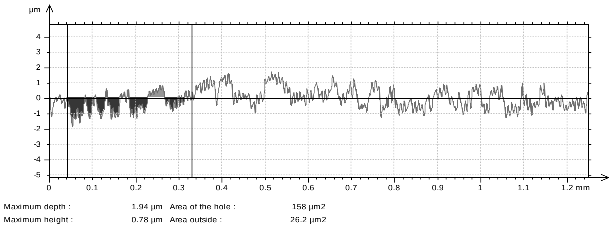

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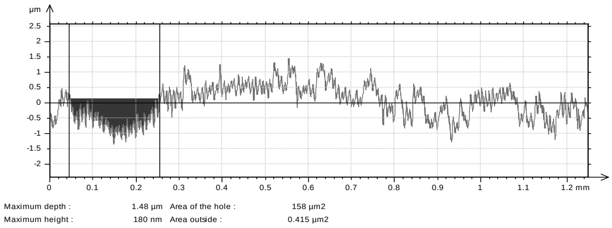

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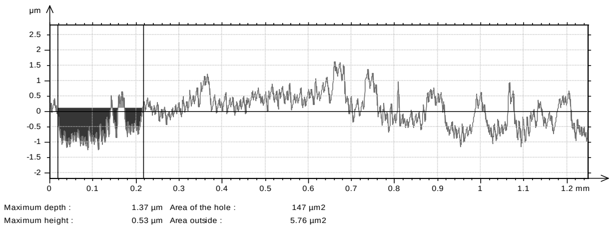

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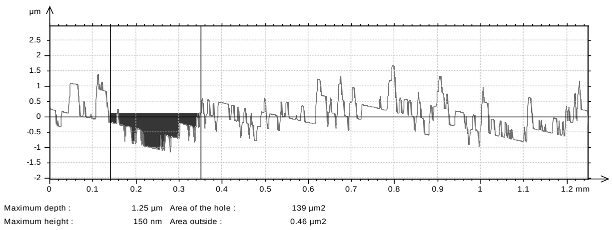

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Fig. 6. Warn track sections of the samples: a) sample A1 as sintered; b) sample A1 as aged; c) sample A2 as sintered; d) sample A2 as aged; e) sample A3 as sintered; f) sample A3 as aged; g) sample A4 as sintered; h) sample A4 as aged.

4. RESULTS AND DISCUSSIONS

Experimental research leads to the following conclusions:

- It can be developed materials based of Cu/Cr and Cu/Cr/W used for welding electrodes with a concentration of Cr higher than 1% as it is the standard concentration;

- Regarding the MA process, by increasing the content of Cr the particle size decrease;
- The higher values of microhardness were attained for the samples with 2%Cr as sintered and after aging treatment;
- Aging treatment improves the wear properties and all the parameters: friction coefficient, worn track section and wear rate are influenced by Cr content

Acknowledgements

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