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STUDY OF THE PROPERTIES OF METAL MATRIX 25.2%FE-49.5%CU-24.1%CO USED IN DIAMOND TOOLS[1]

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Abstract
Most of the alloys used as bonding matrix in diamond tools show a high content of cobalt - which is undesirable due to a series of reasons. In the last decade, some attempts were made towards the reduction of the Co content in these alloys. NEXT 100® alloy (25.2%Fe-49.5%Cu-24.1%Co) by Eurotungstene is an example of it. This study aims to characterize some mechanical properties of the NEXT 100® - this is a comercial alloy widely used as bonding matrix for diamonds in cutting tools, and the informations about its properties are scarce in the literature. The metallic powders were hot pressed in a graphite matrix at 35MPa/800°C/3 minutes. In these sintered samples, it was made wear resistance and hardness HRB tests. Densification and compression test were performed. It was determined that the NEXT 100® alloy obtained by hot pressed has good mechanical properties and high densification.
Key words: Next 100® alloy; Hot pressed; Properties.

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1 INTRODUCTION

The cutting tools for ornamental stones are characterized by presenting as the main part the cutting elements is its periphery, made of diamond composites, composed primarily of diamonds embedded in a matrix binder, usually metal. The link between diamonds and matrix should be strong enough for high performance. The adhesion between the matrix and the diamond is what determines the microstructural characteristics and performance of cutting tool to perform well. The impregnation of diamond in metal often shows a reaction between the diamond surface and the matrix. Besides the mechanical bond, a chemical relationship can also be formed.(1)

The use of diamond cutting tools depends on the ability of the matrix to hold the diamonds, and thus their support for the cutting process. Thus, the choice of certain metals as binder results in high adhesion to the crystals with diamond tools.(1-2)

The metal alloys used in diamond tools have a high content of cobalt which is undesirable, despite its high adhesion to the diamond, since it is highly toxic and uneconomical because of its scarcity in the world.(3-5) Over the years some alloys with reduced Co content processed such as Cobalite HDR, Cobalite CNF, KEEN and NEXT. (3,6-9)

This study aims to evaluate the mechanical properties of metal matrix 25.2%Fe-49.5%Cu-24.1%Co, for later use in diamond tools and information about their properties are very scarce in the literature.

2 MATERIALS AND METHODS

In this paper, was studied the commercial NEXT 100® alloy for use in diamond tools with the chemical composition (wt%):

- 25.2%Fe-49.5%Cu-24.1%Co

The sintering of metal powders was performed a industrial hot pressing by Pyramid, using the parameters: 35MPa/800°C during 3 minutes. The densification (bulk density - MEA) was determined using the Archimedes method, based on the buoyancy exercised on the sample during its immersion in a water container coupled to a balance. The calculation of the bulk density (MEA or densification) builds on the value of dry mass (DM), immersed mass (IM) and the saturated mass (SM), as shown in Equation (1).

$$MEA = \frac{DM}{(SM - IM)} \qquad \text{Eq. (1)}$$

The measure of hardness Rockwell B (HRB) was performed in a hardmeter Pantec, RBS model, applying a load of 62.5 kgf, and 5 indentations per sample.

The metallic matrix was submitted to test of wear resistance (WR). The testing material was gray granite, with oriented structure and coarse grain size, ranging from 4-20 mm. Hard granite was installed horizontally on the table of a Physical simulator interfaced with computer type AMSLER modified microprocessor model AB800-E, manufactured by Contenco, using the software Pavitest – Abrasion Tester 2:31, to obtain the data. The sample was attached vertically to the hard granite on a pedestal

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with a fixation. The rotation of the granite table was 20 rpm, with a vertical force (weight) on samples of 2 kgf, which represents the best conditions according to studies by Oliveira[4] and Oliveira and Filgueira.[5] Once positioned on the hard granite, the sample remained fixed on a cutting line. The samples were assayed in a total time of 2, 6, 12 and 20 minutes.

