HIGH POWER ELECTRIC CONTACTS FROM W-Ni-Cu COMPOSITE POWDERS MANUFACTURED BY MECHANICAL Alloying

Authors: Irina Cârceanua, Patricia Neagu – Manicatidé, Adrian Boteanu
Ioan Vida - Simitib, Nicolae Jumate

Institute: a Metallurgical Research Institute Bucharest
b Technical University Cluj-Napoca

Abstract
Nowadays technology development is closely related with new materials development that have greater mechanical properties due to chemical composition modifications or to manufacturing route transformations.

Mechanical alloying process as new technology was considered from the beginning an interesting alternative for current manufacturing methods. A special class of materials in powder metallurgy area is that of “heavy alloys” with composition containing about 88-97 % tungsten balanced with Ni-Fe or Ni-Cu.

This paper presents the preoccupation of author in production of homogenous mixtures of W-Ni-Cu powders system by mechanical alloying. Elemental powder mixtures of W-7%Ni-3%Cu were mechanically alloyed with a low-speed rotating drum attritor, without protective atmosphere or lubricant. The milling time was 150 hours. Powder samples were taken every 10 hours during the 150 hour milling time for qualitative and quantitative evaluation by X-ray diffraction.

An increase in the degree of homogenization and amorphization was observed with increased milling time. The mechanically alloyed materials gave an increased density on sintering with a larger volume of intermetallic products in microstructure.

1. INTRODUCTION

Mechanical alloying is a versatile method of some advanced materials producing by the solid state powder processing and has already received numerous industrial applications.

At a qualitative level, the phenomenon occurring during mechanical alloying have been understand and consists, essentially in a continuous process of deformation, fracturing, local heating, solid state welding and re-fracturing of powder particles under the effect of the transferred energy from the milling balls /1/.

It could obtain submicron or nanocrystallin powders, amorphous phase, intermetallics or other compounds at room temperature. Mechanical alloying has a wide range of possibly processed materials: alloys (Al-Fe, Al-Ni, W-Cu, W-Ni-Cu, W-Ni-Fe); intermetallics (Si-Cu, Ti-C, Ti-Si, Ti-Br); magnetics (Fe-Si, Fe-Be-N, Ba-Fe-O); hard materials (W-C, V-C, Ti-C, Si-N, Fe-C) and many others /2/. Those technique has a very important influence on the resulting material characteristics, firstly on microstructure (very fine structure, high dispersion grade, amorphous phase, etc.). /3 /

2. EXPERIMENTAL CONDITIONS

Experiments concerning the obtaining of composite powders using mechanical alloying were performed by: • experimental materials systems choose; • powder characterization in accordance with actual international standards; • gravimetric dosage of component powders; • filling in planetary mill with W-Ni powders and balls followed by milling during 150 h period;
dosing the W-Ni powders mixture after the mechanical alloying, by homogenization of this mixture with the reduced copper powder and by grinding the pulverous W-Ni-Cu mixture during 35 h; binding the obtaining powder mixture, with was obtained with pressing binder; pressing; debinding- presintering; sintering; characterizing the products resulted; mechanical processing.

As raw materials has been used pure W, Ni, and Cu powders with the following weight ratio: W: Ni: Cu = 90:7:3. The characteristics were determined according to International Standards: ISO 3923/1 – Apparent density; ISO 4490 – Flowing rate. The particle size was measured with a Fisher apparatus (powder permeability to water). A mixture of tungsten and nickel powders were ground in an attritor, without protective atmosphere or lubricant.

Table 1 – Raw powders characteristics for the starting materials

<table>
<thead>
<tr>
<th>Material</th>
<th>Flowing rate g/50g</th>
<th>Apparent density g/cm³</th>
<th>Particle size FSSS (µm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>W</td>
<td>not flowing</td>
<td>3.40 ± 0.01</td>
<td>1.62 ± 0.01</td>
</tr>
<tr>
<td>Ni</td>
<td>not flowing</td>
<td>2.46 ± 0.01</td>
<td>4.86 ± 0.01</td>
</tr>
<tr>
<td>Cu</td>
<td>not flowing</td>
<td>1.34 ± 0.01</td>
<td>5.81 ± 0.01</td>
</tr>
</tbody>
</table>

For milling it has been used an attritor with the following parameters: milling speed = 100 rot/min; milling time = 150 hours; ball / powder weight ratio = 3 : 1; filling grade = 25 %; Copper powder used for the experiment had an average particle size of 6 µm and a morphology of irregular shape. Tungsten powder was of a spheroidal particle shape with an average size of 1 µm.

