STUDIES REGARDING THE INFLUENCE OF BORON ADDITION ON THE HARDNESS AND FRICTION COEFFICIENT OF THE Mn, Mo AND Cr ECOLOGICAL ALLOYED SINTERED STEELS

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Abstract. In this paper are presented the experimental results regarding the elaboration of the Fe-Mn-Mo-Cr-B-Graphite and Fe-Mn-Mo-Cr-Graphite ecological alloyed sintered steels. There have been produced mixes containing 3% Mn, 1%Mo, 1.5%Cr, 0.5% B, 0.45Grafit and Fe which were exposed to the process of Mechanical Alloying (MA) for 20, 40, and 60 hours. The mixtures were pressed in a cylindrical die at three pressures (600,700 and 800 MPa), after that the green densities were calculated. The compacts were sintered in a furnace with protective atmosphere (Ar) at different temperatures (1050, 1100 and 1150 °C) and the dwell time was 120 minutes. The samples obtained after sintering treatment were investigated by optical and electronic microscopy. The mechanical properties such as hardness and friction coefficient were studied too. It is observed that high values of hardness (HV0.2) and friction coefficient μ = 0.158 were obtained for the Fe-Mn-Mo-Cr-B-Graphite ecological steels obtained after 60 h of mechanically alloying, pressed at 800 MPa and sintered at 1150 ^{o}C.

Keywords: mechanical alloying, alloyed sintered steels, hardness, friction coefficient

1. Introduction

Molybdenum, chromium and manganese offer considerable potential as alloying elements in sintered steels, especially for PM precision parts used for example in automotive engines and transmissions and in particular for recycling and health/safety aspects [1, 2, 3].

Based on the data from bibliographic research, the paper is focused in the direction of replacing Cu and Ni with Mn, Mo and Cr adding to these B in proportion of 0.5% to facilitate liquid phase sintering and to contribute to the sintered steel densification [4, 5, 6].

The presence of B as alloying element leads to the formation of Fe_2B compound which had good influences on the mechanical characteristics. [6].

In the structures of Fe-Mo-B and Fe-Cr-Mo-B steels the presence of Mo and Cr borides as fine particles dispersed in ferrite matrix lead to the hardening of sintered steels [5, 7].

There are a lot of transformations in the Fe-B system at the sintering temperature. At 1000 ºC boron is presented as particles and at higher temperatures 1125-1150 ºC it is observed the presence of eutectic liquid phase [4].

The presence of the liquid phase leads to the decreasing of sintering temperature and porosity of the sintered materials.

In the Fe-B-C system the addition of C have o good influence in the formation of liquid phase too. For 0.2% C contents the temperature of liquid phase formation decreasing with 25 ºC [5].

2. Materials and experimental procedure

For the experimental research it was used atomization Fe powder ANCORSTEEL 1000B, made by S.C. Ductil S.A. Buzău with the characteristics presented in the table 1.

Table 1. Technological characteristics for ANCORSTEEL 1000B powder [8]

Particle size distribution (µm)	-250 / +150	-150 / +45	-45
%	12	67	21

Table 2. Characteristics of the alloying powders

Elements	Particle size [µm]	Purity [%]
Mn	45	97.5%
Mo	2	99.9%
Cr	<10	99.9%
B	500	-
C (graphite shape)	>1	-

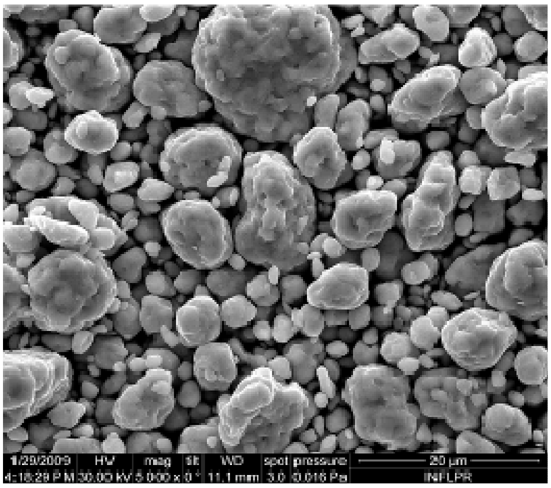
The powders used as alloying elements were achieved from Goodfellow Cambridge Limited England with the characteristics presented in the table 2.

