Modification of Low Alloyed Steels by Manganese Additions

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Abstract

The present study examines the sintering behaviour and effect of manganese addition both mechanically-blended and mechanically alloyed on Cr-Mo low alloyed steels to enhance the mechanical properties. Mn sublimation during sintering provides some specific phenomena which facilitate the sintering of alloying elements with high oxygen affinity. First step is the optimization of milling time to attain a master alloy with 50% of Mn which is diluted in Fe-1.5Cr-0.2Mo water atomized prealloyed powder by normal mixing. These mixtures are pressed to a green density of 7.1 g/cm^3 and sintered at 1120 ºC in 90N$_2$-10H$_2$ atmosphere.

Keywords : Mn alloyed sintered steels, mechanical alloying

1. Introduction

It is of doubtless importance the fact of decreasing the content of oxides in PM sintered materials. Mn sublimation during sintering has proved [1] to help reducing oxides content with the so called "Mn Self-cleaning effect", which also allows to sinter in different atmospheres improving the continuity of the process and thus its industrial applications.

Mn was added to the base powder through a master alloy, which was obtained by mechanically alloying Fe-1,5Cr-0, 2Mo and Mn powders at two different milling times. The purpose is to modify the state of Mn in the master-alloy, to make a distinction between solid state or gas-state diffusion and its effect on sintered steels. To adjust the alloy system to a sublimation-condensation process provided by a gas-state diffusion is necessary to keep Mn sources, and hence, the milling time will be short enough to distribute small Mn particles inside the steel particles. But to adapt the alloy system to a solid-state diffusion, Mn must be as solid solution in steel particles, which leads to longer milling times. In both methods the powder is activated which improves the sinterability of the alloy and at the same time, the compressibility of the alloy is not worsened because only 2% of the final alloy has been milled with the base powder. In every case, the remaining Mn as solid solution strengthens the final material, improving its mechanical properties [2].

2. Experimental and Results

Starting powders were water atomized prealloyed Fe-1.5Cr-0.2Mo (Astaloy CrL granted by Höganäs) and electrolytic Mn. The first step was to optimise the milling time in order to get two different master mixtures, one where the Mn was mechanically blended with the Astaloy particles and a second one in which the Mn was inside the AstCrL particles. The milling process was performed in a planetary ball mill with an Ar atmosphere. In order to prepare the two desired master mixtures, two different milling times were taken into account, 45 and 240 minutes respectively. During the milling process the vessel was refilled with Ar after 15 minutes of milling to avoid the loss of purity of the atmosphere and the heating of the powder which could produce the increasing of plasticity of the powder. Particle size distribution was studied by image analysis; considering the two factors shown in (1) and (2) to accomplish a study as it is described in [3].

$$F_s = \frac{feret_{\min}}{Feret_{Max}} \tag{1}$$

$$F_c = \frac{4 \cdot \pi \cdot Area}{(Perimeter)^2} \tag{2}$$

Just 2% of the corresponding master mixture was mixed with the base powder (AstCrL), 0,6% C and 0,8% Amide-wax as lubricant, in order to get a final Mn content of 1%.

Prepared mixtures were uniaxially pressed to a green density of 7.1 g/cm^3 and then sintered at 1120 ºC for 30' in 90N$_2$-10H$_2$ atmosphere with a cooling rate of 0.8 ºC/s. Mechanical properties were analysed by impact tests with an available energy of 300J and impact velocity was 5.47 m/s. Metallographic study and dimensional change were considered to better understand the behaviour of the material to deform plastically.

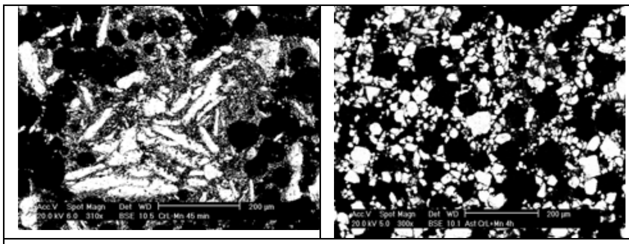

Fig 1. Mechanical alloying evolution with alloying time

The initial effect is a severe plastic deformation which forms flattened particles. As milling progress starts, the welding processes dominate, finally followed by the equiaxed particle formation. Longer times lead to a random welding orientation and lowering the powder size [4].

