EFFECT OF B₄C ADDITION ON THE PROPERTIES OF SINTERED FE-CU-NI-SN-WC COMPOSITE APPLIED IN CUTTING TOOLS FOR ORNAMENTAL ROCKS: THE PROCESS OF OBTAINING SAMPLE DENSITY

EFEITO DA ADIÇÃO DE B₄C SOBRE AS PROPRIEDADES DO COMPÓSITO SINTERIZADO FE-CU-NI-SN-WC APLICADO EM FERRAMENTA DE CORTE DE ROCHAS ORNAMENTAIS: O PROCESSO DE OBTENÇÃO DA DENSIDADE DAS AMOSTRAS

EFFECTO DE LA ADICIÓN DE B₄C SOBRE LAS PROPIEDADES DEL COMPUESTO SINTERIZADO FE-CU-NI-SN-WC APLICADO EN HERRAMIENTAS DE CORTE PARA ROCAS ORNAMENTALES: EL PROCESO DE OBTENCIÓN DE LA DENSIDAD DE LA MUESTRA

Vivianne Rosestolato Daruich Pereira Tannus
Master in Engineering and Materials Science, Universidade Estadual do Norte do Rio de Janeiro (UENF), Campos dos Goytacazes, Rio de Janeiro, Brazil.
E-mail: viviannetannus@hotmail.com

Frederico Muylaert Margem
Doctor in Engineering and Materials Science, Universidade Estadual do Norte do Rio de Janeiro (UENF), Campos dos Goytacazes, Rio de Janeiro, Brazil.
E-mail: fmargem@uenf.br

Diego Júlio Pacheco
Doctor in Production and Systems Engineering, Centro Federal de Educação Tecnológica (CEFET-RJ), Rio de Janeiro, Rio de Janeiro, Brazil.
E-mail: diego.pacheco@uenf.br

Márcia Giardinieri de Azevedo
Doctor in Chemical Engineering, Universidade Federal do Rio de Janeiro (UFRJ), Rio de Janeiro, Rio de Janeiro, Brazil.
E-mail: mgazevedo@uenf.br

Sergio Neves Monteiro
PhD in Engineering and Materials Science, Universidade Federal do Rio de Janeiro (UFRJ), Rio de Janeiro, Rio de Janeiro, Brazil.
E-mail: sergio.neves@gmail.com

ABSTRACT
The experiments conducted in this work aimed at studying and developing a Fe-Cu-Ni-Sn-WC-based alloy, with different additions of Boron Carbide. The production of this metallic matrix is intended for the manufacturing of beads, to be used in diamond wires for cutting ornamental rocks. Five compositions were

DOI: https://doi.org/10.23900/2359-1552v13n1-23-2024
Submitted on: 05.07.2024 | Accepted on: 05.29.2024 | Published on: 06.05.2024
used for the investigation: samples with 2% B\textsubscript{4}C, 4% B\textsubscript{4}C, 5% B\textsubscript{4}C, 8% B\textsubscript{4}C, and 10% B\textsubscript{4}C. Initially, rectangular geometry composites were obtained via hot pressing, and then sintered under the same temperature conditions (800°C) and pressure (34MPa). The obtained segments reached approximately 18.00 mm in length, with widths between 12.80 mm and 15.20 mm, and a height of 3.00 mm. The process of obtaining the density of the samples involved using the Archimedes’ method, which consists of submerging the sample in a liquid of known density and measuring the amount of displaced liquid. The density of the sample is then calculated by the ratio of its mass to the volume of displaced liquid. This method is particularly useful for determining the density of irregular or porous solid materials, such as the mentioned composites. The conducted studies serve as a basis for the development of new research aimed at the production of diamond matrices for use in cutting tools.

