

MECHANICAL PROPERTIES AND STRUCTURE OF CR-MO LOW ALLOYED PM/STEELS OBTAINED FROM PREALLOYED POWDERS

M. Bodea, N. Jumate

Technical University of Cluj-Napoca, România

ABSTRACT: This paper present a study concerning the influence of Cr-Mo contents about the mechanical properties and structure of low alloyed PM/steels obtained from prealloyed powders.

KEYWORDS: homogeneity improvement, high strength, prealloyed powders

1 INTRODUCTION

Presently in PM technology, the strength of the sintered parts is frequently required. By consequence alloying powders are used as starting materials due to the improved mechanical properties obtained of the sintered parts. There are used essentially two types of such alloying powders: powder mixtures and so-called atomized pre-alloyed powders.

The advantages of using water atomized prealloyed bass powder is that segregation problems are reduced and the distribution of alloying elements after sintering is improved which in turn results in an improved dimensional stability and more uniform and increased strength.

The prealloyed atomized powder has however the drawback, that is compressibility which will be relatively low depending on the solution-hardening, effect the alloying elements have on each powder particle. High compressibility is however essential, when a part of high density and strength are desired.

2 POWDER CHARACTERISATION

The requirements put on a powder in order to obtain the highest strength properties and the best homogeneity of the structure are:

- high compressibility of the powder;
- the powder shall not contain alloying particles with high hardness as to result in a abnormal tool wear in the pressing operation (alloying elements should have a Vickers hardness bellow 400 units as measured at a 10 g load);
- the alloying elements must be capables of comminution of the fine particle size in order to obtain a better distribution in the pressed shaped body and a more homogeneous structure.

The use of an alloying element of coarse particle size result in a situation where the alloying particles do not have time to diffuse out in the material with acceptable sintering times. Also, can be observed as more or less separate islands in the sintered structure, which in turn results is the non-obtainment of the strength-increasing effect, expected from the alloying element.

The chemical composition of the alloy steel powder for sintered bodies having high strength, high fatigue strength and high toughness is shown in the table below:

Table 1

C	Cr	Mo	Mn	S	P	O ₂
< 0.1 wt. %	0.5-3 wt. %	0.1-2 wt. %	< 0.08 wt. %	< 0.01 wt. %	< 0.01 wt. %	< 0.2 wt. %

The reason why carbon in the alloy steel powder is no larger than 0.1 wt. % is that carbon is an element, which serves to harden the ferrite matrix through formation of a solid solution as, penetrated in the steel. If the content exceeds 0.1 wt.%, the powder is hardened considerably with a lowering of the compressibility of the green compact [3]. The component carbon is added to the sintered body by mixing of graphite powder with the alloy steel powder or by subjecting to carburization treatment to permit carbon to be left in the sintered body. When the carburization treatment is effected, carbon may be distributed in a varying concentration in the sintered body. The addition of carbon is dictated by the final use of the component (e.g. carburized gears can be of low carbon, connecting rods can be a middle carbon range, while induction hardened parts can have a near eutectoid carbon (0.7 – 0.8 wt.% carbon composition)).

3 INFLUENCE OF CHROMIUM

Chromium is an element with a high affinity for oxygen. Because of this high affinity for oxygen, chromium should be added to the iron powder in a lower concentration (e.g. as carbides, ferrochromium, etc.) or less frequently in elemental form. Presently, essentially six different methods of adding chromium can be extracted from the powder-metallurgical literature: [1].

- 1) by pre-alloying process, iron-chromium smelt is comminuted to a powder by atomization. The disadvantage of this type of powder is the low compressibility.
- 2) by admixing a pure chromium powder with an iron powder to desired chromium content. The disadvantages of this method are the high affinity for oxygen of chromium powder and due to the low hardness of the chromium powder it is very difficult to comminute it to a fine particle size.
- 3) by adding ferrochromium (up to 0.1 wt.% carbon), the disadvantage of using such alloy is that it's not capable of comminution to the desired fine particle size due to the low hardness.
- 4) using chromium in the form of sigma-phase (e.g. Fe-Cr alloy 40-50 wt.% chromium). The sigma-phase is characterized by being very hard (about 2000 units Vickers) and is therefore easily ground to a powder of a fine particle size. The disadvantage results in a tool wear which is not acceptable in the production of long series of precision parts.
- 5) by adding ferrochromium carbure (e.g. Fe-Cr having 4-7 wt.% carbon). The iron-chromium alloy has a very high hardness and is capable of grinding to a powder of fine particle size, but the tool wear cannot be maintained at an acceptable level.
- 6) This method is described in Swedish patent specification 70-16925-5. The method is characterized thereby that an iron-chromium alloy having a chromium content of 35-55 wt.% and a particle size of less than 150 µm is annealed with exclusion of air for 2 hours at 850°-950°C, the alloy obtaining a lower hardness, the annealed powder being then by admixture of iron powder having a particle size of less than 400 µm adjusted to the desired chromium content. The disadvantage of this process is however the coarse particle size shown in the iron-chromium alloy, less than 150 µm which in turn results in the decreasing of the mechanical properties of the sintered material.