Therefore, the changes during milling time are related to particle shape and alloying grade, for this reason powder samples have been taken every 15 min during the first hour to analyse the early stages of milling, and every hour till 6 hours of milling to evaluate when is achieved an equiaxial morphology. Two criteria were followed to achieve the desirable state of milling in this work because two main objectives are pursued, attain a homogenous mixture where Mn remains free and a complete alloyed powder. In both cases, powders are activated for sintering because of the increasing in the defect concentration with the milling process. Fig. 1 shows the evolution of the mechanical alloying with the milling time. Two milling times were finally chosen: 45min where Mn remains free and 240 min when particle shape is almost equiaxial and alloying is complete and the final composition of every particle is 50Mn : 50Astaloy CrL.

The introduction of powders with a high level of lattice defects is evident when sintered density is considered (fig 3). This increment in density level is more significant in the samples containing MA powders which were milled for 240 minutes. Therefore, is not only achieved an improvement of the properties due to the well-known strengthening effect of Mn, but also the mass transport enhancement.

According to [5] the effect that Mn has on the dimension change during sintering is clearly seen in fig. 3 where it is easily perceived the swelling produced by the addition of Mn. The Mn strengthening effect on AstaloyCrL alloy is pointed out with the results shown in Fig.5, where a decrement of the total energy absorbed during the impact test is perceived with the addition of Mn.

The decrement is different though depending on the milling time of the MA-powder added. The strengthening is higher when the milling time of the MA is higher because the amount of Mn able to sublimate is reduced, being bigger the tendency of Mn to form solid solution inside the iron lattice.

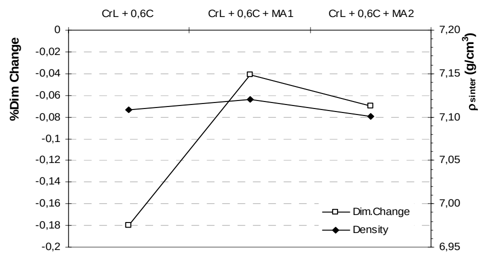

Fig. 3. Density and dimensional Change of specimens studied

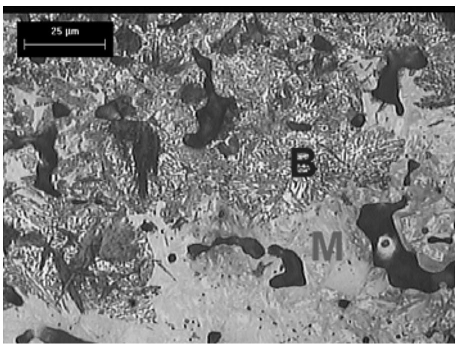

Fig 4. Metallography of Astaloy CrL+MA1+0.6C

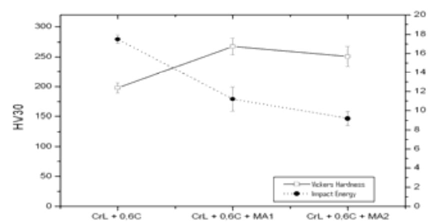

Fig. 5. Impact Energy and Vickers Hardness

3. Summary

The milling time determines the response of the sintered material, because affects the morphology, microstructure and lattice defect concentration of powders which favours diffusion during sintering.

The mechanical properties are affected by activated sintering process as well as by the addition of Mn as alloying element. The dominant influence in sintered steel with mechanically-blended powders is the activation of diffusion process due to the increase of defects and the sublimation of Mn that allows the diffusion into the iron particles.

4. References

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