Researches Regarding the Influence of Cu Content on Static and Dynamic Properties of Sintered Steels

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Abstract

The utilisation of iron powder in sintered steels subjected to variable loadings was confined because of their low fatigue resistance and the fact that this kind of loading is unknown for the users. Lately, a lot of effort was made to determine the fatigue behaviour and to identify new methods for improving these properties.

In this paper are analyse the behaviour of elaborate materials from iron powder, DWP 200.28 with cooper addition, pressed at 600 MPa and sintered at 1120°C for 30 minutes in endogas. The cooper is add to improve the mechanical characteristics, by forming some favourable microstructures and more round pores from the material macrostructure. For this materials tensile resistance, elongation, Young modulus and the number of cycles until failure are analysed. We find that the cooper add say in a different way these properties.

Keywords

Materials fatigue, Materials properties, Powder metallurgy

Introduction

A major part of the well known and used materials at this time on the market can be better obtained by powder metallurgy. Because the mechanical properties of this parts are lower than those obtained from the compact material, their use is relatively limited, especially for high and variable loadings. It results that for these materials the fatigue limit is very dangerous. It seems that 90% of failures during loading are due to the fatigue of sintered steel. The causes for this lower properties of sintered steels are generally determined by the pores existence in their structure, pore characterized by shape, size and localisation. These pores make in materials applicator stress at intergranulars necks level forming starting and crack propagation of the source.

A general analyse of mechanical properties of the sintered materials shows that both static and dynamic properties are mostly determined by density, respectively porosity. If tensile strength increases almost proportional with density, in case of dynamic properties are not the same, especially for fatigue strength. It results that sintered materials are more sensitive in dynamic loadings that in static ones, and so, is more difficult to determined their fatigue behaviour upon the results obtained from static loadings.

Due to the fact that almost 80% of sintered steels fatigue loaded are materials obtained from iron powders, the goal of these researches is the establishment of the static and dynamic properties for sintered materials produced from iron powder, by S.C. Ductil S.A. Buzău.

The Influence of Alloying Elements on Mechanical Properties

For steels, the most important alloying elements are C, Cu, Cr, Mn, Mo, P, S, W and V. Some of them are added in sintered metallic powder materials to influence some specific properties. They can be used alone or in a combination. The most common alloying elements, used in practice, are carbon - as graphite, cooper, molybdenum, nickel, manganese, chromium and vanadium [1-3].

Carbon, one of the most important elements in sintered ferrous materials, is cheap and it is added as high purity graphite powder. As a result of graphite introduction in iron powders, it is possible to obtain ferrous sintered materials with different structures and properties. In addition, it improves the sintering behaviour, a higher graphite content leads to a better diffusion.

Cooper is also used mostly in pure or alloyed ferrous powder mixtures. This increase the mechanical properties, allowing the obtaining of more homogeny structures, produce the liquid phase sintering and increase the dimensional stability of sintered parts.

Nickel, one of the most important alloying elements in steels, can be also used in low and medium-alloyed ferrous powders. 0.5-5% Nickel addition increase the tensile strength, the depth of chill and improve ductility and toughness.

Molybdenum alloying method has, as a goal, the obtaining ferrous sintered materials with superior mechanical properties. Molybdenum produces a more fine structure, with fine grains that improve almost all properties.

Use Materials

Experimental researches presents the effect of cooper content on static and dynamic properties of ferrous powder sintered materials, produced by Ductil Iron Powders, Buzău. The size and the morphology of the alloying powder have a major effect in forming and sintering process, in defining the sintered material microstructure [5, 6].

DWP 200.28 iron powder is produced by water atomizing method, and its characteristics are given in table 1.

Table 1. The characteristics of DWP 200.28 Iron powder [4]

Particle size distribution	Value	M.U.	Chemical composition	Value	M.U.
>160 μm	≤ 15	%	C	≤0.02	%
160-100 μm	20-40	%	Si	≤0.05	%
100-63 μm	20-40	%	Mn	≤0.20	%
<63 μm	25-45	%	P	≤0.015	%
Apparent density	2,5-2,7	g/cm^3	S	≤0.02	%
Flow time	≤ 33	sec/50g	O_2	≤0.20	%
			Compressibility		
			P = 6 t/cm^2	≥6.95	g/cm

This powder was mixed for 15 minutes with different amounts of cooper, and, after that, the mixtures were pressed at 600 MPa. The samples were sintered at 1120 °C for 30 minutes in endogas. The investigated properties for these sintered parts were hardness, tensile strength, elongation and fatigue strength.

Experimental Results

The sintering materials hardness was evaluated by Rockwell (HRG) method. The experimental results are given in Table 2.

Table 2. Hardness for cooper alloyed ferrous sintered materials

Cu content, %	0	1	1.5	2	2.4	3.
Hardness, HRG	63	70	78	76	78	87

The obtained results analysis shows that, for the cooper increasing contents, the hardness is increasing too (fig. 1). This is because of the formation of a very hard cooper alloyed ferrite. The cooper maximum solubility in ferrite is for 1.5% Cu. This point has the maximum value for hardness, and, beyond that, the hardness decreases easily. A new increase in hardness is due to the cooper excess, which precipitation in the material [7].