Two mixtures containing Fe; 3Mn, 1Mo, 1.5Cr, 0.45B, 0.45Graphite and Fe, 3Mn, 1Mo, 1.5Cr, 0.45Graphite were prepared by Mechanical alloying (MA) process for 20, 40, and 60 hours. There were noticed that a granulation decreasing respectively a homogeneity increasing of powder particles with increasing MA time were obtained. In table 3 is presented the chemical composition for the mixtures used in the research.

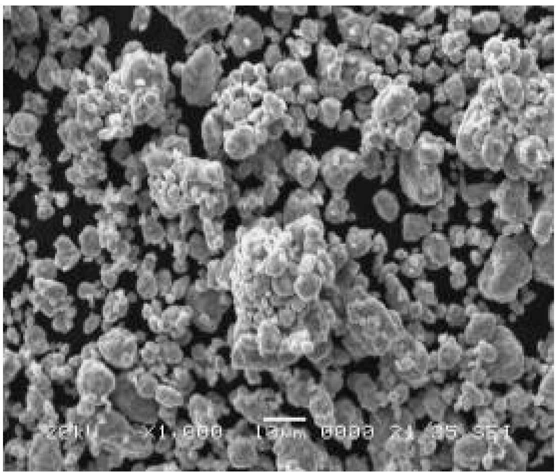
Table 3. The chemical composition of the mixtures used for the experiments

Notation	Complex constitution	Chemical composition [%]					
		Mn	Mo	Cr	B	Graphite	Fe
HM	[Fe-3Mn-1Mo-1,5Cr-0,45 Graphite]$_{\text{homogeneous mixture}}$	3	1	1.5	-	0.45	Bal.
$MA_{20....60}$	[3Mn-1Mo-1,5Cr-0,45 Graphite] $_{\text{mechanical alloyed 20…60h}}$	3	1	1.5	-	0.45	Bal.
HM+B	[Fe-3Mn-1Mo-1,5Cr-0,5B-0,45 Graphite] $_{\text{homogenous mixture}}$	3	1	1.5	0.5	0.45	Bal.
$(MA+B)_{20...60}$	[3Mn-1Mo-1,5Cr-0,5B-0,45 Graphite] $_{\text{mechanical alloyed 20….60h}}$	3	1	1.5	0.5	0.45	Bal.

The SEM micrographs, EDAX analyses of the mechanically alloyed mixtures are presented in the following figure 1.



a)



b)

Figure 1. SEM image of a) MA_{60}, b) $(MA+B)_{60}$

In order to elaborate sintered steels, the mixtures were compacted at three pressures: 600, 700, 800 MPa, through unilateral pressing in a die with 10 mm diameter.

Next, the samples underwent to the sintering treatment through heating in argon medium, using the diagram presented in figure 2.

