Hardenability of Low Alloy Sintered Mn Steels

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Abstract

Manganese is an alloying element that improves the hardenability of steels. It could be a valid substitute in sintered steels, increasing mechanical properties.

The hardenability of three low alloy Mn steels was studied to establish the influence of manganese on the heat treatments. The Grossmann approach was adopted, which uses cylinders with different diameters to induce different gradients of cooling rate in the cross section.

The correlation of microstructure and microhardness to the actual cooling rate makes the results independent on the process parameters and applicable to each industrial condition, once the actual cooling rate in the parts is known.

Keywords : Manganese, hardenability, low alloy steels

1. Introduction

Manganese, as an alloying element, is attracting the interest of powder metallurgists since it provides good hardenability and good toughness to sintered steels [1, 2, 3], and its used in the mass production is expected to increase in the future for new base materials for the structural applications of sintered parts. Given the effect on hardenability, Mn can be a favourable alloying element for sinterhardening powders [4]. In this context, the present work aims at investigating hardenability of some new powders, under the typical cooling conditions of sinterhardening processes. The maximum cooling rate in the continuous furnaces is about 4 K/s, whilst in the vacuum furnaces with high pressure nitrogen flow [5] it rises up to 10 K/s. Sintered specimens, alloyed with different carbon contents, have been heat treated in a vacuum furnace, with different cooling rates, by recording the actual cooling rate by a thermocouple in the central axis of the specimens. This way, the results can be correlated to the actual cooling rate, and may be used to predict the behaviour of the investigated powders independently on the specific production conditions.

2. Experimental and Results

The composition of the powders used in this work and provided by Höganäs AB Sweden, is reported in Table 1.

Table 1. nominal composition (wt.%) of the powder investigated

powder	% Mn	% Cr	% Ni	% Mo
E	0.8	1		
F	1.2	0.2		
G	0.7	1.2	0.4	0.4

Three different carbon contents were considered, adding 0.42%, 0.62% and 0.92% graphite to the base powders. Impact bars were cold compacted to 6.8 g/cm^3 and sintered in $90N_2/10H_2$ atmosphere. The as sintered carbon content was determined by LECO CS244. Heat treatment was carried out in a vacuum furnace. The austenitization temperature was chosen as $A_3(A_{cm})$+20°C, holding time was 30 minutes. A_3 and A_{cm} were determined on the phase diagrams of the different materials calculated by ThermoCalc [6]. Three different pressures were adopted, 2, 5 and 8 bars, which resulted in 4.5, 8.3 and 11.1 K/s actual cooling rates, respectively.

As expected, microhardness increases with the carbon content and the cooling rate. To evaluate hardenability, reference has to be made to the microhardness pertaining to martensite for a given carbon content. In a first approximation, the effect of the other alloying elements has been neglected, since, as well known, the effect of the interstitial carbon is much more pronounced than that of the substitutional alloying elements.

From the figures, the following indication may be drawn:

-) material E: only when cooled down with the two higher cooling rates specimens with the highest carbon content transform to a fully martensitic microstructure;

-) material F: a fully martensitic microstructure is never obtained even combining the highest carbon content to the highest cooling rate;

-) material G: a fully martensitic microstructure is obtained independently on the carbon content by cooling down with the highest cooling rate, and with the highest carbon content by cooling down with the intermediate cooling rate.

To confirm these conclusions, the microstructural analysis has been carried out. In Figures 1, 2 and 3 the microstructural features are described individuating four different conditions: ferrite/pearlite (F/P), ferrite/pearlite/bainite (F/P/B), bainite/martensite (B/M) and fully martensite (M). A more detailed description, based on a quantitative metallographic analysis, is in course and will be published elsewhere.

Figures 1, 2 and 3 confirm the indication from microhardness data. The agreement between the conclusions from microhardness and from the microstructural analysis allows a general conclusions on the hardenability of the investigated materials when alloyed with different carbon contents to be drawn.

