CHROMIUM STEEL POWDERS FOR COMPONENTS

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ABSTRACT

Chromium as an alloying element is of great interest due to its low cost, high hardenability and possibility to recycle. Use of pre-alloyed chromium powders has increased recently due to its accessibility at low cost. Low total cost is and has been the driving force to convert parts made from conventional steel to PM material. By use of pre-alloyed chromium material, the PM industry can further increase its market share, compared to conventional steel. Two pre-alloyed iron powders, one for high strength applications containing 3 % Cr and 0,5 % Mo and one for medium strength applications containing 1,5% Cr and 0,2% Mo are considered in this paper. The mechanical properties for mentioned materials in the carbon range from 0,2 to 0,8% are described.

INTRODUCTION

Powder metallurgy has a strong growing market. Since most of the parts made by P/M are aimed for the automotive industry, cost is a major driving force. In development work for new grades, not only cost but also performance has to be taken into account. Chromium as an alloying element is of great interest due to low cost and the possibility to recycle, compared to Fe-Cu-C grades. In 1998 a water atomised Cr/Mo pre-alloyed material, Astaloy CrM, was presented [1]. Astaloy CrM is to be used as complement to the existing Cu/Ni/Mo alloyed materials for mass production of high performance components, no matter if sintering is performed at high temperature or in conventional belt furnaces. In this paper Astaloy CrM and an additional experimental water atomised pre-alloyed powder will be presented. The experimental material is aimed for medium strength applications. Mechanical/physical properties in the carbon range from 0,2 to 0,8 %, CCT diagrams and phase amount versus cooling rate diagrams of the two materials will be covered in this paper.

EXPERIMENTAL PROCEDURE

Two water atomised powders were investigated. The chemical composition of the base powders used is reported in table 1.

Table 1. Chemical composition of the base powders

Grade	**Composition**	**Cr %**	**Mo %**	**C %**	**O %**
Astaloy CrM	Fe-3Cr-0,5Mo	3,0	0,5	<0,01	<0,25
Experimental	Fe-1,5Cr-0,2Mo	1,5	0,2	<0,01	<0,25

The powder grades were admixed with 0,2-0,8 % of Kropmülf graphite UF4. Compressibility is evaluated according to ISO 3927-1985. For the evaluation of hardness and mechanical properties,

tensile testing bars according to ISO standard 2470-1986 with a length of 90 mm were compacted in a laboratory press.

Chromium containing materials have to be sintered in an atmosphere with a partial pressure of oxygen below $5 * 10^{-18}$ atm at 1120 ºC, to prevent oxidation of chromium [2]. Endogas can for that reason not be used for sintering these materials, a mix with nitrogen/hydrogen is necessary. Sintering was performed in two different furnaces. Astaloy CrM and Fe-1,5Cr-0,2Mo were sintered in a laboratory belt furnace at 1120°C for 30 minutes. The sintering atmospheres used were 75/25 N_2/H_2 when sintering Astaloy CrM and 90/10 N_2/H_2 when sintering Fe-1,5Cr-0,2Mo. Methane was added to the sintering atmosphere to prevent decarburisation. An oxygen probe was used for controlling the partial pressure of oxygen in the sintering zone in the laboratory belt furnace. The high temperature sintering was performed in a walking beam furnace used for production at 1250 °C for 70 minutes in 90/10 N_2/H_2 with no methane addition.

CCT diagrams were prepared for the investigated materials and phase analysis were carried out, with help of an image analyser and point count analysis on the samples cooled at different rates in a dilatometer.

RESULTS

Compressibility

Compressibility is presented in table 2. Cold compacted specimens by die wall lubrication and a mix with 0.8% Amid Wax are evaluated. Fe-1,5Cr-0,2Mo have due to the lower alloy content, better compressibility than Astaloy CrM.