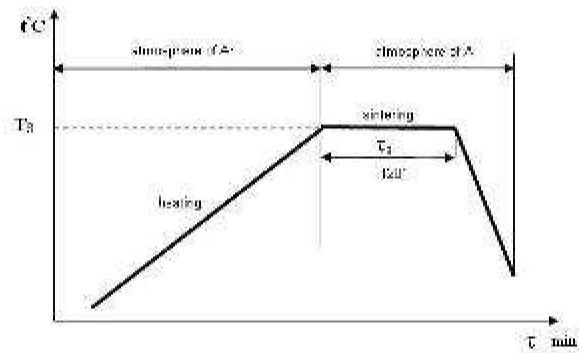


Figure 2. Sintering diagram

3. Experimental results

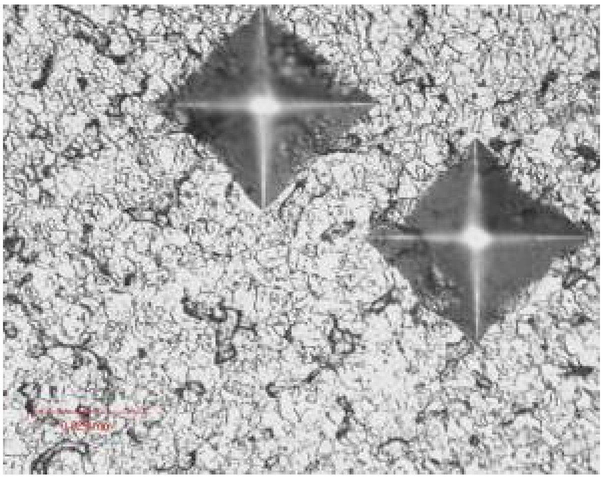
The addition of boron had a good influence on the porosity of the sintered steels. The microstructure observation was done on the resulting steels there have been conducted metallographic determinations by optical and electron microscopy and mechanical properties (hardness and friction coefficient (table 4 and 5)) were measured.

Figure 3 presents the SEM images of the mixtures MA_{40} with and without B addition.

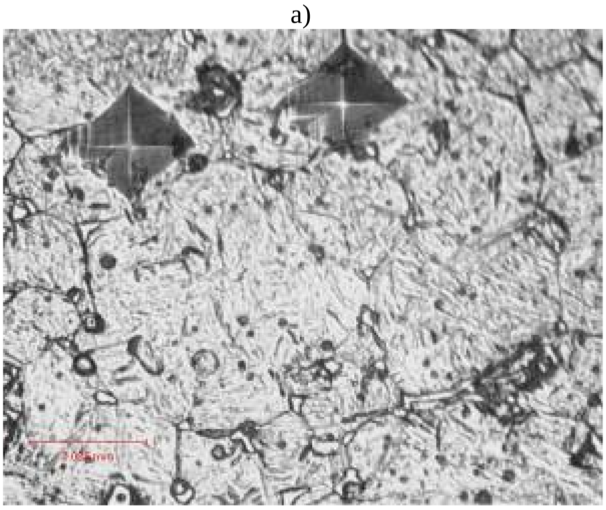
The sintered steels obtained from mixtures mechanically alloyed for 40 hours present a finest structure than the steels obtained from mixtures mechanically alloyed for 20 hours.

The AM_{40} steel presents perlitic structure with graphite diffused in all the Fe mass and a value of microhardness equal to 239 $HV_{0.2}$ – figure 3a.

The presence of boron as alloying element leads to a increasing of microhardness 376 $HV_{0.2}$ – figure 3b and the structure is perlito-bainitico.



a)



b)

Figure 3 Microhardness a) MA $_{40}$ and b) (MA+B) $_{40}$, pressed at 800 MPa, sintered at 1150 $^{\circ}$C / 120 min, using Ar atmosphere, Nital 1%

In the figure 4 is presented SEM microstructure and in figure 5 the maps of iron and alloying elements distribution for the sintered steels obtained from composite powders containing B, resulted through mechanical alloying of elemental powder mechanically alloyed during 60 hours.

In the table 4 is presented the evolution of hardness fun about 600 nm; the compaction pressure and sintering temperature.