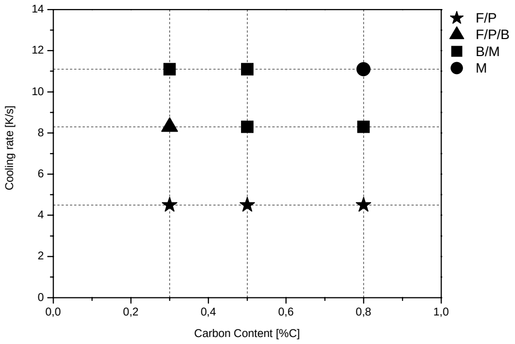

Fig. 1. Relation cooling rate, carbon content and microstructure of material E.

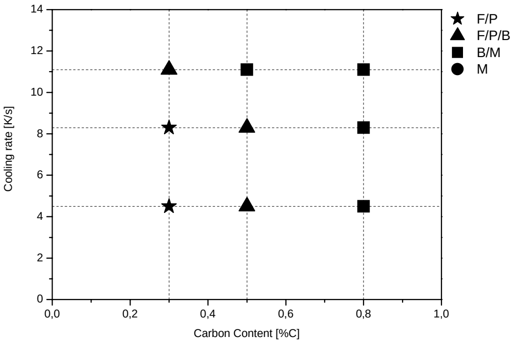

Fig. 2. Relation cooling rate, carbon content and microstructure of material F.

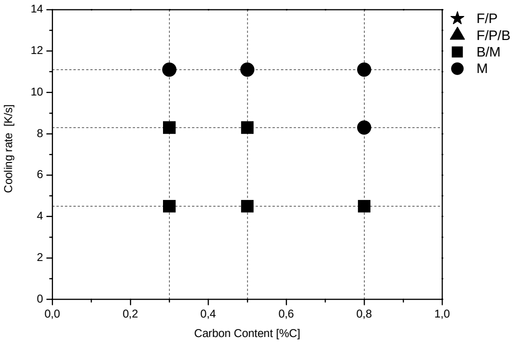

Fig. 3. Relation cooling rate, carbon content and microstructure of material G.

The conclusion that hardenability is G>E>F could be drawn directly from the chemical composition. Using the hardenability multiplying factors [7], the ideal diameters of the three powders (for the same carbon content) are in the following ratios: D_{IG} = ~2.5 D_{IE} = ~3 D_{IF}. However, the results of the present investigation, may be used to design the material for a specific application, when processed in a sinterhardening furnace.

3. Summary

The hardenability of three different Mn alloyed sintered steels has been investigated in the cooling rate range between 4 K/s and 10 K/s, to evaluate they suitability for Sinterhardening. Microhardness and microstructure has been correlated to the carbon content and to the cooling rate measured in the central axis of the specimens. Hardenability depends on the chemical composition and the experimental results confirms what can be predicted by the hardenability multiplying factors. Moreover results, being based on the actual cooling rates, may be used to choose the base powder and the carbon content to get a fully martensitic microstructure or, alternatively, a given microhardness, in any specific industrial conditions.

4. Acknowledgement

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5. References

1. A. Salak: Powder Metall. Int. 2 (1980), p.72-75
2. A. Salak, E. Dudrova and V. Miskovic: Powder Metall. Sci. Technol. 3 (1992), p.26-35
3. M. Youseffi, S:C: Mitchell, A.S. Wronski and A. Cias: Powder Metallurgy vol. 43, 4 (2000), p.353-358
4. W. Brian James in : Ferrous Powders – How Alloying Method Influences Sintering, presented At MPIF Sintering Seminar, Pittsburgh, Oct '91
5. V. Stoyanova, A. Molinari: Powder Metallurgy Progress vol. 4, 2 (2004), p.79
6. B. Sundman, B. Jansson and J.-O. Andersson: Calphad 9 (1985), p. 153-199
7. R.E. Reed-Hill in : Physical Metallurgy Principles, edited by PWS Publishing Company (1994)