**Keywords:** Boron Carbide. Fe-Cu-Ni-Sn-WC-Based Alloy. Material Density Characterization. Production of Diamond.

**RESUMO**
Os experimentos realizados neste trabalho tiveram como objetivo estudar e desenvolver uma liga à base de Fe-Cu-Ni-Sn-WC, com diferentes adições de Carboneto de Boro. A produção desta matriz metálica destina-se à fabricação de contas, para utilização em fios diamantados para corte de rochas ornamentais. Cinco composições foram utilizadas para a investigação: amostras com 2% B\textsubscript{4}C, 4% B\textsubscript{4}C, 5% B\textsubscript{4}C, 8% B\textsubscript{4}C e 10% B\textsubscript{4}C. Inicialmente, os composites de geometria retangular foram obtidos por prensagem a quente e posteriormente sinterizados nas mesmas condições de temperatura (800°C) e pressão (34MPa). Os segmentos obtidos atingiram aproximadamente 18,00 mm de comprimento, com larguras entre 12,80 mm e 15,20 mm e altura de 3,00 mm. O processo de obtenção da densidade das amostras envolveu o método de Arquimedes, que consiste em submergir a amostra em um líquido de densidade conhecida e medir a quantidade de líquido deslocado. A densidade da amostra é então calculada pela razão entre sua massa e o volume do líquido deslocado. Este método é particularmente útil para determinação da densidade de materiais sólidos irregulares ou porosos, como os composites mencionados. Os estudos realizados servem de base para o desenvolvimento de novas pesquisas voltadas à produção de matrizes diamantadas para utilização em ferramentas de corte.

**Palavras-chave:** Carboneto de Boro. Liga à Base de Fe-Cu-Ni-Sn-WC. Caracterização da Densidade de Materiais. Produção de Diamante.

**RESUMEN**
Los experimentos realizados en este trabajo tuvieron como objetivo estudiar y desarrollar una aleación a base de Fe-Cu-Ni-Sn-WC, con diferentes adiciones de Carburo de Boro. La producción de esta matriz metálica está destinada a la fabricación de cuentas, para su uso en hilos diamantados para el corte de rocas ornamentales. Para la investigación se utilizaron cinco composiciones: muestras con 2% B\textsubscript{4}C, 4% B\textsubscript{4}C, 5% B\textsubscript{4}C, 8% B\textsubscript{4}C y 10% B\textsubscript{4}C. Inicialmente, los composites con geometría rectangular se obtuvieron mediante prensado en
caliente y posteriormente se sinterizaron bajo las mismas condiciones de temperatura (800°C) y presión (34MPa). Los segmentos obtenidos alcanzaron aproximadamente 18,00 mm de longitud, con anchos entre 12,80 mm y 15,20 mm y una altura de 3,00 mm. El proceso de obtención de la densidad de las muestras implicó el método de Arquímedes, que consiste en sumergir la muestra en un líquido de densidad conocida y medir la cantidad de líquido desplazado. Luego, la densidad de la muestra se calcula mediante la relación entre su masa y el volumen de líquido desplazado. Este método es particularmente útil para determinar la densidad de materiales sólidos o porosos irregulares, como los compuestos antes mencionados. Los estudios realizados sirven de base para el desarrollo de nuevas investigaciones encaminadas a la producción de matrices diamantadas para su uso en herramientas de corte.

**Palabras clave:** Carburo de Boro. Aleación a Base de Fe-Cu-Ni-Sn-WC. Caracterización de la Densidad de Materiales. Producción de Diamantes.

**INTRODUCTION**

This Currently, access to specific and in-depth knowledge is becoming more frequent due to increased ease of transportation, enrollment in specialized institutes, and almost instantaneous sharing of bibliographic references via the internet. Based on this fact, the growing research on material properties, as well as the acquisition of these materials, is contributing to significant technological advancements worldwide, leading to the emergence of new applications for materials. This fact results in increased competition among manufacturing companies and, therefore, the need for improved performance related to their final application, as well as constant evolution of certain specific properties. In this context, the search for new materials that bring some benefit becomes essential.

Brazil ranks fourth in the world in terms of production with 8.9 million tons and sixth among the largest exporters of rocks globally (DRM-RJ, 2012). Among the major national producers are the states of Espírito Santo, Minas Gerais, and Rio de Janeiro (Martinez & Heider, 2011). The Northwest Fluminense region is the main mineral hub in the state, composed of about 300 microenterprises employing around six thousand people (Peiter et al., 2001).

However, Brazil's participation in the international market for processed rocks is still limited, much inferior to China and India, our biggest competitors.
Despite its potential, the great diversity of rock types, political issues, and technical difficulties linked to exploration and processing prevent the Brazilian sector from fully leveraging its potential (Vargas et al., 2001). The Brazilian industrial park for processing is technologically outdated, especially due to the use of old machinery and equipment. Its modernization could be achieved through the adaptation and automation of machines and equipment already installed and up to 10 years old, and especially through the acquisition of technologically updated capital goods (Peiter & Chiodi Filho, 2001).