Table 2. Compressibility

Grade	Compacting Pressure MPa	Lubricated Die g/cm^3	0,8 % Amid wax g/cm^3
Astaloy CrM	400	6,48	6,56
	600	6,98	6,98
	800	7,28	7,14
Fe-1,5Cr-0,2Mo	400	6,55	6,59
	600	7,04	6,99
	800	7,32	7,17

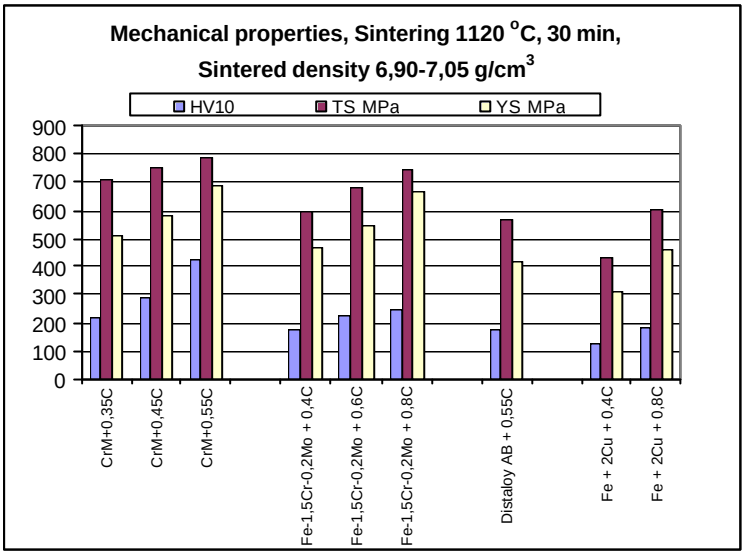
Mechanical properties

Mechanical properties for Astaloy CrM and Fe-1,5Cr-0,2Mo when sintered at 1120 °C for 30 minutes are shown in figure 1. There are also two reference materials in figure 1, Distaloy AB and Fe-2Cu-C, which will be compared with the Fe-1,5Cr-0,2Mo material. The base powder to the Fe-Cu-C material is AHC100.29 that is mixed with 2 % Cu-200 mesh and graphite. The carbon contents presented in diagram 1 are sintered carbon contents.

The tensile strength, yield strength and hardness increase with carbon content for all materials as expected. The increase is a consequence of the change in microstructure in the materials, more perlite/bainite/martensite is formed. The Astaloy CrM material with 0,55% carbon achieves a hardness of approximately 400 HV10. The Fe-1,5Cr-0,2Mo material with 0,80 % carbon has a hardness of 245 HV10. The tensile strength is approximately 800 MPa for the Astaloy CrM material with 0,55% carbon and 750 MPa for Fe-1,5Cr-0,2Mo with 0,80 % carbon.

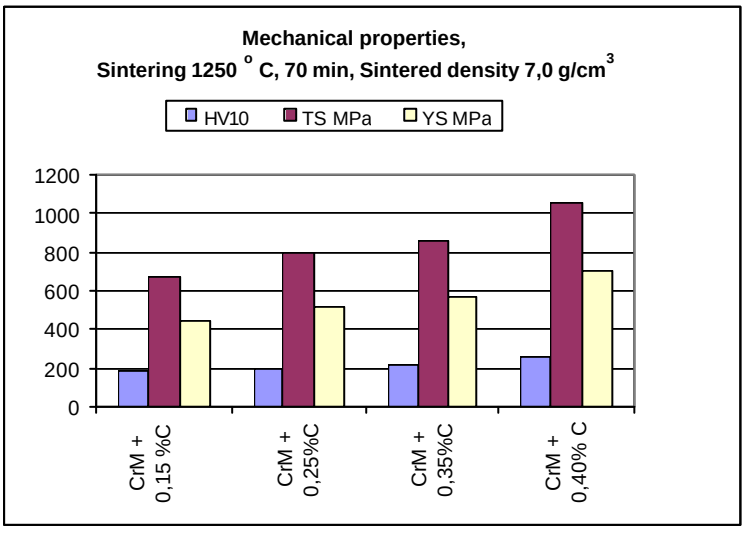
The tensile strength, yield strength and hardness are higher for the Fe-1,5Cr-0,2Mo material than for Distaloy AB and the Fe-Cu-C material at the same carbon content.

