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PROCESSING OF AISI M2 HSS WITH ADDITION OF NbC BY MECHANICAL ALLOYING USING TWO DIFFERENT TYPES OF ATTRITOR MILLS

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Abstract. The processing of a molybdenum AISI M2 high speed steel with the addition of NbC (6% in mass) by a Powder Metallurgy technique of Mechanical Alloying is the aim of this work. Mechanical Alloying (MA) has been used primarily for particle size reduction, to its present status as an important method for the preparation of either materials with enhanced physical and mechanical properties or, indeed, new phases, or new engineering materials. In this work, niobium carbide (NbC) was added to the AISI M2 HSS powders by Mechanical Alloying technique in two different types of attritor mills and the materials which resulted were characterized by means of SEM plus EDS. The powders were processed in a horizontal attritor Zoz mill and in a vertical attritor mill developed in our laboratory. The parameters of milling were distinct and the results of the processing were compared.

Introduction

A wide variety of materials have been developed to perform as tools. However, tool steels are still the most used tool materials. Both the traditional grades, developed empirically, and new grades are being upgraded by special processing or by the use of new metallurgical concepts, e.g. microalloying, to optimize properties. Niobium, a strong carbide-forming element, is a newcomer to this field which is progressively finding its way into a variety of tool steels.

Usually tool steels rely on a variety of alloying elements to fulfill these requirements. Among them are the carbide-formers chromium, molybdenum, tungsten and vanadium. Therefore, at a first glance it is surprising that niobium, being their neighbor in the periodic table, is only little used in tool steel. The reason might be seen in the empirical development of most of the steel grades and the fact, that niobium is plentiful and inexpensively available only after pyrochlore reserves were developed in Brazil and Canada during the 1960's [1].

The basic consideration when applying niobium to steels, is that it forms very stable carbides to facilitate grain refinement and precipitation hardening as strengthening mechanisms in structural steels. The heat treatment procedure applied to high speed tools steels needs high temperatures of austenitizing and quenching to promote higher hardness and better cutting properties. The addition of niobium carbide to tools steels prevents the grain growth at these high temperatures of hardening procedures of heat treatment [1].

Hardness, adequate toughness and wear resistance are the properties generally required for tool steels. The increased demand for high-quality tool steels at the present time has resulted in the need to produce steels with larger amounts of carbon, as well as other alloying elements. However, increasing the level of the alloying elements tends to promote segregation effects and the coarsening of carbides, and hence a considerable reduction in the toughness results. One way to suppress segregation and coarsening is to use a powder metallurgy (P/M) process [2].

The demand for low-cost high-performance tool steels has resulted in a number of attempts to replace some of the expensive alloying elements (W, Mo) with niobium [3,4]. However, niobium is strong carbide former and modifies the solidification sequence of the steel. In the first stage of solidification, niobium-rich MC carbides are formed [5]. In addition, increasing the niobium content in steel up to a mass fraction of approximately 1.8 % causes an increase in hardness, the wear resistance and the toughness compared to the material without niobium. The affinity of niobium for carbon is greater than that of vanadium. As result, the presence of niobium increases the content of vanadium in the solid solution after austenitizing, and consequently a higher secondary hardness is obtained. In steels containing a mass fraction of more than approximately 2 % Nb, coarse NbC+γ quasi-eutectic regions are formed. These regions are very stable and do not change during high-temperature heat treatment. The presence of these regions in the microstructure is deleterious because they affect the brittleness of the steel, but by using a powder metallurgy process they can be prevented. In order to achieve an alloy with maximum hardness it is necessary to find the optimum heat treatment for the steel [2,3,4,5].

In this work NbC was added to AISI M2 high speed steel by a suitable procedure of mechanical alloying using two different types of attritor Mills: A horizontal Zoz Atritor and a vertical atritor developed in our laboratory types. 6% in mass of niobium carbide (NbC) was additioned to AISI M2 HSS in these two atritor Mills using a ball to powder ratio of 10:1. The efficiency of the milling procedures were evaluated by SEM and EDS techniques.

Materials and methods

AISI M2 supplied by Höganäs was added and mixed with niobium carbide (6% in mass) powders supplied by CBMM and then submitted to a suitable powder metallurgy high energy milling procedure in two types of attritor Mills. The milling times used were 30 minutes and 1 hour. A mass of ball/mass of powders ratio of 10:1 was used. The powders produced by this experimental procedure were characterized by means of scanning electronic microscopy (SEM) and Dispersive Energy Spectroscopy (EDS).

Table I. Chemical composition of M2 steel supplied by Höganäs (% in mass)

wt%	Mo	W	Mn	Cr	Si	V	Fe	C
M2	4.8	6.2	0.25	4.1	0.27	1.97	Bal.	0.83

Figures 1 and 2 present images of the horizontal (Zoz) and the vertical attritor Mills used, respectively. Figures 3 and 4 present images of the AISI M2 and NbC powders used in this investigation.

