International Review of Mechanical Engineering (IREME)

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Praise Worthy Prize

€ 160,00
Results Produced by Adding Nb, Mo, Cr and Ti in Microstructure of the WC-6Co

J. R. Savi, V. Brustoj, V. Brustoj, S. Schaeffer, M. Martin, W. Rodrigues, C. Ferreira

Abstract — The hard metals constitute a group of materials known as composite sintered hard phases that are used in cutting tools, dies, drills, and mining wear-resistant components. The high hardness and resistance to corrosion, abrasion, and high thermal expansion are the main reasons for their increasing use. WC-Co is a material consisting of hard particles enclosed in a metal binder produced by powder metallurgy. The particles of high hardness are formed of carbides of tungsten and carbon (WC-Co) [4]. The metal used as the binder is iron, which is also used in industrial manufacturing processes. This process is extremely essential [2]. This paper aims to present the main effects of adding Nb, Ti, Cr, and Mo in the microstructure and mechanical properties of cemented carbide WC-6Co processed via sintering [5].

I. Introduction

Produced by powder metallurgy, the carbide is a composite material that has found many applications in industrial fields, especially in the manufacture of cutting tools, dies, drills, and mining wear-resistant components. The high hardness and resistance to corrosion, abrasion, and high thermal expansion are the main reasons for their increasing use. WC-Co is a material consisting of hard particles enclosed in a metal binder produced by powder metallurgy. The particles of high hardness are formed of carbides of tungsten and carbon (WC-Co) [4]. The metal used as the binder is iron, which is also used in industrial manufacturing processes. This process is extremely essential [2]. This paper aims to present the main effects of adding Nb, Ti, Cr, and Mo in the microstructure and mechanical properties of cemented carbide WC-6Co processed via sintering [5].

II. Materials and Methods

For this study, we started with the WC-powder 6Co, 99.5% composition given in Table I, supplied by Alfa Aesar, -325 mesh, which served as a raw material base.

<table>
<thead>
<tr>
<th>TABLE I: COMPOSITION OF THE COMPOSITE POWDER WC-6Co</th>
</tr>
</thead>
<tbody>
<tr>
<td>Component</td>
</tr>
<tr>
<td>WC</td>
</tr>
<tr>
<td>Co</td>
</tr>
</tbody>
</table>

The desired composites were obtained by mixing conventional WC-6Co with 1% wt. of Nb, Mo, Cr and Ti. To this composite was added zinc stearate (1.5 wt%) as a lubricant. The composite was pressed in a mold with a diameter of 25 mm and a height of 25 mm, with a pressure of 400 MPa and a sintering temperature of 1450 °C for 1 hour. The resulting composite was cooled to room temperature and then machined to the desired shape.

The desired composite was subjected to sintering at a temperature of 1450 °C for 1 hour under a nitrogen atmosphere. The resulting composite was cooled to room temperature and then machined to the desired shape.

The samples were compressed in size, geometry, and composition of the required material, having sufficient integrity to be handled. It was found by curve comprehensibility of the material, which from 400 MPa to a green density pressure became constant. It was determined the compression pressure, obtained through the compressibility curve of the alloy, drawn based on ASTM B331. We chose to use a 200 MPa pressure and therefore the average green density around 8.21 g/cm³ for samples with the addition of elemental powders of Nb, Mo, Cr, and Ti.

III. Results and Discussion

At this stage of the study, we will present the following results: a micrograph of the powders, the green density, sintered density, shrinkage, hardness and microstructure of the composites studied for sintering cycle. We used scanning electron microscopy to submicron scales of the powders used in this work. Fig. 2 shows the starting powder particles of WC-6Co with magnification of 5000× and Fig. 3 shows the powder particles of WC-6Co with magnification of 5000×. Two figures show that the particle sizes range from 1 to 5 μm and are bonded with sizes 10-20 μm.

The Fig. 4 shows the powder particles of niobium (Nb) with magnification of 1500× and Fig. 5 shows the powder particles of molybdenum (Mo) with magnification of 2000×.

Fig. 1. Details powder type Y used in this step of the process

The sintering was performed in argon atmosphere due to the fact that it is inert gas. From a scientific viewpoint, the vacuum is considered the best atmosphere because they enable the sintering of metals whose oxides are

Table II shows the values obtained from the green density for a compression pressure of 200 MPa. In this stage of the process, it reached particles with the green density, used in industrial manufacturing processes.