Figure 1. Mechanical properties at 1120 °C for Astaloy CrM and Fe-1,5Cr-0,2Mo



High temperature sintering improves the mechanical properties compared to sintering at 1120°C. Sintering is more efficient at higher temperatures as the diffusion is faster. This results in better sintering necks, lower oxygen content, larger shrinkage, and higher density compared to sintering at 1120°C. The pores in the material will also get more rounded when sintering at high temperature. Mechanical properties for Astaloy CrM when sintered for 70 minutes at 1250 °C are shown in figure 2. The carbon contents presented in diagram 2 are sintered carbon contents. Astaloy CrM with 0,4% carbon has a tensile strength of 1060 MPa and a hardness of 255 HV10. The hardness is slightly lower compared to Astaloy CrM with the same carbon content sintered at 1120 °C. This is due to a higher cooling rate in the laboratory belt furnace than in the walking beam furnace.

Figure 2. Mechanical properties at 1250 °C for Astaloy CrM



The elongation for the materials in figure 1 and 2 are shown in table 3 and 4. The elongation decreases with increasing carbon content. The Astaloy CrM material sintered at 1250 °C has larger elongation than Astaloy CrM sintered at 1120 °C. The Fe-Cu-C material and Distaloy AB have larger elongations than the Fe-1,5Cr-0,2Mo material.

Table 3. Elongation when sintering 1120 ºC for 30 min

Material	Elongation %
CrM + 0,35C	1,2
CrM + 0,45C	0,6
CrM + 0,55C	0,3
Fe-1,5Cr-0,2Mo + 0,4C	1,7
Fe-1,5Cr-0,2Mo + 0,6C	1,0
Fe-1,5Cr-0,2Mo + 0,8C	0,5
Fe-2Cu-0,4C	3,6
Fe-2Cu-0,8C	1,7
Distaloy AB + 0,55C	2,5

Table 4. Elongation when sintering 1250 ºC for 70 min

Material	Elongation %
CrM + 0,15C	2,3
CrM + 0,25C	2,5
CrM + 0,35C	1,9
CrM + 0,40C	1,2

CCT diagrams and phase amount versus cooling rate diagrams

The microstructure of a material and its mechanical properties can be modified by varying the amount of alloying elements and/or the cooling rate. The influence of the cooling rate on the microstructure of Astaloy CrM and Fe-1,5Cr-0,2Mo with two different carbon contents each, have been investigated.

Figure 3a and 3b show the CCT diagrams and phase amount as a function of the cooling rate for Astaloy CrM with 0,4 and 0,5% C. The microstructure of Astaloy CrM with 0,5%C consists of more than 90% martensite for cooling rates ≥1 °C/s. The microstructure of Astaloy CrM, with 0,5 % carbon is less sensitive to variations in cooling rate, than the microstructure of Astaloy CrM with 0,4% carbon, at cooling rates above 1 °C/s.