Fig. 1 – Horizontal attritor type Mill (Zoz).

Fig. 2 – Vertical attritor type Mill developed in our laboratory.

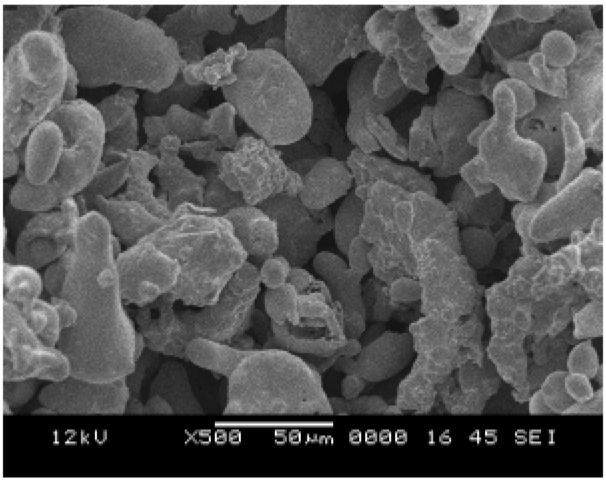


Fig. 3 – AISI M2 high speed steel powder supplied by Höganäs.

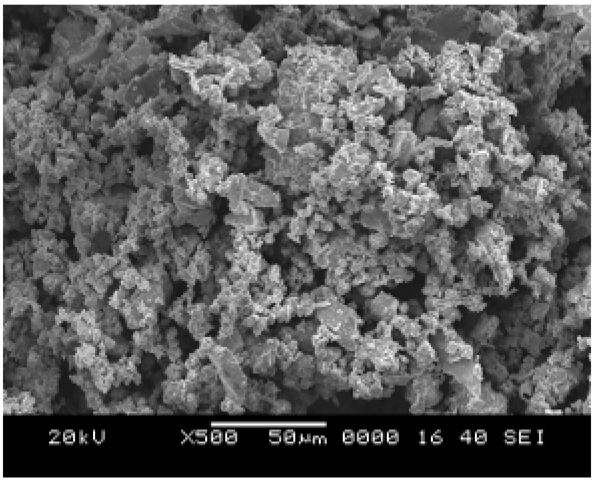


Fig. 4 – NbC powder supplied by CBMM.

Results and discussion

The pair of figures 5, 6; 7,8; 9,10; 11,12 and 13,14 presents images of SEM with the microstructures of M2 + NbC and microanalysis of EDS of the powders produced by mechanical alloying. The milling times were 30 minutes and 1 hour, respectively. Powders of M2+NbC processed and obtained by mechanical alloying object of this work present similar morphology even when different types of attritor Mills were used.

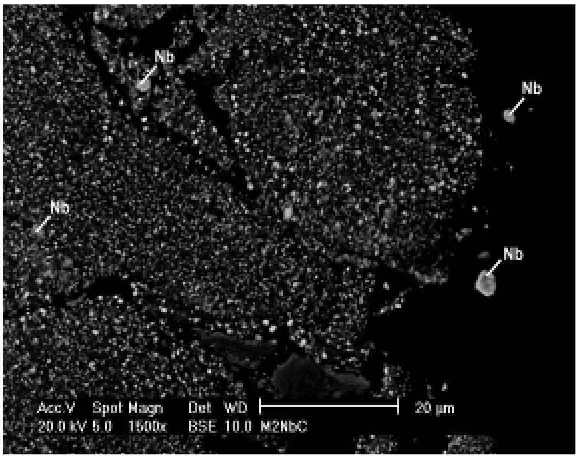


Fig. 5 – SEM Image M2+NbC powder processed during 1 hour, BSE. Zoz Mill.

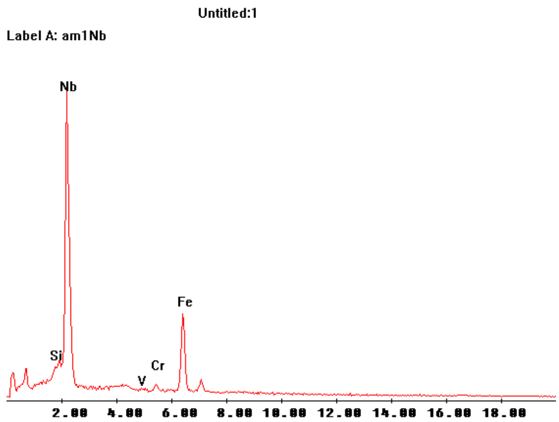


Fig. 6 – Microanalysis of EDS of M2+NbC powder processed during 1 hour, Zoz Mill.

