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Mechanical Characterization of Alumina-Doped Tungsten Carbide

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Abstract. Cemented carbides have dominated the cutting tool market. Recent works have shown the development of new WC-materials in order to improve their mechanical properties and oxidation behavior. This work reports the first results produced by the addition of aluminum oxide in a tungsten carbide matrix. WC-material with 10 wt.% of cobalt was mixed with 5 and 10 wt.% of Al_2O_3 in a planetary ball mill. Subsequently, samples with 10 mm in diameter were uniaxially hot-pressed. The composite material was characterized by X-ray diffraction, hardness and scanning electron microscopy. The results showed that the addition of 10 wt.% of Al_2O_3 has improved the hardness value of the tungsten carbide matrix.

Introduction

Cemented carbides are actually the most used cutting tool material [1], mainly because of their good mechanical properties such as hardness and fracture toughness. Recent studies have presented the possibility to improve the quality and the performance of tungsten carbide. The works have shown an increase of the mechanical behavior of WC-Co through the addition of TiC, Mo_2C, VC or NbC, that act as grain growth inhibitors, different binding phases and the use of nanocomposites [2-7]. The presence of such refractory carbides causes in WC-Co and also in an alumina-based composite material a restriction of the grain growth of the matrix and as a consequence an improvement of the mechanical properties [8-11].

The objective of this study is to present the preliminary results obtained for tungsten carbide reinforced with aluminum oxide.

Experimental Procedure

Tungsten carbide (Wolfram Bergbau, Áustria) with D50 = 1.0 μm and 10 wt.% Co powder (binder phase) were mixed with 5 and 10 wt.% Al_2O_3 (APC 2011 SG, Alcoa, Brazil). The powder mixtures were milled and homogenized for 4 hours in a planetary ball mill. Pellets of 10 mm in diameter were then uniaxially hot pressed at 1360 °C for 60 minutes in flowing argon under a pressure of 20 MPa.

The analysis of crystalline phases was carried out by X-ray diffraction, using monochromatic CuKα-radiation. Microstructural analysis was performed in a light microscope and scanning electron microscope on samples polished with diamond paste and chemically etched with Murakami reagent. Hardness values were measured at WC-Co matrix by Vickers indents using a load between 30 and 50 N.

Results and Discussion

Fig. 1 shows the variation of hardness as a function of the alumina content. Hardness values of WC-composite materials did not increase monotonically with alumina contents. The presence of 5 wt.% alumina has produced no effect on hardness behavior as compared to tungsten carbide. Otherwise, the addition of 10 wt.% Al_2O_3 has improved the hardness of the composite from 1700 to an average value of 1878 GPa. This behavior suggested that the increase of hardness could probably be attributed to a finer microstructure. The presence of 10 wt.% Al_2O_3 may inhibit the grain growth of tungsten carbide grains and produces an increase of the hardness value. Similar result was observed in WC reinforced with vanadium carbide [3]. The dispersion of VC in a tungsten carbide matrix decreases the grain size of WC-matrix, increasing the hardness values. Studies have also shown that the addition of NbC and WC to alumina causes a reduction of the average grain size of the alumina matrix and an improvement of the mechanical properties [8,10].

Table 1 compares the hardness values obtained in this work with others data published in the literature for WC and Al_2O_3-composite materials. The hardness values obtained in this work for WC-Co-Al_2O_3 are comparable with others works and consistent with the composite processing method. Pressureless sintering resulted in lower hardness values, ranging from 1400 to 1717 GPa. Hot-pressed [8,10] and ultra fine WC-composite materials [3] produce a denser samples and as a consequence harder composite materials.

Fig. 2 and 3 show the microstructure of WC-Co reinforced with 5 and 10 wt.% of alumina, respectively. The composite materials show a homogeneous microstructure and the presence of pores and no large grains (exaggerated grain growth).

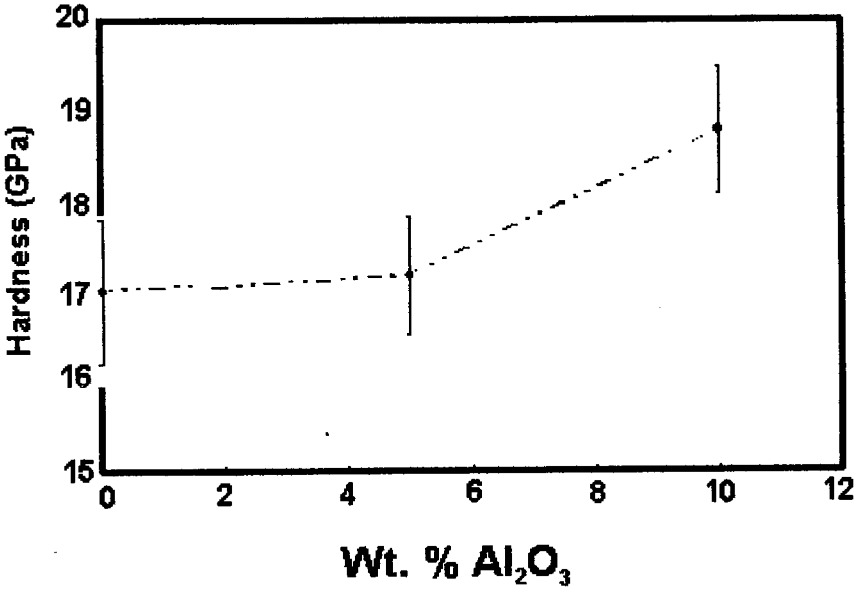

Fig. 1: Variation of WC-Co-hardness as a function of alumina content.