Chromium improve the hardenability of a sintered body, also improve the tensile strength, fatigue strength and a wear resistance. To obtain such effects, the content of chromium should not be less than 0.5 wt.%. However, the sintered body is formed from powders materials which contain chromium in amounts exceeding 3 wt.%, oxide are formed in large amounts.

When the water-atomised powder is used and the oxygen concentration is higher than 0.5 wt. %, the added graphite will be consumed mainly for oxide reduction during sintering at 1250°C. Internal oxides will be not reduced and the tensile strength will be low because the formation of interparticle necks are detrimentally affected by the surface oxides present in the material. When a ferrochromium powder with an oxidised surface is used, these oxides are not reduced at 1100°C and consequently prevent diffusion of chromium and remain in the material as inclusions.

When chromium is added to the iron powder in the form of Cr_3C_2 , carbon is also added to the system thus increasing the homogeneity of the structure. To ensure efficient dissolution of the chromium carbide in γ -iron and also of carbides of Mo, compacts should be sintered at temperature usually higher than 1250°C, when the carbides start to dissolve by diffusion or liquid phase forms. Long-term sintering is required to ensure complete dissolution of carbide particles in order to obtain the highest strength properties and optimum homogeneity of the structure [7].

Problems with the heterogeneity of the structure, which does not have to be detrimental, are eliminated by prealloyed powders. High strength structural parts can be produced efficiently using a low alloy prealloyed powder with the main composition shown in the table 1.

4 INFLUENCE OF MOLYBDENUM

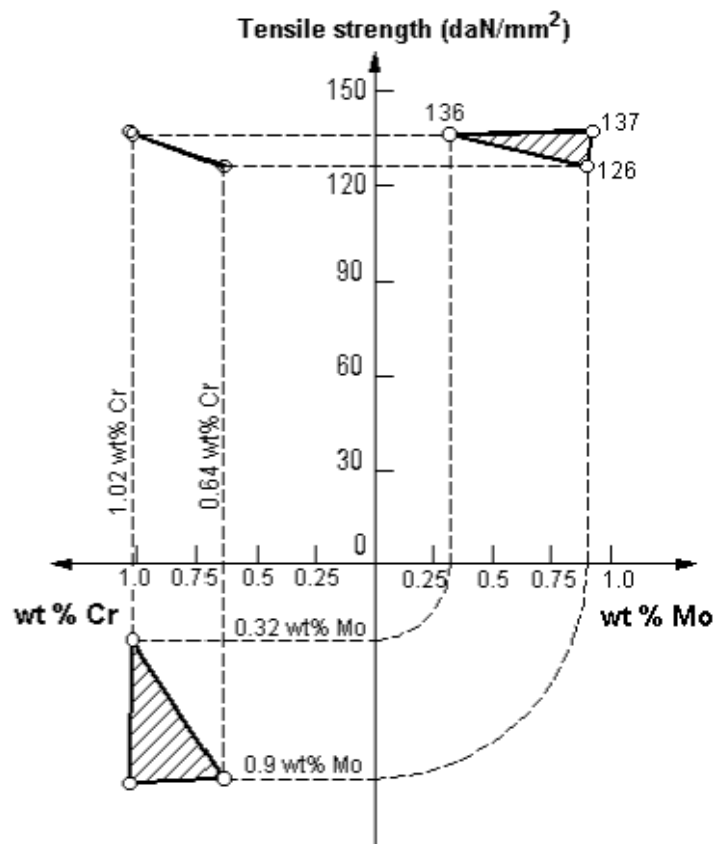


Fig. 1. Influence of Cr-Mo content versus tensile strength (C content was 0.4 wt.% in the sintered body).

Molybdenum is an element with a relative low density (10.22 g/cm³) and a high melting point (2610°C) that confere him a thermal shocks resistance and fatigue, properties very often required in aerospace applications. Mo improves the strength of steel by solution hardening and precipitation hardening of molybdenum carbide. When molybdenum content is less than about 0.1 wt.%, its effect is small and when exceeds about 0.6 wt.% upper bainite is liable to be produced because molybdenum greatly delays pearlite transformation during cooling after sintering, thus lowering strength. A preferable lower content limit is about 0.15 wt. % from the viewpoint of increasing strength, and a preferable upper limit thereof is about 0.4 wt. % from the viewpoint of easily producing pearlite [2]. Prealloyed powders ensures a homogeneous structure of the material and is suitable for the fabrication of parts subjected to heat or thermomechanical treatment. The process can be enhanced by a transient liquid phase, which is formed at temperatures above 1240°C, depending on the respective carbon content.