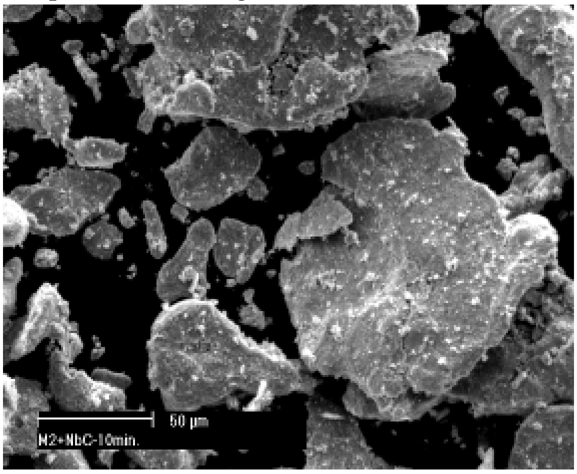


Fig. 7 – SEM Image M2+NbC powder processed during 1 hour, BSE. Zoz Mill.

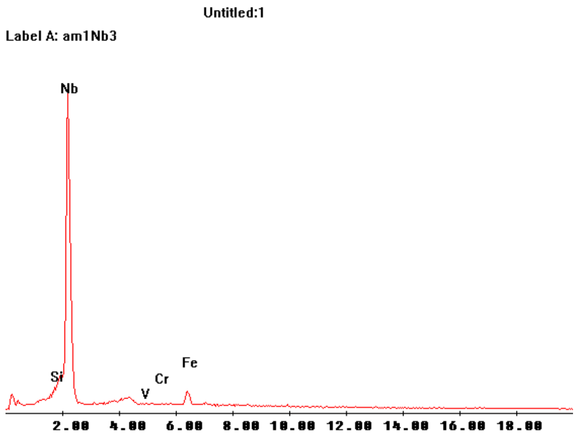


Fig. 8 – Microanalysis of EDS of M2+NbC powder processed during 1 hour, Zoz Mill.

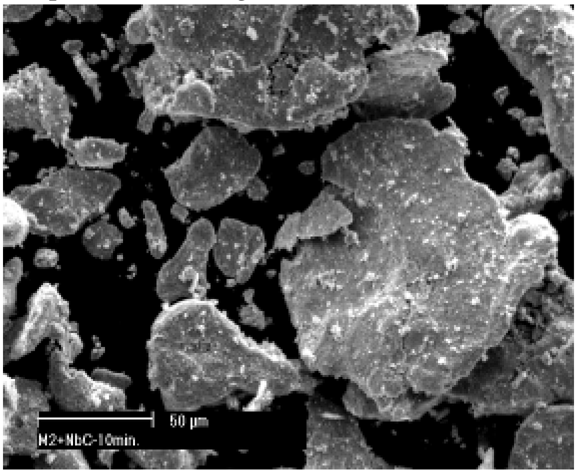


Fig. 9 – SEM Image M2+NbC powder processed during 30 minutes, BSE. Zoz Mill.

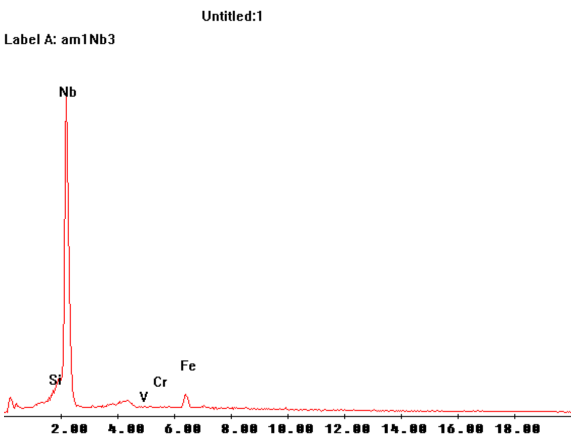
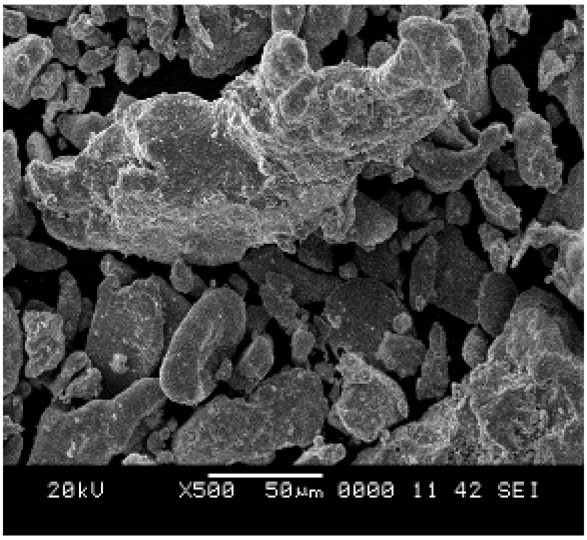


Fig. 10 – Microanalysis of EDS of M2+NbC powder processed during 30 minutes, Zoz Mill.