To measure the mass loss of the samples and to investigate the wear resistance during the end of each time of test, we used the respective equations (2) and (3):

$$\Delta M = \frac{M_i - M_f}{M_i} 100 \qquad \text{Eq. (2)}$$

where: ΔM is the mass loss (%) Mi is the initial mass and Mf is the final mass.

$$WR = \frac{1}{\Delta M} \qquad \text{Eq. (3)}$$

Where: WR is the wear resistance (%).

The diametral compression test was carried out on a universal testing machine – INSTRON, model 5582 - 100 KN capacity, using a speed of 1 mm/min. Details of this test are found in the literature.[10]

3 RESULTS AND DISCUSSION

The mechanical properties and the densification, which indicates the densification achieved by the sample evaluating effectiveness of sintering, are presented in Table 1.

Table 1 - Mechanical Properties and densification of the NEXT 100 alloy obtained in this work

Metallic Alloy	*Densification (%)*	*Hardness HRB*	*Yield stress σ_e (MPa)*	*Compressive Strength σ_m (MPa)*	*Modulus of Elasticity E (GPa)*
NEXT 100	99.5	95.5	244.0	617.9	61.9

According to the research conducted with the NEXT 100 commercial alloy,[6,9] its structure is composed of two phases, ductile phase rich in Cu and solid solution rich in Fe(α). The presence of CoFe solid solution embedded in Cu matrix, improves the properties of the alloy.

It is known that the main phenomenon of mass transport for densification are basically limited by the phase rich in Cu. This densification process has two important contributions. First, during the compression stage, where due to low stress field of the particles of Cu and the effect of stress concentration produced by the presence of the second hard phase CoFe, while Cu can achieve significant plastic deformation and consequently a relatively high density. Second, during high temperature pressing, plastic flow for these highly strained Cu particles is seen as an important role in the activation of mechanisms of material based on diffusion through agglomeration at grain boundaries.[6]

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Considering the stage of compaction and its influence in pressing the high temperature, an interesting question arises regarding the effect of stress concentration of hard particles CoFe into ductile phase Cu for the NEXT 100 alloy. The amounts present in solid particles of CoFe induce a high deformation that act by increasing the driving force for densification. Therefore, the concentration of Cu in the alloys has a stronger effect on densification kinetics than in its state of deformation, confirmed by the high value of densification to NEXT 100 alloy (99.5%).

According to literature, Cobalite HDR [(3)] presented a densification of 98% for sintering temperatures between 750 and 850°C. The cobalt alternatives alloys, called DIABASE (Fe-Co-Cu-Sn)[(11)] sintered in a temperature range between 780 and 900°C has a density of about 98.5%. While the NEXT 100 alloy[(6)] showed a density of 97% using sintering temperature of 720°C.

At this point, one can say that the NEXT 100 alloy studied in this work, sintered at 800°C, presented higher densification than other alloys that are intended to replace or decrease the Co content, sometimes mentioned above, even when compared to itself NEXT 100 alloy[(6)] sintered at 720°C.

The metallic matrix NEXT 100 showed results as good as those in the literature for the HRB hardness.[(2,3,7-8,11)] The NEXT 100 alloy studied here had a value HRB of 95.5 ± 2.8, while for the Cobalite HDR was 108 HRB, the DIABASE with hardness between 94-97 HRB and the NEXT 100 obtained from literature, 109 HRB. The authors noted that the final hardness of the alloy is initially controlled by porosity verified by the density of up to 95%, since above this value, the property is strongly dependent on the proportion of Fe-Cu or the greater the proportion of the hard phase (solid solution CoFe), the higher the hardness of the alloy.

In diametral compression test, the value of σ_e and σ_m may be related to the material's resistance to plastic deformation, since this matrix has a high hardness, 95.5 ± 2.8.

This commercial matrix presented a high value of E and low elastic deformation due to the presence of hard phase CoFe that generates stress concentrations, leading the Cu to achieve significant plastic deformation, and therefore a modulus of Elasticity and high density,[(6)] as noted in Table (1).

This relationship between density and compressive strength of the materials was observed in the work of Jonsen, Häggblad and Sommer,[(10)] noting that the resistance of the material to deform plastically increases as the density increases.