The mixed Fe-Mo-C system can be used to illustrate the formation of a liquid phase by means of reaction between the alloying elements (Mo and C) during sintering at a corresponding temperature. In this case, the Mo particles are first carburised to form Mo_2C and Fe diffuse into carbide to form η -carbide M_6C (approximately Fe_3Mo_3C).

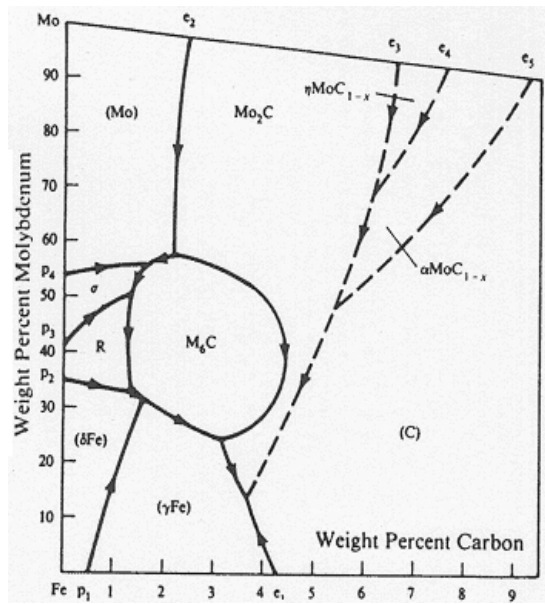


Fig. 2 C-Fe-Mo Liquidus projection [8].

The liquid phase is formed between the η -carbide and the austenite surrounding the particles. According to isothermal sections of the Fe-Mo-C system (see Figure 2), a liquid phase between M_6C and austenite is formed at 1230°C and for a carbon content of 0.7 wt.%, the liquid phase is formed above 1240°C . The mechanical properties (with the exception of hardness), increases with increasing sintering temperature, exhibit a drastic improvement as a consequence of liquid-phase sintering [7]. When the sintering temperature is less than 1100°C , sintering does not proceed well, whereas when the sintering temperature exceeds 1300°C , production costs increase. Thus, the sintering temperature is set to about $1100\text{-}1300^\circ\text{C}$. When the cooling rate after sintering exceeds $0.6^\circ\text{C}/\text{sec.}$, an upper bainite structure is formed and the strength decrease. A fine pearlite structure can be obtained by setting the cooling rate to about $0.6^\circ\text{C}/\text{sec.}$ or less in the temperature range of from about 800°C to about 400°C , so that the strength of the sintered bodies can be improved [2].

5 CONCLUSIONS

- Chromium itself contributes significantly to increasing surface hardness by, for example, nitriding, induction hardening, formation of a homogeneous structure and also case hardening.
- Molybdenum improves the strength of steel by solution hardening and precipitation hardening of Mo carbide. Preferable content of Mo is set to about 0.15-1 wt.%. The microstructure changes from ferrite/perlite to bainite/martensite and the tensile strength is improved. The tensile strength is increased by increasing graphite additions.
- The content of carbon in the sintered body ranges 0.2-1.2 wt.% because is an element for improving the steel strength. In that order the content of carbon in the sintered body should not be less than 0.2 wt.%, and when the content exceeds 2 wt.%, cementite precipitates to lower the strength and toughness.
- The high temperature results in a more active sintering and produces rounder pores than do low sintering temperatures. The rounder pores also increase the impact energy. Thus, the sintering temperature is set to about $1100\text{-}1300^\circ\text{C}$.

REFERENCES

1. US patent US4518427 Iron or steel powder, a process for its manufacture and press-sintered products made therefrom, (1985).
2. US patent US5605559 Alloy steel powders, sintered bodies and method, (1997).
3. US patent US5666634 Alloy steel powders for sintered bodies having high strength, high fatigue strength and high toughness, sintered bodies, and method for manufacturing such sintered bodies, (1997).
4. US patent US5703304 Iron-based powder containing chromium, molybdenum and manganese, (1997)
5. US patent US5728238 Iron based powder, component produced therefrom and method of producing the component, (1998).
6. US patent US5872322 Liquid phase sintered powder metal articles, (1999).
7. A.Šalák, Ferrous Powder Metallurgy, Cambridge International Science Publishing, (1995).
8. ASM Handbook, vol.III, Alloy Phase Diagrams, ASM International, (1997).