In figures nr. 1-2 is showed the morphological aspect of W and Ni particles; it could be notice micronics particles of irregular shapes with surface roughness (tungsten particles), respective particle with spherical shape with a powerful tendency of agglomeration (nickel particles).

The copper powder used for the realisation of homogenised mixed powder, was reduced preliminary in Siemens Plania, in hydrogen atmosphere at the 270°C temperature.

Figure 3 shows the scanning electron microscopy (SEM) morphologies of reduced copper powder particles before mechanical alloying processing; it could be noticed the micronic particles of irregular shapes (dendritic structure).

The mechanically alloyed powder was taken out of the container periodically to follow the progress of alloying every 10 hours. The grinding total time is 150 hours. After 20 hours milling we can observe the sticking of the powder to steel balls and tank of attritor. After a longer time the powder started to agglomerate.

The powders were mechanically alloyed together with the copper reduced powder, then they were homogenized during 35 h, in a taper closed having a 75 mm diameter and 95 mm length, fixed on a rotating device, the rotation n= 60 rot/min.
Figure 1 - Morphologic aspect of Ni powder 2480X

Figure 2 - Morphologic aspect of W powder 2480X

Figure 3 - Morphologic aspect of reduced copper powder - particles of dendritic shapes 3000X
2.1. Experimental results and discussion

The characteristics of powder mixtures which are mechanically alloyed are presented in table no. 2.

Table no. 2 – The characteristics of processed powders

<table>
<thead>
<tr>
<th>Powder type</th>
<th>Main diameter FSSS (µm)</th>
<th>Flow rate s/50 g</th>
<th>Free descharged apparent density g/cm³</th>
</tr>
</thead>
<tbody>
<tr>
<td>W-Ni</td>
<td>0.10 ±0.01</td>
<td>No flow</td>
<td>5.08 ±0.01</td>
</tr>
<tr>
<td>W-Ni-Cu</td>
<td>0.30 ±0.01</td>
<td>No flow</td>
<td>4.78 ±0.01</td>
</tr>
</tbody>
</table>

From table 2 could be observed that increasing milling time lead to increasing apparent density and decreasing particle size; increasing of apparent density could be explained by particle shape changes during milling, so, by increasing milling time, the sharp edge of the particles becomes rounded. It means that particles packing amount increase and, also mechanical interlocking are reduced /4/.

The powder mixtures were, then, binded to paraffin (3%), sieved in a semidry state by a sieve with 0,1 mm mesh size and dried, finally obtaining a mixture “ready to be pressed”.

The pressing was performed bilaterally on a steel die with a circular section, showing following characteristics: \( \Phi_{\text{ext}}=47 \text{ mm}, \Phi_{\text{int}}=14.3 \text{ mm} \); \( S=(\Phi_{\text{ext}}^2-\Phi_{\text{int}}^2)=15.73 \text{ cm}^2 \); for a specific pressure, were debinded in the Siemens Plania Furnace, in a hydrogen atmosphere, by using as packing agent - allumina, which was calcined in advance at 1450 °C, during 5 h, in order to provide heat resistance (endurance).

The parameters of the debinding presintering process were: \( \Phi_{\text{H}_2} \) atmosphere; \( \Phi_{\text{heating rate up to 500°C}}:0.8 \text{ °C/min}; \Phi_{\text{hating rate between 500-800°C}}:3.5 \text{ °C/min}; \Phi_{\text{presintering temperature}}:800\text{°C}; \Phi_{\text{30 min exposure time to presintering temperature}}; \Phi_{\text{total duration of the debinding – presintering cycle: 8h 30 min}}; \)

The sintering operation was realized in heating evacuated induction furnace, with intermediate frequency currents, of Balzers type, the sintering operation parameters are: \( \Phi_{\text{sintering temperature}}:1150\text{°C}; \Phi_{\text{60 minute exposure time to sintering temperature}}; \Phi_{\text{total duration of the cycle: 8 hours}}. \)

The produced sintered material was characterised by the physical – mechanical and structural properties all along the stage. In table no 3 are emphasized the physical and mechanical characteristics of the sintered markers from mechanically alloyed powder mixtures as compares with the materials offered by recognized producers in the field – the reference material type *Electroputere Craiova ROMANIA*.