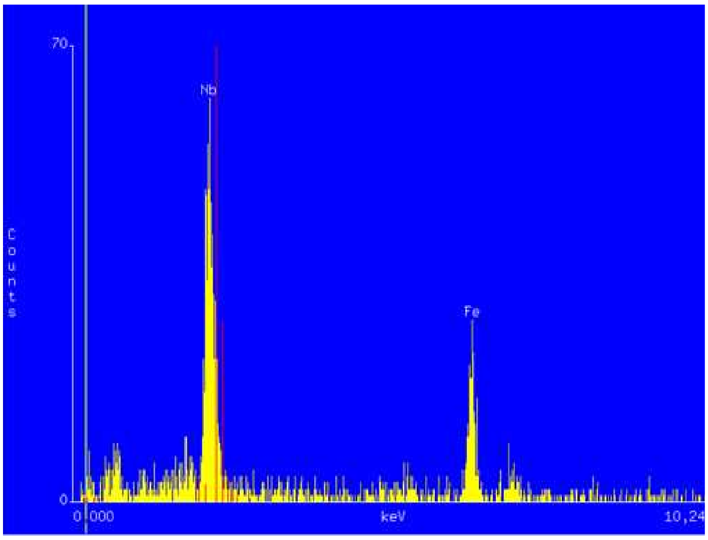
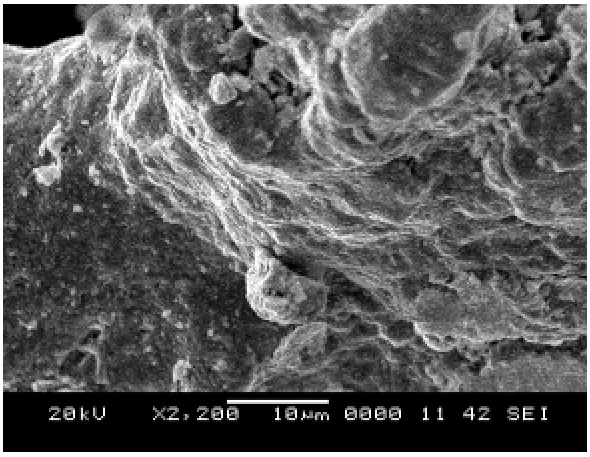


Fig. 11 – SEM Image of M2+NbC powder processed during 1 hour, SE. Vertical attritor Mill.

Fig. 12 – Microanalysis of EDS of M2+NbC powder processed during 1 hour, Vertical attritor Mill.



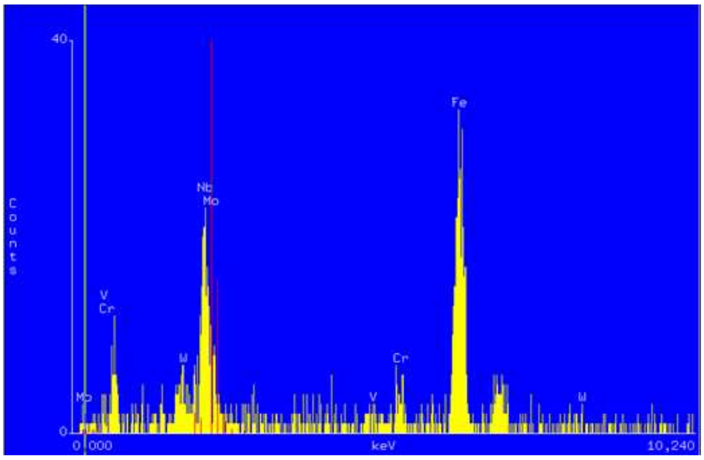


Fig. 13 – SEM Image of M2+NbC powder processed during 30 minutes, SE. Vertical attritor Mill.

Fig. 14 – Microanalysis of EDS of M2+NbC powder processed during 30 minutes, Vertical attritor Mill.

The observation of the microstructures followed by microanalysis of EDS shows the efficiency of the procedures of milling througth the utilization of the two different attritor Mills types. Nevertheless, the characteristic phases of niobium carbide are present so we can verify the success of the PM method of mechanical alloying object of this work of investigation.

Conclusions

1. A suitable Powder Metallurgy high energy milling technique was successfully used to add niobium carbide (NbC) to AISI M2 powders;
2. Both attritor Mills used in this research to add by the Powder Metallurgy high energy milling technique observed by means of characterization of SEM and EDS techniques were effective to produced the M2 reinforced by NbC;
3. Higher milling times must be used in order to investigate the morphology of the NbC powders and to obtain refined powders;
4. The analyzed samples showed that the high-energy milling by using the two kinds of attritor mills are an alternative route for the obtaining of of M2 + NbC powders.

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