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STRUCTURE - PROPERTIES CORELATION IN SINTERED HARD ALLOYS WITH HIGH TOUGHNESS AND STRENGTH

Victor STANCIU
„Gh. Asachi” Technicalal University Iaşi
email: stanciu.victor@hotmail.ro

ABSTRACT

The researches effectuated until now in the field of sintered hard alloys based on metallic carbides have the aim to improve them properties through modifications of existing technologies and by creating other news ones, like mechanical alloying. The present paper has the purpose to study all influencing factors on the hard alloys properties and his correlation in order to obtain materials with ultra fine structures able to assure superior properties for pieces made from this alloys.

KEYWORDS: sintered metallic carbides, structure, properties.

1. Introduction

Sintered hard alloys based on metallic carbides represent a very important field of powder metallurgy. High hardness combined with a very good wear resistance recommends these alloys for a large number of industrial applications: machining tools, active parts for ball mills, mining tool, tunneling etc. Metallic carbides have low sinter ability, the final product being very fragile, in useful. To increase the toughness of these materials, in the carbide powder is introduced a metal from the iron group, the most utilized being the cobalt, in a proportion of 3-30% like binder. Alloy is sintered at temperatures which is favorising liquid faze apparition. In this way it is possible to obtain a density close to the theoretical ones and a corresponding toughness [1]. All over the world, exist at this time a continuously preoccupation for improving sintered hard alloys’ properties. With all progresses, the ways for better properties are still open. The possibility to obtain powders much more finely using more efficient technologies, utilization of special procedures for sintering or by introducing alloying carbides in materials composition it’s opening new research directions [2]. The main objective of present paper consists in a study on the relation between sintered hard alloys structure and their properties, in order to improve materials performance. The researches done in this field has demonstrated that hardness and toughness of these materials are very close together with carbide particles dimensions that form the alloy. The values of these properties are increasing when particles dimensions decrease. The next step is to study the factors that have an influence on the hard alloys structure and their optimization, in order to obtain the best properties in the final product.

2. Influence factors

Resistance, ductility and toughness of samples made form hard alloys based on sintered metallic carbides are depending by matrix proportions, carbide particles dimensions and presence of secondary phases. This secondary phase is formed from other type of carbides, like chromium carbide, vanadium carbide, tantalum carbide and titanium carbide. The cobalt is the most utilized material for matrix in sintered hard materials because it presents a high capacity to wet the hard phase.

Properties of sintered hard alloys depend on many factors, the most important being:

- Chemical composition
- Constituents individual properties
- Size, shape and distribution of hard phase
- Insufficiency or excess of carbon
- Hard phase solubility in matrix
- Composition variation
- Production method

To have optimum properties, a WC-Co alloy has to present a very low porosity, a uniform distribution of carbide particles in matrix and a stoechimetrical content of carbon. Tungsten carbide presents a much-reduced tolerance at carbon content variations (stoechiometrical content 6, 13% C). Small increases of carbon content favors the apparition of graphite separations whitch reduce bending strength and hardness. On the other side, carbon content lower than 6,13 %, caused by decarburizing at sintering or by a carbon deficiency in carbide powder, lead to apparition of W_2C phase, a compound hard and very brittle, which decrease alloy toughness and ductility.

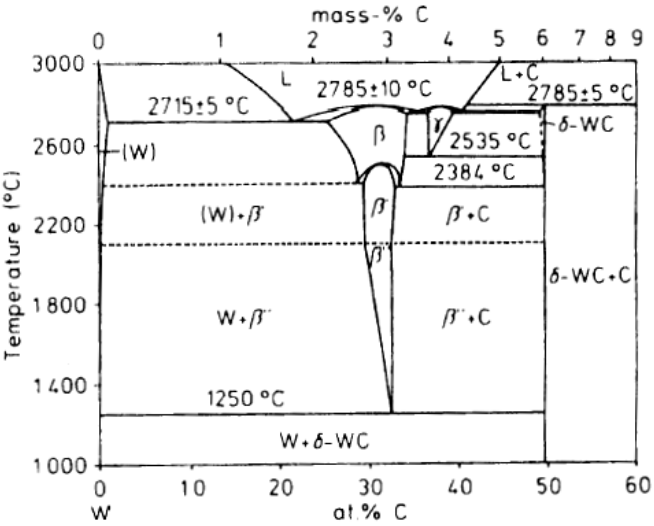
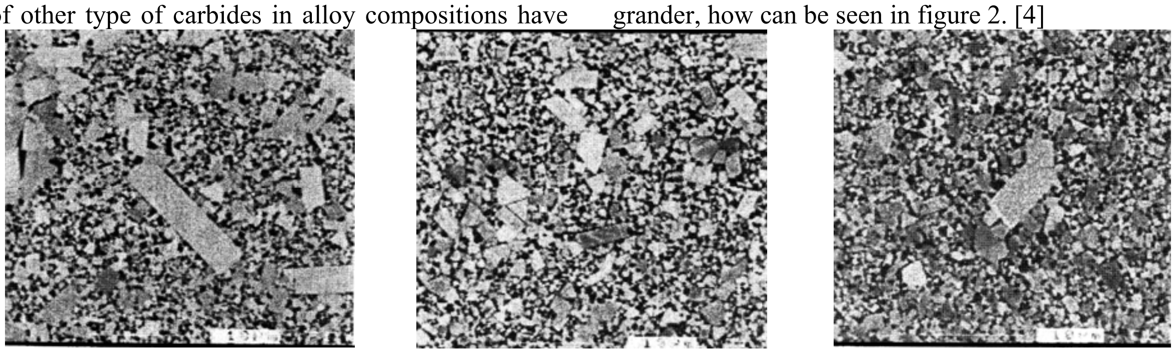