Companies in these regions depend on the importation of rock extraction technologies, as well as various diamond tools used in cutting and polishing processes. Thus, a potential "market niche" emerged in the Fluminense region. Consequently, researchers in this region have invested time and knowledge to develop new tools for rock cutting (Martinez & Heider, 2012).

However, with the increasing demand for these types of tools, especially for use in construction, several problems have been identified regarding rock cutting, mainly in terms of efficiency and cost of the cutting process, leading to concerns about developing new metal alloys for these elements to increase their cost-effectiveness (Almeida, 2012).

There is a wide variety of materials used in manufacturing tools for the cutting and processing of ornamental rocks in the engineering universe. However, the most employed is the binder metallic matrix system – diamond crystals (Oliveira, 2007-a).

In the realm of engineering, this system is known as a diamond composite and shows satisfactory performance in various application areas. These elements have properties that are interesting for the desired purposes in terms of cutting ornamental stones, such as high mechanical strength, low thermal conductivity, and high chemical stability. Linear and circular saws, polishing crowns, diamond bead wires, among others, are diamond cutting tools used in the dismantling, cutting, and polishing of ornamental rocks, ceramic materials, and non-ferrous metals in general (Filgueira, 2001).

The choice of metals for the alloys requires an analysis of the abrasiveness and hardness of the material to be cut. According to Sideris (2013), tungsten (W)
has the ability to form a high-performance alloy when applied to extremely hard materials, such as reinforced concrete. W-Co alloys and pure Cobalt (Co) are used for high-hardness materials like granites. Cobalt-bronze, iron-cobalt, and iron-bronze are binders used in cutting materials of moderate hardness, such as marbles.

Cobalt acts as a binder in diamond tools. Silicon (Si), when present in the binder composition in small quantities (< 2% by weight), increases its adhesion to diamond crystals, preventing premature diamond loss due to detachment. Tungsten Carbide (WC) increases the wear resistance of the binder matrix, controlling the rate of binder loss due to abrasion (Shibuta, 1983).

Cobalt shows perfect chemical compatibility with diamond crystals at processing temperatures, which explains its current dominance as the binder matrix in most diamond tools compositions. In terms of processing temperature, Co also retains the crystals adequately and shows good wear resistance after several cutting operations. However, this element is not the best choice for certain applications due to its toxic content, as well as its fluctuating commercial value as a strategic material (Del Villar, 2001).

Cobalt is toxic, and thus researchers have recently sought to develop or propose new alloys that can serve as alternatives to minimize cobalt content in diamond tools, such as Fe-Cu-Co and Fe-Ni-Cu-Sn-Co alloys (Niktiewicz and Swierzy, 2006; Weber and Weiss, 2005; Clark, 2002; Del Villar, 2001).

Boron Carbide (B₄C) and zirconium dioxide (ZrO₂) have also been widely applied in cutting tools to improve the physicochemical properties of binders, thus increasing cutting efficiency. According to Sideris (2013), the addition of B₄C in Fe-Ni-Cu-Sn-Co alloy shows better results compared to the same alloy with ZrO₂ addition. The former has lower porosity and higher toughness, which directly influences the tool's lifespan.

Metallic alloys using Fe-Cu-Ni-Sn-Co with the addition of B₄C have been tested and approved by Sideris (2013) for use in diamond wires. With reference to this project, the present paper aims at the production and characterization of diamond test specimens by modifying an element of the aforementioned base,
thus being composed of Fe-Cu-Ni-Sn-WC, with the addition of B₄C, to be applied in diamond wires for cutting ornamental rocks such as gneiss.

The objective of this article was to characterize the final density of the carbide pellets created, as the material, although having controllable dimensions, presents, according to Sideris (2013), a highly porous and irregular microstructure. This justifies more detailed investigations into the material's density. Therefore, we used different processes for this study to identify the density of the samples.

The study details how the bulk density, relative density or densification, and apparent porosity were obtained. Understanding the density of a material is crucial for several reasons. A better understanding of the physical properties, based on the relationship between mass per unit volume, helps us understand parameters such as performance and functionality of the material in different applications.

Density can be an indicator of material quality. Materials with inconsistent densities can exhibit issues such as porosity, lack of structural uniformity, or impurities. Understanding the density of a material is crucial during the manufacturing process. This can help ensure that the material is being processed correctly and that the desired properties are achieved. In certain applications, such as in materials engineering or component production, density can be a specific requirement.