<table>
<thead>
<tr>
<th>TABLE II: DENSITY VALUES FOR THE GREEN CARBIDE COMPOSITES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Component</td>
</tr>
<tr>
<td>WC-6Co</td>
</tr>
<tr>
<td>WC-6Co-Nb</td>
</tr>
<tr>
<td>WC-6Co-Mo</td>
</tr>
<tr>
<td>WC-6Co-Ti</td>
</tr>
</tbody>
</table>

The sintering was performed in argon atmosphere due to the fact that it is inert gas. From a scientific viewpoint, the vacuum is considered the best atmosphere because they enable the sintering of metals whose oxides are
The composite WC-6Co-Mo showed the third highest density of the sintered and worst microhardness of the composites studied, this can mean a good weldability with respect to molybdenum disilicide, causing the grain growth in the composite, but the sintering temperature is relatively correct. The composite commercial ceramic showed the sample hardness in relation to carbide compounds studied with the second worst density. The carbide WC-6Co-Ti had the second lowest hardness and low density, the latter being directly influenced the density of titanium. The Table IV shows a relationship between sintering temperature, density and volumetric shrinkage for samples WC-6Co.

**Fig. 13.** Sintering temperature, density and volumetric shrinkage for samples WC-6Co.

**Table IV.** Sintering Temperature, Density and Volumetric Shrinkage for WC-6Co.

<table>
<thead>
<tr>
<th>Composition</th>
<th>Sintered Density (g/cm³)</th>
<th>Shrinkage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>WC-6Co</td>
<td>14.75</td>
<td>45.3</td>
</tr>
<tr>
<td>WC-6Co-Mo</td>
<td>14.38</td>
<td>41.0</td>
</tr>
<tr>
<td>WC-6Co-Mo-Cr</td>
<td>13.87</td>
<td>38.6</td>
</tr>
<tr>
<td>WC-6Co-Ti</td>
<td>13.95</td>
<td>38.1</td>
</tr>
</tbody>
</table>

The Table IV lists the density of sintered composites with shrinkage, indicating the possibility of a greater need for deeper study of sintering temperature of the composites. The shrinkage may indicate that the sintering temperature used was below the necessary temperature for satisfactory contraction, as indicated in literature range from 40 to 50%. Assays of potentiodynamic polarization curves were performed in acetic 0.5 M in H₂SO₄, using the sweep rate of 30 mV/min to make possible an overview of the electrochemical behavior of sintered carbides compared curves as a function of current density.

The cathodic curves for WC-6Co-Mo and WC-6Co-Cr exhibit similar behavior. A sample of WC-6Co-Ti showed a large reduction of anodic current when compared with the other samples. The potentiodynamic curve of the sample apparently no titanium oxide film had its destroyed, i.e., the material is undergoing slower corrosion, this means it is more resistant. The Fig. 14 shows potentiodynamic polarization curves with different additions of 1% of elemental metal powders. It is noted that the potential of the samples refers to the saturated calomel electrode (SCE).

**Fig. 14.** Potentiodynamic polarization curve.

<table>
<thead>
<tr>
<th>Composition</th>
<th>Ecorr (mV)</th>
<th>Icorr (μA/cm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>WC-6Co</td>
<td>-3.91</td>
<td>1.54x10⁻⁴</td>
</tr>
<tr>
<td>WC-6Co-Mo</td>
<td>-3.32</td>
<td>1.58x10⁻⁴</td>
</tr>
<tr>
<td>WC-6Co-Mo-Cr</td>
<td>-3.32</td>
<td>3.67x10⁻⁴</td>
</tr>
<tr>
<td>WC-6Co-Ti</td>
<td>-2.68</td>
<td>8.31x10⁻⁴</td>
</tr>
</tbody>
</table>

**IV. Conclusion**

This study consisted of the determination of the production and properties of grain density, relative density, hardness, volumetric shrinkage of a composite material of WC 6% Co added with 7% of Nb, Mo, and Cr and Ti. The experiments showed that the sintering temperature corresponded satisfactorily results due to shrinkage and sintered density.

The compressive curve determined the correct pressure for compaction around 200 MPa, which does not require much of the tooling and parts are obtained with the green resistance in handling.

The percentage of metal added in commercial trading carbide WC-6Co is down to the metal identification in the MSF micrograph of the post. The green density according to the results found in literature, ranging from 7.5 to 8.5 g/cm³.

The relative density shows that the percentage of high densification occurs in the composite WC-6Co-Mo followed by WC-6Co-Nb, WC-6Co-Mo, WC-6Co-Cr and WC-6Co-Ti, presenting this trend due to weldability of the metal powder matrix with tungsten carbide. The shrinkage may indicate that the sintering temperature used was below the necessary temperature for satisfactory contraction, according to literature range of 40 to 50%. This information offers a more detailed study of the last two composites in relation to temperature and time effective sintering.

The micrographs of the compositions showed similar to the literature validating again the mass balancing process for obtaining the compositions. In microstructures presented was not possible to identify the alloying elements that have been added due to its solubility in WC-6Co.
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