Table 1: Hardness values of Al_2O_3 and WC-composite material.

Material	Hv [GPa]	Reference
WC-Co	1700	This work
WC-Co- 5 wt.% Al_2O_3	1718	This work
WC-Co- 10 wt.% Al_2O_3	1878	This work
WC-Co-TiC	1400	[5]
WC-Co-TiC-Mo_2C	1420	[5]
WC-Co-VC [1]	1925	[3]
WC-Co	1717	[12]
Al_2O_3 + WC	1750	[10]
Al_2O_3 + NbC	1800	[8]

[1] ultra fine powders

Fig. 2: Microstructure of WC-Co reinforced with 5 wt.% Al_2O_3.

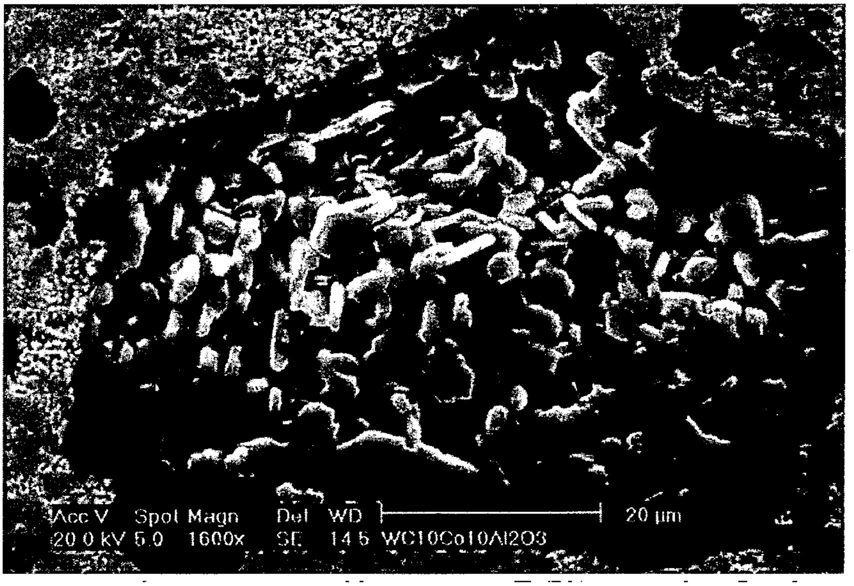

Fig. 3: Microstructure of WC-Co reinforced with 10 wt.% Al_2O_3.

Fig. 4 shows the diffraction pattern of WC-Co with 10 wt.% alumina. X-ray diffraction analyses have shown the presence of WC, Co and Al_2O_3. No presence of oxidation products or new crystalline phases was identified.

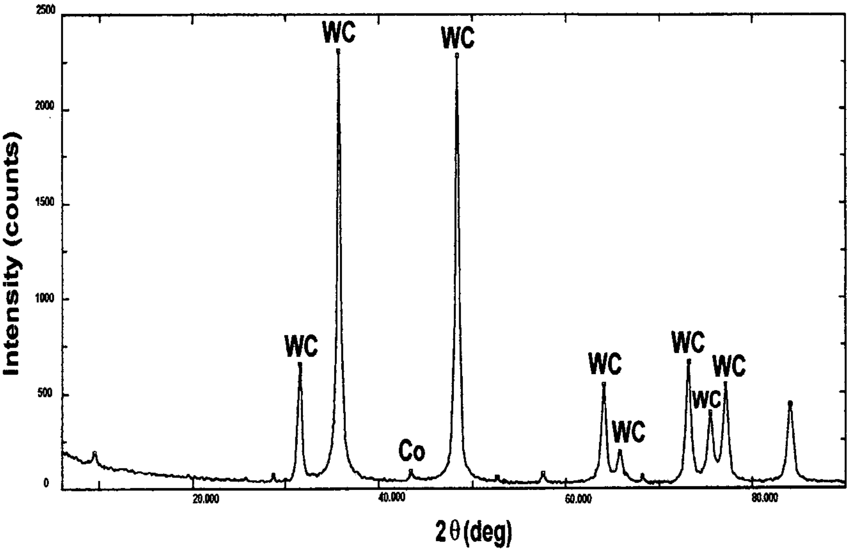

Fig. 4: X-ray diffraction of WC-Co-10 wt.% Al_2O_3.

Therefore, WC-Co reinforced with Al_2O_3 presents good hardness and has the potential to be further developed as a alternative cutting tool material. Further investigation are under way to identify the optimal alumina content to produce a homogeneous microstructure with higher hardness and also to study the oxidation behavior of the WC-Co-Al_2O_3 composite material.

Conclusions

The results obtained from the characterization of WC-Co reinforced with alumina revealed that:

1- The addition of 10 wt.% of alumina has improved the hardness of tungsten carbide.
2-
3- The hardness values observed in this work are similar to other WC-composite materials.
4-
5- No oxidation products and no new crystalline phases were identified.

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