In structural components, density is critical to ensure adequate strength and durability. Measuring density is an important part of quality control to ensure that the material meets the necessary standards and specifications for its final application.

MATERIALS AND METHODS

According to Konstanty (2003), the production of diamond segments is a step in the manufacturing of diamond tools, which consists of eight topics in total. Of these, four are dedicated to diamond segments and are therefore followed and described below.

1) selection and mixing of powders – seeking the ideal chemical composition
and particle size distribution of the mixture, typically carried out in high-performance tumble mixers (Turbula mixers with chaotic movements).

2) hot pressing;

3) quality control of segments – usually performed by Rockwell B hardness testing, due to its low cost and ease of execution. Additional data is obtained through density evaluations when hardness data is insufficient;

4) deburring – Alumina or silicon carbide grinding wheels are used for cleaning and removing residues from the edges of produced segments.

Composites based on Fe-Cu-Ni-Sn-WC, with additions of B₄C, were produced to be used as a metallic matrix for beads applied in diamond wires used for cutting ornamental rocks such as gneiss, in accordance with the study by Sideris (2013), presented below:

1. Sintering under parameters (800°C / 8 min / 35 MPa) industrially used in the production of diamond composites. Twenty samples based on Fe-Cu-Ni-Sn-WC at 100% mass will be produced, following the composition presented in Table 1:

<table>
<thead>
<tr>
<th>Twenty (20) Samples</th>
<th>Chemical Elements</th>
<th>Mass (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fe</td>
<td>35-40</td>
<td></td>
</tr>
<tr>
<td>Cu</td>
<td>35-40</td>
<td></td>
</tr>
<tr>
<td>Ni</td>
<td>10-18</td>
<td></td>
</tr>
<tr>
<td>Sn</td>
<td>5-8</td>
<td></td>
</tr>
<tr>
<td>WC</td>
<td>2-5</td>
<td></td>
</tr>
</tbody>
</table>

Source: Prepared by the authors

2. Out of the twenty (20) samples, four (4) have an addition of 2% B₄C, four (4) have an addition of 4% B₄C, four (4) have an addition of 5% B₄C, four (4) have an addition of 8% B₄C, and four (4) have an addition of 10% B₄C. Initially, diamond was not added, as the production of a pure matrix aims to conduct a more detailed metallographic study on the compositions proposed by this research.

3. After the production of the composites, the samples were subjected to characterization for subsequent comparison of the behavior of the produced test specimens with higher or lower additions of B₄C.
4. The production of all composites was carried out at the company Comércio e Indústria de Ferramentas e Abrasivos – ABRASDI, located in the city of Campos dos Goytacazes – RJ. The powder grinding was performed in the Superhard Materials Sector of the Advanced Materials Laboratory at UENF.

The following materials were used in the production processes of diamond composites: Fe powder, 0.98 µm, 99.8%, 7.86 g/cm³ (Derivata); Cu powder, 1.2 µm, 99.8%, 8.96 g/cm³ (MetalPó); Ni powder, 2.0 µm, 99.7%, 8.9 g/cm³ (Derivata); Sn powder, 2.0 µm, 99.9%, 7.3 g/cm³ (Derivata); WC powder, 2.0 µm, 99.6%, 15.7 g/cm³ (WorldFram); B4C powder, 10 µm, 98.8%, 2.51 g/cm³ (TetraBor®); Diamond crystals with a particle size between 400 and 500 µm (Trust).

The Equipment and Accessories applied at the research were an analytical balance model SBC 31-220g (Scaltec); Hydraulic press model PHB30.REF220 (EKA) equipped with electric heating system (ABRASDI).

The Preparation of Segments: The preparation of test specimens followed these steps:

Selection and weighing of mixtures - Initially, it was necessary to obtain the density of the metallic base without the presence of B4C, using the percentage of each element previously chosen for the composition. Subsequently, to determine the relative quantity of each component added to the mixture, the rule of mixture was used to obtain the density of each composition.