***Figure 3a**. CCT diagram for Astaloy CrM with 0,4 and 0,5%C*

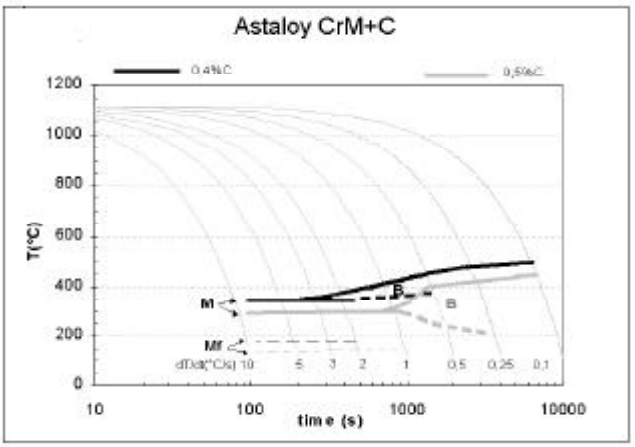


***Figure 3b.** Phase amount versus cooling rate for Astaloy CrM with 0,4 and 0,5% C*

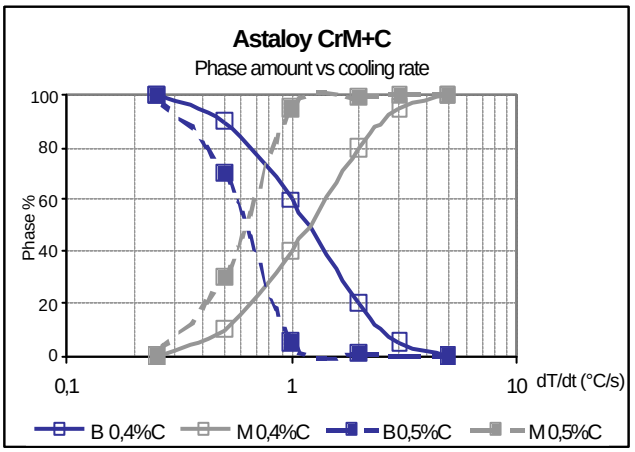


Figure 3c and 3d show the CCT diagram and phase amount as a function of the cooling rate for Fe-1,5Cr-0,2Mo with 0,3% carbon. For cooling rates in the range 0,5-1 °C/s a mixture of ferrite, pearlite and bainite with small amounts of martensite is observed. The amount of bainite and martensite increases with increased cooling rate. When cooling at 25 °C/s, approximately 25% martensite and 75% bainite are obtained.

The microstructure of Fe-1,5Cr-0,2Mo with 0,3% carbon consists of ferrite, perlite, bainite and small amounts of martensite. A transformation from this microstructure to a complete bainitic structure occur at 0,4% carbon [3].

***Figure 3c**. CCT diagram for Fe-1,5Cr-0,2Mo with 0,3 % C*

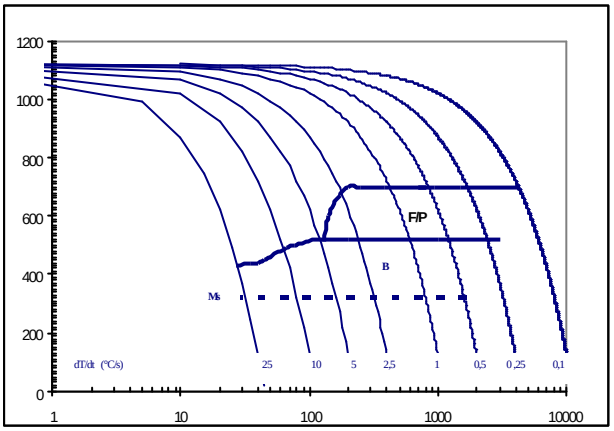


***Figure 3d.** Phase amount versus cooling rate for Fe-1,5Cr-0,2Mo with 0,3% C*

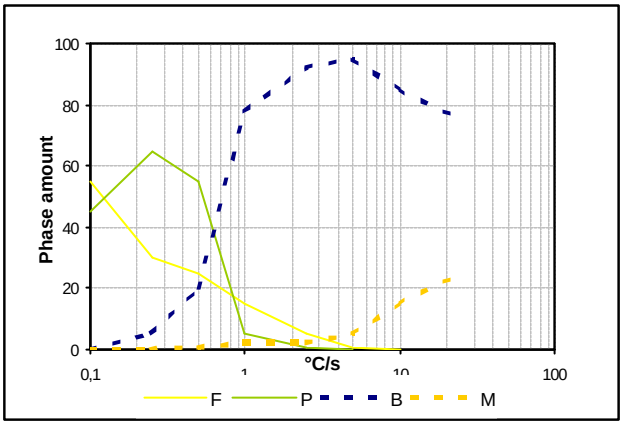


Figure 3e and 3f show the CCT diagram and phase amount as a function of the cooling rate for Fe-1,5Cr-0,2Mo with 0,7% carbon. The amount of martensite is strongly dependent on the cooling rate in the interval 1-2,5 °C/s. At the cooling rate 2,5 °C/s, more than 95% martensite is formed. At a cooling rate of 5 °C/s a completely martensitic structure is obtained.