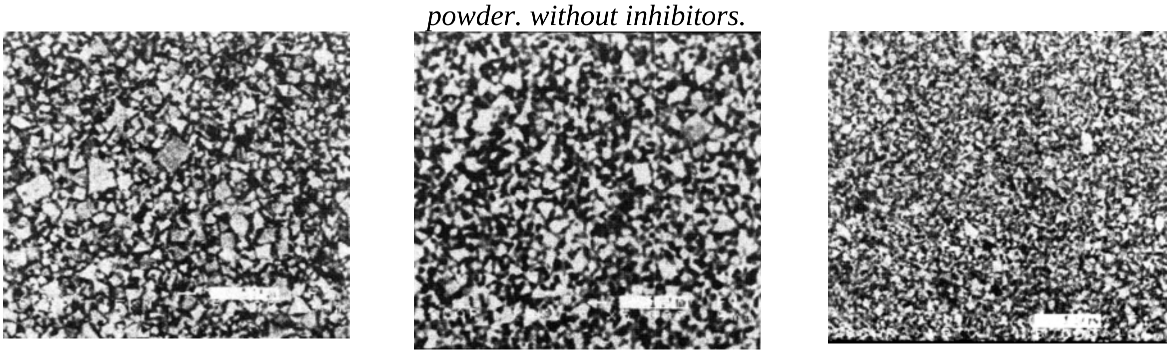
***Fig. 1**. W-C phase diagram* [2].

This compound reacts with matrix metal forming complex carbides by type $W_xCo_yC_z$ (η phase). The presence of η phase determines a coarse and unregulated microstructure. This type of structure makes the material very brittle by reducing proportions of matrix material. [3] The introductions of other type of carbides in alloy compositions have as purpose to avoid grain growth at sintering, to increase hardness, toughness, wear resistance and to improve corrosion resistance. The utilization of tungsten carbide powder without grain growth inhibitors is not recommended. How much finer is the start powder, for that grain growth at sintering will be grander, how can be seen in figure 2. [4]



0,6 µm, 6% Co, X3000 | 0,8 µm, 6% Co, X3000 | 1 µm, 6% Co, X3000

***Fig. 2**. The growth of carbide grains after sintering in alloys with different dimensions of initial powder. without inhibitors.*



0,6 µm, 10% Co, 0,3% Cr_3C_2 | 0,6 µm, 10% Co, 0,5% Cr_3C_2 | 0,6µm, 10 % Co, 1,35% Cr_3C_2

***Fig.3**. The effect of inhibitors (Cr_3C_2) addition on the microstructure of WC-Co alloys.*

Chromium carbide (Cr_3C_2) and vanadium carbide (VC) is the most utilized crystalline grain growth inhibitors. In alloys composition the inhibitors are present in a proportion of maximum 1.5 %, as functions of binder content and his solubility in binder. A higher content of inhibitors lead to apparition of γ phases. At sintering temperature, the inhibitor is dissolved in cobalt, limiting the solubility of tungsten carbide in the binder. At cooling, VC precipitate like nano particles of complex carbide (V,W)C and chromium carbide remains in solution, presenting the tendencies to diffuse on grain boundaries [5]. A corresponding wetting of hard phase by the binder leads to improved mechanical and technological properties. A thick layer of tough binder who separates the carbide particles will stop the crack propagation. Next figures show the effect of binder proportions on the hardness and toughness of sintered hard alloys.