To ensure that all samples had the same dimensions, it was necessary to calculate the masses of each combination without varying the volume of the compositions. Thus, using the standardized dimensions by ABRASDI, as illustrated in Figure 1, the standard volume of the segments is:

![Figure 1. ABRASDI segment model.](source: ABRASDI (2019))
With the data regarding the density of each composition and the standard volume, it was possible to calculate the mass quantity for each component element of the alloy. After weighing the powders, each composition was manually mixed using a spatula and then divided into the specific quantity for each segment (Figure 2).

After separating the compositions, the mixtures were placed in the sintering mold (Figure 3a and 3b), following the order shown in Figure 3c. The mold designed to receive the mixtures consists of pressers and graphite blocks, which are insulated by plates. A steel clamp is used in its assembly, which is done manually, including the addition of the mixtures (metals + alloys + diamonds). This construction allows the production of up to twenty test specimens per process.

![Figure 2](image1.png)

Source: Prepared by the authors themselves.

**Figure 3.** (a), (b) Insertion of the mixture into the graphite mold, (c) Sintering Matrix with the mixtures arrangement.

![Figure 3](image2.png)

Source: Prepared by the authors themselves.

The sintering process was carried out at the industrial plant of ABRASDI using a hydraulic press from the manufacturer EKA. The sintering process followed the following steps:
1) the matrix, manually assembled, was installed in the hydraulic press;  
2) next, the press force system was activated, developing an initial pressure, previously adjusted, of 20 MPa;  
3) after the establishment of the initial pressure (20 MPa), the heating system was activated, which by Joule effect heated the mold to a temperature of 750°C in a time of 4 minutes and 29 seconds;  
4) once the temperature of 750°C was reached, the pressure was increased to 35 MPa. After 30 seconds, the system reached a temperature of 800°C. From this point, the countdown of 3 minutes began;  
5) after a total time of 8 minutes, the heating system was turned off, and the matrix, still subjected to a pressure of 35 MPa, was cooled to room temperature for 5 minutes;  
6) once it reached 300°C, the force system was gradually discharged;  
7) the mold was then removed from the press for the removal of the produced test specimens. The values of the sintering parameters were chosen based on the manufacturing line data from the company ABRASDI.  

After production, the test specimens were numbered according to their compositions and subjected to characterization tests and mechanical tests to evaluate the efficiency of the composite in the sintering process and to choose the best composition for diamond crystal incorporation.  

After extracting the segments from the sintering mold, the specimens were taken to the Advanced Materials Laboratory at UENF (LAMAV/UENF) to measure their dimensions using a caliper and their mass using a precision balance.  

Specific mass or density of a substance is the ratio between its mass (m) and its volume (V). In obtaining the density of solids and liquids, often there are no readily available means to accurately determine their volume. The determination of bulk density applies to real situations, where the sample is composed of pores, cracks, crystal defects, amorphous phases, etc. Density can have different meanings such as theoretical density, bulk density, and relative density (Axt, 1981).  

The samples were subjected to density testing according to the Archimedes method (Figure 4a and 4b). From the calculation of bulk and
theoretical density, the relative density, also called densification of the samples, was obtained. With these data, the apparent porosity of the samples was also calculated.

The densification curve was calculated for different compositions. This parameter is important for determining the efficiency of the sintering process. Thus, the difference between sintering and densification becomes relevant at this point. Sintering is the phenomenon resulting from the tendency of particulate systems to decrease their free energy. It is a spontaneous process but is accelerated by increasing the temperature. Densification is the increase in the density of the body formed by the particle system. This increase in density is an effect of decreasing the system's energy, but this may not necessarily occur. There are systems that sinter without an increase in density (Silva, 2003).

Figure 4. Archimedes' Density. (a) Measurement of immersed mass; (b) Wet segments for weighing.

Source: Prepared by the authors themselves.

RESULT AND DISCUSSION

Using the rule of mixture and considering the density of B₄C as 2.51 g/cm³, we obtained a base density of 8.45 g/cm³. For the composition with 2% B₄C addition, we have 98% of the mixture and 2% of the additive. This results in a density of 8.068 g/cm³. In this composition, the test specimens M1, M2, M3, and M4, based on the percentage of each component of the mixture, will have a total mass of 15.103 g.

Here are the calculations for using 2% of B₄C to compose the total mass of 15.103g: Mass of B₄C = 2% of 15.103g = 0.303g; Mass of the base = 15.103g - 0.303g = 14.800g; Mass of Iron = 39% of 14.800g = 5.772g; Mass of Copper = 35% of 14.800g = 5.180g; Mass of Nickel = 18% of 14.800g = 2.664g; Mass of
Tin = 6% of 14.800g = 0.888g; Mass of Tungsten Carbide = 2% of 14.800g = 0.296g

This calculation procedure was repeated by varying the addition of B₄C and the percentage of the base for the other mentioned mixtures. The results are presented in Table 2 and 3.