De Châlus[(12)] comments that for optimum productivity and cutting efficiency, the metallic matrix should contain good mechanical properties, because during the cutting operation, the diamonds are subjected to stress by direct contact with the material to be cut. These stresses are transmitted directly to the matrix, and their mechanical behaviors are very important.

Since the yield stress is related to the hardness of the metal matrix, this may be indirectly related to the retention for friction (adhesion) of diamond crystals in the metal matrix. Given this, the metallic matrix NEXT 100 presented a satisfactory relationship of hardness to yield stress, this may be feasible in the manufacturing of diamond composites.

In Figure 1 and Table 2, it is shown the value of WR obtained for the metallic matrix NEXT 100, showing its behavior in different time intervals after suffering mass loss during the wear tests.

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Table 2 - Wear Resistance of matrix NEXT 100

Time (min)	***Wear Resistance (%)***
	NEXT 100
2	0,453
6	0,171
12	0,150
20	0,149

Initially there was a decrease in the WR, probably due to the as well as due to the higher content of pores on the samples surfaces. After six minutes, the curve of WR linearizes until it reaches 20 minutes. This shows that after 6 minutes of work cutting the alloy did not lose enough mass to lower the cut quality of it.

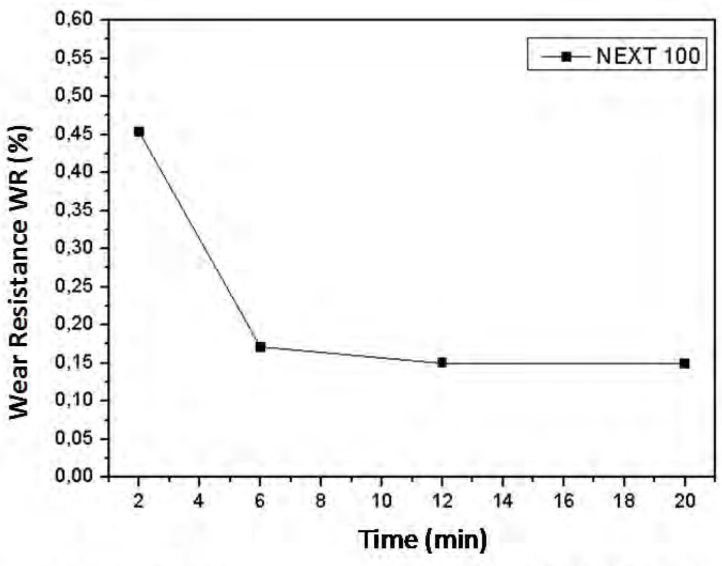

Figure 1 - Wear Resistance *versus* time for the NEXT 100 alloy.

There is no direct relation between hardness and WR. Not always the hardest material is what sets a good power of cutting, because the material has a very high hardness, the matrix may suffer fracture and with the addition of diamonds, they will not be able to keep fixed in the metallic matrix during cutting, consequently hindering the improvement of ornamental rocks cutting.

This can be seen clearly when faced with the industrial NEXT 100 alloy, which had the best result of toughness, but during the trial of WR, did not act efficiently in the face of metal matrix that aim to decrease the use of Co in these tools.

4 CONCLUSIONS

NEXT 100 alloy obtained in this work, sintered at 800°C, had a score of densification and hardness than the other alloys that are intended to replace or decrease in Co in them, sometimes mentioned above.

The density obtained by the NEXT 100 alloy is associated with the mechanism of mass transport during pressing at high temperature. Where the quantities present in solid particles of CoFe induce a high strain in Cu which act by increasing the driving force for densification and consequently the decrease of porosity and increased hardness.

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NEXT 100 alloy showed with a high value of E and low elastic deformation due to the presence of a hard phase CoFe.

NEXT 100 presented a relationship of hardness and yield stress satisfactory, this may be feasible in the manufacturing of diamond composites.

The good mechanical properties compared to the literature, is related to the presence of solid solution CoFe dispersed in Cu matrix.

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