Study for the Development of Fe-NbC Composites by Advanced PM Techniques

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Abstract

The development of Fe-based metal matrix composites (MMCs) with high content of hard phase has been approached by combining the use of advanced powder metallurgy techniques like high-energy milling (HEM), cold isostatic pressing (CIP) and vacuum sinterings. A 30 % vol. of NbC particles was mixed with Fe powder by HEM in a planetary mill during 10h, characterising the powder by the observation of morphology and microstructure by scanning electron microscopy (SEM). After of sintering process the variation of density, hardness ,carbon content and the microstructural changes observed, permits to find the optimal conditions of processing. Afterwards, a heat treatment study was performed to study the hardenability of the composite.

Keywords : Fe-based MMCs; high-energy milling; sintering; heat treatment

1. Introduction

Ceramic particles of NbC have high hardness and thermal stability and can be used to produce iron-based composites by powder metallurgy route, involving the addition of NbC particles to iron powder. However, some difficulties have been found for the introduction of hard particles in a Fe matrix [1], the main of which is the agglomeration of ceramic particles leading to a heterogeneous microstructure[2]. High energy milling (HEM) is proposed as a method to avoid this problem; this process permits to obtain a homogeneous dispersion of hard phase into the ductile metal matrix [3,4,5]. In binary chemical compounds of M-C (M= Cr, Mo, Mn) during the milling process, the dissolution of carbon into the iron-Matrix is promoted[6,7,8]. However, NbC is difficult to decompose by HEM and ball milling only promotes the formation a composite powder with smaller grain size. Most of the work on the Fe-Nb-C systems with lower content of C is concentrated in the technologically important iron-rich side, where the equilibrium between α/δ and γ-iron with the ϵ-Fe2Nb Laves is presented [9]. In this work the ϵ-Fe2Nb is obtained during the sintering process and the effects of heat treatment are studied in order to improve the final properties.

2. Experimental and Results

The powder used as binder was plain iron powder (grade ASC 100-29, Höganäs, Sweden). As reinforcement, 30 % vol. of NbC particles was employed. An addition of 0.25 % wt C was made to avoid the loss of carbon during the milling and to obtain a steel matrix. High-Energy Milling (HEM) was carried out in a planetary ball mill. The maximum time of milling was 10 hours and, during the process, samples were taken every 2 hours for their characterization by X- ray diffraction (XRD), determination of particle size with a laser equipment, morphology and microstructural analysis by scanning electron microscopy (SEM), and carbon content by LECO. After the preparation of powders, compacts were produced by cold isostatic pressing at 3000 bar and sintering under vacuum. The sintering temperatures varied between 1300 ºC and 1375 ºC, for 30 min and 60 min. Sintered samples were characterised by determination of density, dimensional change, Vickers hardness (HV30) and C contents (by LECO). The microstructural study was carried out by scanning electron microscopy (SEM). After these analyses, the material sintered at 1350ºC was selected to study the hardenability of the composite. The heat treatment includes a hardening step, by heating to 950 ºC and 1000 ºC for 10 and 60 minutes and cooling in water, followed by double tempering at 540 ºC. Finally, Vickers hardness (HV30) was measured and a microstructural study were carried out. The results obtained after the milling process shows no transformations or new compounds appear after the time of milling used [10]. After 10 hours the particles are rounded and the microstructure is more homogeneous. Once selected the powder after 10 hours of milling, was compacted and sintered. All samples shrunk due to the liquid-phase sintering process. The maximum shrinkage was obtained for the samples sintered during 1 hour at 1350 ºC. Relative density remains constant between 1325ºC and 1350ºC in spite of the increasing of shrinkage(Fig1).

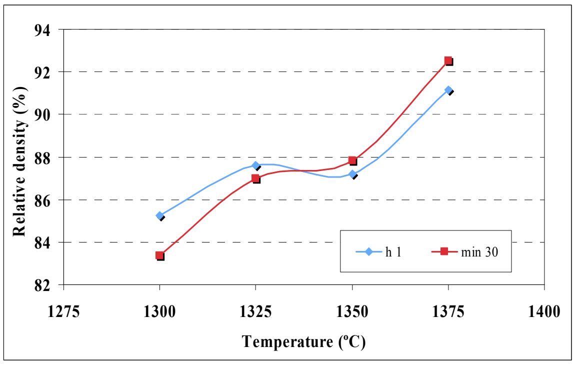

Fig. 1. Variation with temperature of relative density.

The reason is the presence of the higher content of intermetallic Fe2Nb at 1325 ºC, which presents higher density, increasing the measured density in relation to the theoretical. The materials show lower values of hardness (140-240 HV30), similar values than other Fe-NbC systems for similar conditions of sintering [11]. With these results, samples sintered at 1350 ºC were selected to study the hardenability of the cermet at different temperatures. The criteria to choose these sintering conditions were the highest contraction, highest hardness (233 HV30) and lowest content in intermetallic phase. The phases present after treatments were: NbC, Fe and Fe2Nb, but theirs compositions were not constant, changing with the conditions of treatment: the higher the temperature and time, the lower the ratio Nb/Fe both in carbides and intermetallic phase, and the higher the quantity of Nb dissolved into the matrix.

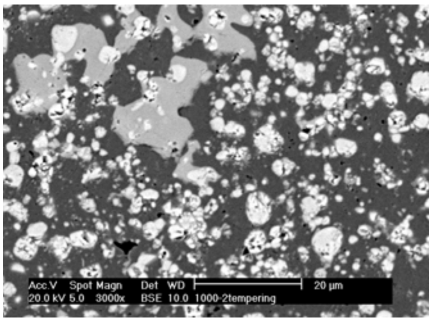

Fig. 2. Microstructure after complete heat treatment. Hardening temperature: 1000ºC.

These changes indicate that Nb diffuses from the Nb-rich phases into the matrix as a result of the activation of diffusion processes, and it has an effect on the hardness. The maximum hardness after hardening was obtained when the composition of the intermetallic is closed to the stoichiometry of Є-Fe2Nb. However, after tempering the hardness decreases, showing similar behaviour than a carbon steel. On the contrary, for the highest temperature of hardening, the higher dissolution of carbides and intermetallic lead to a softer material, that hardens after tempering. In this case, the behaviour is more similar than a tool steel, and precipitation of secondary carbides could have taken place (Fig. 2).

3. Summary

Composite Fe-NbC powder produced by HEM can be processed by PM techniques to obtain high-dense cermet-type materials. However, the hardness is low due to the plain iron matrix and the transformation of part of the added carbides into the intermetallic phase Є-Fe2Nb.

The heat treatments performed to harden the material provoke changes in the composition and distribution of the phases present in the microstructure, but do not increase the hardness. It seems that the intermetallic phase play a role in the hardenability of the material.

The microstructure of heat treated materials is more homogeneous than as-sintered materials and presents low porosity.

4. References

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