***Figure 3e**. CCT diagram for Fe-1,5Cr-0,2Mo with 0,7 % C*

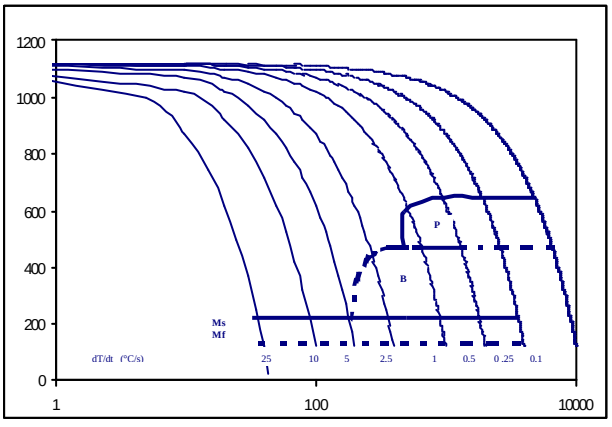
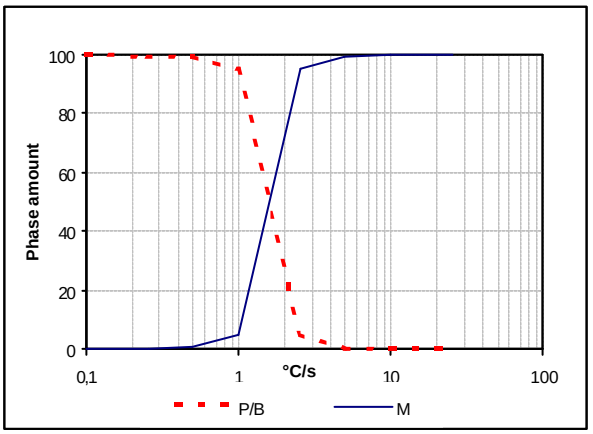


***Figure 3f.** Phase amount versus cooling rate for Fe-1,5Cr-0,2Mo with 0,7% C*



DISCUSSION

The Astaloy CrM material with 0,5% carbon has a good hardenability. More than 90% martensite is obtained at a cooling rate of 1 °C/s. With increased carbon content in Astaloy CrM, above 0,6 % carbon, the martensite becomes more brittle, which results in increased hardness but decreased mechanical properties. This can be overcome by an additional tempering. Sintering Astaloy CrM at 1250 °C give improved mechanical properties and larger elongation than sintering at 1120 °C.

The mechanical properties are higher for the Fe-1,5Cr-0,2Mo material than for Distaloy AB and the Fe-Cu-C material at the same carbon content, but the elongation of the Fe-1,5Cr-0,2Mo material is slightly lower than for Distaloy AB and the Fe-Cu-C material.

CONCLUSIONS

- The Astaloy CrM material with 0,55% carbon achieves a hardness of approximately 400 HV10 when sintering at 1120 °C. The Fe-1,5Cr-0,2Mo material with 0,8 % carbon achieves approximately 250 HV10 at the same sintering temperature.

- Achievable tensile strengths when sintering at 1120 °C are approximately 800 MPa for the Astaloy CrM material with 0,55% carbon and 750 MPa for the Fe-1,5Cr-0,2Mo material with 0,80 % carbon.

- High temperature sintered, 1250 °C, Astaloy CrM with 0,4% carbon has a tensile strength of above 1000 MPa, a hardness of 250 HV10 and an elongation of 1 %.

- The Fe-1,5Cr-0,2Mo material has higher tensile strength, yield strength and hardness than the Fe-Cu-C material and Distaloy AB at the same carbon content.

- The microstructure of Astaloy CrM with 0,5 % carbon consists of >90% martensite when cooled at a rate of 1 °C/s.

- The microstructure of Fe-1,5Cr-0,2Mo with 0,7 % carbon consists of >95% martensite when cooled at a rate of 2,5 °C/s.

REFERENCES

[1] O. Eriksson et al. ”Binder of new pre alloyed Cr/Mo-steel powder” released by Höganäs AB during Powder Metallurgy World Congress, Granada, 1998

[2] J. Arvidsson et al. ”On-Line Measurement of Sintering Atmospheres”; Proceedings 1998, Powder Metallurgy World Congress, Vol 2, pp. 253 - 260

[3] S. Berg ”Pre-alloyed Chromium Material with Consistent Properties for Medium Strength Applications.”; Powder Metallurgy World Congress, Kyoto, Japan Nov 2000