After extracting the segments from the sintering mold, they were taken to the Advanced Materials Laboratory of UENF (LAMAV/UENF) to have their dimensions measured using a caliper and their mass measured using a precision balance.

Table 2. Average theoretical density of the mixtures

<table>
<thead>
<tr>
<th>% B₄C</th>
<th>Mixture</th>
<th>Density (g/cm³)</th>
<th>Volume (cm³)</th>
<th>Mass B₄C (g)</th>
<th>Base Mass (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>M1-M4</td>
<td>8.068</td>
<td>1.872</td>
<td>0.302</td>
<td>14.801</td>
</tr>
<tr>
<td>4</td>
<td>M5-M8</td>
<td>7.720</td>
<td>1.872</td>
<td>0.578</td>
<td>13.874</td>
</tr>
<tr>
<td>5</td>
<td>M9-M12</td>
<td>7.550</td>
<td>1.872</td>
<td>0.707</td>
<td>13.427</td>
</tr>
<tr>
<td>8</td>
<td>M13-M16</td>
<td>7.104</td>
<td>1.872</td>
<td>1.064</td>
<td>12.235</td>
</tr>
<tr>
<td>10</td>
<td>M17-M20</td>
<td>6.830</td>
<td>1.872</td>
<td>1.279</td>
<td>11.507</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td></td>
<td></td>
<td>15.717</td>
<td>263.376</td>
</tr>
</tbody>
</table>

Source: Prepared by the authors themselves.

Table 3. Mass corresponding to each composition and element used in the different mixtures.

<table>
<thead>
<tr>
<th>Element</th>
<th>%</th>
<th>M1-M4</th>
<th>M5-M8</th>
<th>M9-M12</th>
<th>M13-M16</th>
<th>M17-M20</th>
<th>Total Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fe</td>
<td>39</td>
<td>5.772</td>
<td>5.411</td>
<td>5.236</td>
<td>4.772</td>
<td>4.488</td>
<td>102.716</td>
</tr>
<tr>
<td>Ni</td>
<td>18</td>
<td>2.664</td>
<td>2.497</td>
<td>2.417</td>
<td>2.202</td>
<td>2.071</td>
<td>47.408</td>
</tr>
<tr>
<td>Sn</td>
<td>6</td>
<td>0.888</td>
<td>0.832</td>
<td>0.806</td>
<td>0.734</td>
<td>0.690</td>
<td>15.803</td>
</tr>
<tr>
<td>WC</td>
<td>2</td>
<td>0.296</td>
<td>0.277</td>
<td>0.269</td>
<td>0.245</td>
<td>0.230</td>
<td>5.268</td>
</tr>
<tr>
<td>TOTAL</td>
<td>100</td>
<td>14.801</td>
<td>13.874</td>
<td>13.427</td>
<td>12.235</td>
<td>11.507</td>
<td>263.376</td>
</tr>
</tbody>
</table>

Source: Prepared by the authors themselves.

The samples were subjected to density testing according to the Archimedes method, and the apparent density (Figure 5a) of each specimen was determined. From the bulk density (Figure 5b) and theoretical density calculation the relative density (Figure 5c), also known as densification of the samples, was obtained, and the apparent porosity was also calculated.
In terms of porosity, it was observed that the composition with 2% exhibits a lower amount of pores, which characterizes it as better in this aspect. Consequently, this composition incorporated the least amount of water due to the lower number of pores present. Since material densification is directly linked to its porosity, the material that showed better densification was the one containing 2% Boron Carbide.

CONCLUSION

This composition exhibited an average porosity of 6.223% with a standard deviation of 0.859 and densification of 93.062% with a standard deviation of 0.668. The alloy obtained by Sideris (2012), with an average densification of 91.98% and a standard deviation of 1.30, and porosity of 5.82% with a standard deviation of 1.63, has the same percentage of Boron Carbide but an additional element in the matrix, Cobalt. Thus, it can be said that the absence of Cobalt did not significantly alter the densification process or the occurrence of pores in the sample.
REFERENCES