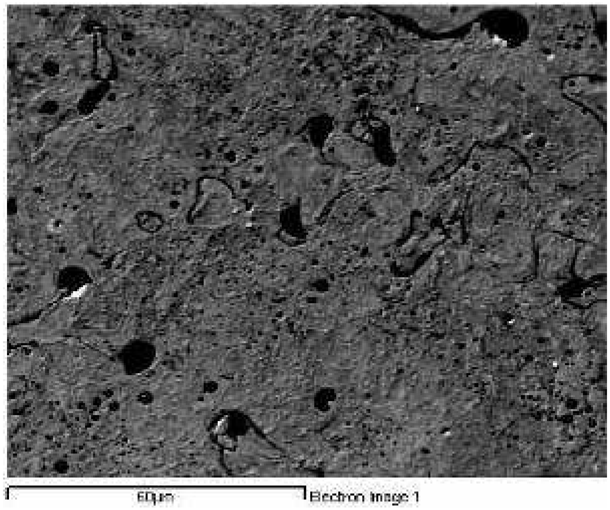


Figure 4. $(AM+B)_{60}$ SEM microstructure aspect

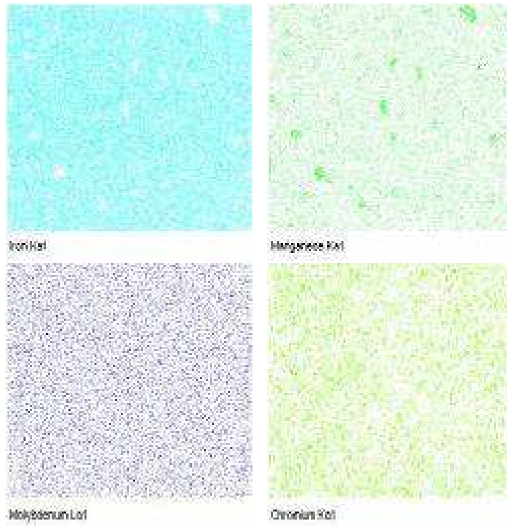


Figure 5. Iron and alloying elements distribution maps on the same surface of AM+B $_{60}$ steel

Table 4. The evolution of the hardness depending on the compaction pressure and the sintering temperatures

T [^{o}C]	Steels used for hardness testing	Hardness $HV_{0.2}$ - samples compacted		
		600 MPa	700 MPa	800 MPa
1050	MA $_{60}$	227	248	258
	(MA+B) $_{60}$	221	243	274
1100	MA $_{60}$	249	264	286
	(MA+B) $_{60}$	268	311	331
1150	MA $_{60}$	271	284	298
	(MA+B) $_{60}$	307	331	342

The tribological test was made using a tribometer type TRN 01 – 02541 from CSM Instruments – Switzerland. The variation of the friction coefficient of steels obtained through pressing and classical sintering can be observed in table 5 and figure 8.

Table 5. The evolution of the friction coefficient of elaborated steels
800 MPa compaction pressure and 1150° C sintering temperature

T ºC	Steels used for tribological testing	μ (samples compacted at 600 MPa)	μ (samples compacted at 700 MPa)	μ (samples compacted at 800 MPa)
1150 ºC	HM	0.674	0.655	0.608
	HM+B	0.597	0.579	0.515
	MA_{20}	0.372	0.3.45	0.333
	$(MA+B)_{20}$	0.319	0.282	0.263
	MA_{40}	0.272	0.255	0.219
	$(MA+B)_{40}$	0.283	0.246	0.200
	MA_{60}	0.268	0.242	0.179
	$(MA+B)_{60}$	0.200	0.237	0.158

4. Conclusions

The results of experimental research presented in this work allow drawing the following conclusions:

- the presence of the B powders allows the smooth division of composite powder granules. It is observed that at 60 hours mechanical alloying time, the composite powders with B contents reach around 300 nm, while the composite powders without B reach dimensions about 600 nm;
- the density of the sintered samples grows together with the growth in mechanical alloying time, meaning that the highest values, of about 7.4 g/cm^3, are obtained in the case of powders elaborated through mechanical alloying for 60 hours;
- the structural and mechanical characteristics of sintered low-alloyed steels depend on the nature and the granulation of the powders used. In this direction, the lowest porosities are those of the steels from nanostructured composite powders obtained though mechanical alloying for 60 hours, thus with the smoothest granulation;
- from the point of view of the nature and granulation of powders, the best values of the friction coefficient are those of the steels elaborated through composite nanopowders with B, resulted from MA;
- the sintering temperature influences mechanical characteristics in this way: from the point of view of hardness and wear, it is allowed by superior sintering temperatures.

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