The sintered grades were prepared for metallographic examination with the aim to:

- determine the presence, time and repartition of pores;
- determine the microstructure.
Table no. 3 – Physical and mechanical characteristics of sintered markers

<table>
<thead>
<tr>
<th>Material type</th>
<th>Density (g/cm³)</th>
<th>Brinell Hardness HB</th>
<th>Electric resistivity (Ω m 10⁻⁸)</th>
<th>Stretch resistance (N/mm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sintered markers</td>
<td>16.93</td>
<td>218</td>
<td>2.83</td>
<td>798</td>
</tr>
<tr>
<td>1150⁰C</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reference material</td>
<td>16-18</td>
<td>185-235</td>
<td>2-4</td>
<td>≥700</td>
</tr>
<tr>
<td>of Electroputere type</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The samples for analyse were realised by gradually emphasizing the phases by Murakami attack. In figures 4 -5 it is presented the microstructure of W-Ni sintered material at 1150⁰ C/1h, as attacked, at 1000X and respectively 2000X magnification.

One can remark a homogenous and uniform structure of the W-Ni sintered material as well as the lack of porosity which has as a result the obtaining of a particular density of material, very close to the theoretical density. In figures 6-8 is presented the microstructure of W-Ni-Cu material, sintered at 1150⁰ C/1h, as attacked, at 1000X, 3000X and respectively 6000X magnification. The microstructural analyse emphasized the uniform repartition of the two phases present in the material: the Ni-Cu metallic binder phase and the tungsten (W) phase.

Besides, the figures 6 -8 illustrate in a relevant way the process stages with liquid phase: the figure 8 emphasizes the “IIIrd stage” of sintering process, which corresponds to the achievement of solide-rigid structure of material, by bridges, grains growing, by coalescence and pores elimination; the figure 7 illustrates exactly and accurately the Ist and IInd stages of W-Ni-Cu system sintering, respectively rearrangement – flowing and melt penetration (IInd stage) and dissolving – reprecipitation – diffusion-control (densification, shape adapting, grain growth, decrease and closure of pores).

The emphasized technological flow will allow the manufacturing of products which are representative to the W-Ni-Cu system – high power electric contacts which fit out the Diesel
Engines with superior physical and mechanical properties, which comply with the users requirements.

In figures no. 9-11 is showed the representative product from W-Ni-Cu system – high power electric contacts which fit out the Diesel Engines.

Figure 6 – Microstructural aspect of W-Ni-Cu sintered material at 1150° C/1h
Murakami attack 500X

Figure 7 – View of W-Ni-Cu sintered material Murakami attack 3000X

Figure 8 – View of W-Ni-Cu sintered Murakami attack 6000X
Figure 9 - Electric contact parts  
Figure 10 – Electric contact plates  
Figure 11 – Raw powders – Final products
3. CONCLUSIONS

The experiments lead to the following conclusions:

• During the milling process, powder particles are trapped between the milling balls and the plastically deformed, thus rupturing the layers of surface contaminants on individual particles and exposing a clean metal surface;

• As processing continues, the alloyed particles further break-up and reweld to give a more uniform structure of stabilizing particle size.

• By the mechanical alloying technique was obtained powder composed of W-Ni-Cu with a very fine granulation, a uniform repartition;

• The more homogeneous of the materials provided by the mechanical alloying process appears to have had a significant effect on the densification of the particular powders, perhaps by allowing both of the liquid-phase-driven sintering mechanisms to proceed more effectively;

• The emphasized technological flow will allow the manufacturing of products which are representative to the W-Ni-Cu system – high power electric contacts which fit out the Diesel Engines with superior physical and mechanical properties, which comply with the users requirements.

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