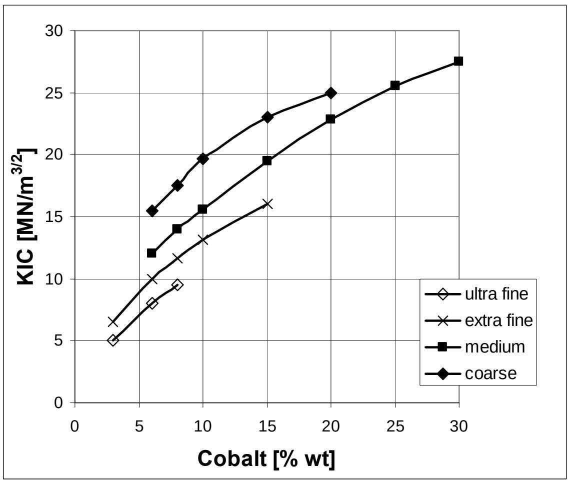


Fig.4. *Toughness of WC-Co as function of cobalt content and carbide size.*

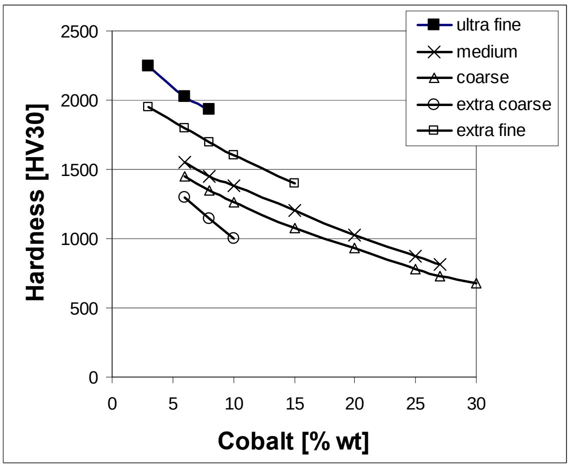


Fig.5. *Hardness of WC-Co as function of cobalt content and carbide size*

3. Structure – properties correlation

The design of hard alloys has to be donning, every time when possible, keeping account by the working conditions of the final product. Interaction between components, maximum temperature and maintaining time at maximum temperature are factors that have a decisive importance in sintered products structure evolutions. Particle dimensions and granulometric distribution of tungsten carbide are very important factors in sintered hard alloy structure determination. WC-Co alloys with a coarse structure are more ductile than that finer. On the other hand, the alloys with a finer structure present higher hardness, toughness and wear resistance. Carbide particles complete separation with an intermediate layer of cobalt with a 0.4-0.6 µm thickness permit to obtain an optimum resistance for sintered hard alloys, this fact being presented in figure 6.

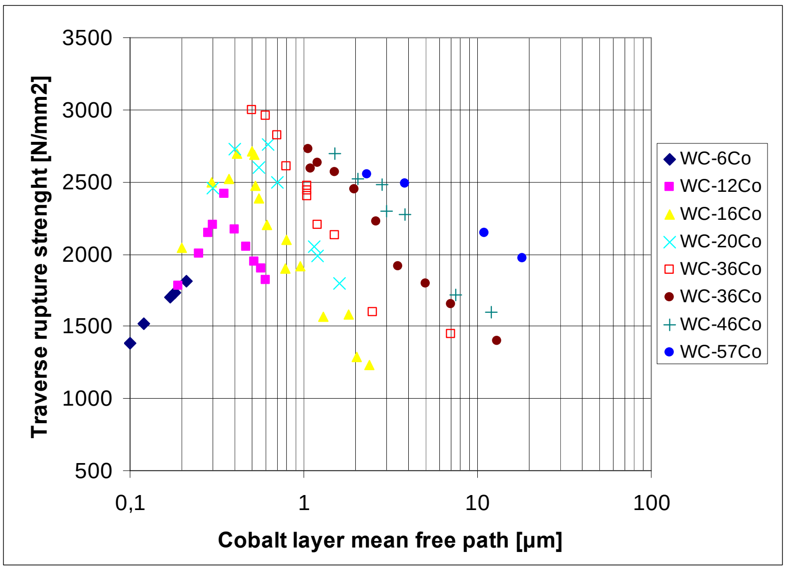


Fig.6. *Traverse rupture strength of WC-Co as function of binder mean free path [1].*

The contact apparition between carbide particles lead to a structure type "skeleton" which must be maintained at low level is possible because the alloy toughness decreases [6].

For increase properties of sintered hard alloys, the classical hard alloy, WC-Co, is modified with an amount of other carbides like titanium carbide, tantalum carbide and niobium carbide. Titanium carbide is less soluble in cobalt comparative with tungsten carbide. Present at lower diffusivity and, for this reason, have a higher wear resistance at high temperatures and low tendencies to adhere to the chip. This property recommends WC-TiC-Co grades for machining tools in steel industry at great work speed where pear high temperatures on chip – tool interface. Instead, TiC reduces the strength of sintered hard alloys and his associated properties: edge resistance, toughness and compression resistance.

Additions of Ta/NbC have improved as results of wear resistance and hardness at high temperatures. Ta/NbC reduce strength alloy less than TiC. With hardness exception, WC-Ta/NbC-Co alloys have superior properties than WC-TiC-Co grades. [6]

4. Conclusions

Hard phase-binder rapport determines hardness and toughness values; increased binder proportions will improve toughness and decrease hardness.

At the same rapport between hard phase and binder, dimensions of carbide particles determine alloys properties. The alloys with more fine structure present increased values for hardness and toughness.

The utilization of ultra fine carbide powders make possible to rise binder content without affecting hardness values.

The fine structures is maintained by introduction of small amount of crystalline grain growth inhibitors in alloys composition, the most utilized being VC and Cr_3C_2. Vanadium carbide assure a high hardness and small dimensions of carbide particles and chromium carbide improve alloy toughness.

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