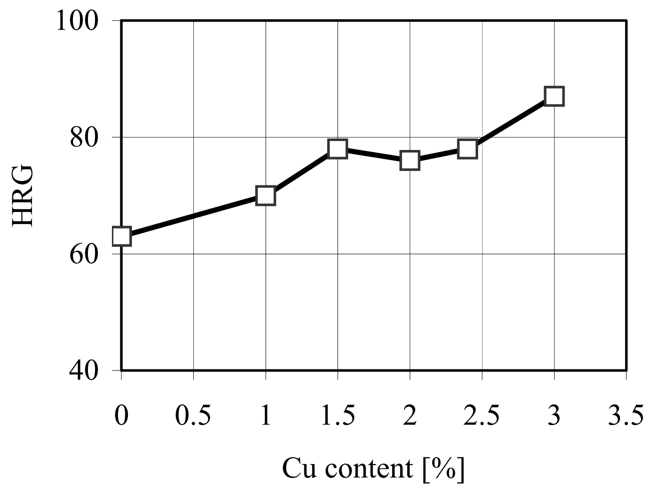

Fig. 1. Correlation between Cu content and hardness for sintered materials

The tensile test was done on a computerized machine, which also computer the mechanical characteristics.

The results are presented in Fig.2. From figure 2, it can be seen that, for cooper content 0-1.5%, the material resistance increase easily and almost linear, due to the better mechanical properties for alloyed ferrite, compared to iron. In the second aisle, cooper 1.5-2.5%, the tensile strength increases faster. This increase is owe spherical pores forming, which decreases the stress concentration at intergranular neck level and delays the cracks beginning.

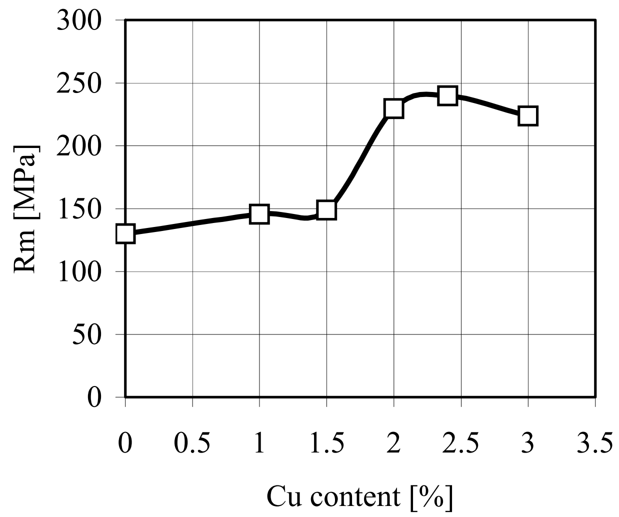

Fig. 2. Correlation between Cu content and tensile strength

Analysing forward it can be seen that, the elongation at failure for mixtures produced from cooper alloyed ferrous powder (fig. 3), presents a continuous decrease until 2.4% Cu. Therefore, it results that alloyed ferrite present a lower plasticity.

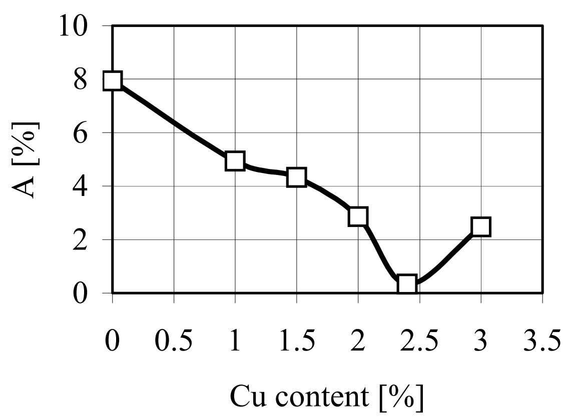

Fig. 3. Correlation between Cu content and elongation

For higher cooper contents, 1.5-2.5% Cu, the elongation is still decreasing, due to the structure of material matrix, and not to the pore shape, which lead to material distortion.

Sow, cooper addition results in a higher tensile strength and Young modulus, but also in a lower fracture elongation.

Figure 4 shows the dependence between Young modulus and cooper content for the iron powder materials that we used. Similar to the static properties, hardness and tensile resistance, Young modulus is also increasing with cooper content, until 1.5-3% cooper added. It results that, between Young modulus and the other two properties there is a correlation, all being influenced by the same structural factors. For higher cooper contents, more than 2% cooper added, elongation present a significant increase but Young modulus is decreasing.

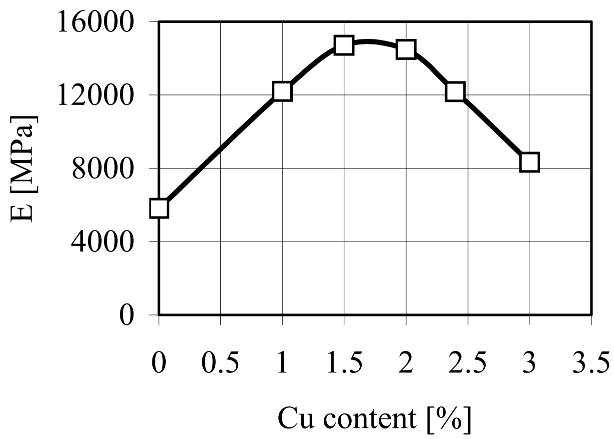

Fig. 4. Correlation between Cu content and Young modulus

Plan bending fatigue test, uses a symmetric alternant cycle and constant frequency until the material is failure, to determine the maximum number of cycles until failure. The bending moment, for all the fracture surfaces is the same for all the samples and due to the different thickness of the parts, the maximum stress for all cycles present a small difference [7,8].

Due to the long time that a part need for fatigue failure, these determinations were made on a small number of samples, only to reveal a trend in fatigue behaviour for the material that we use for this analysis. Table 2 contains the obtained results for these materials.

It results that, increasing the cooper content, fatigue strength is also increasing. This increase shows an obvious increase starting with 1% cooper added.

Table 2. The cooper add influence about fatigue behavior of the sintered materials [7]

No.	Used materials	$N \cdot 10^5$ (cycles until fracture)
1	DWP 200.28	0.01
2	DWP 200.28+1%Cu	0.1
3	DWP200.28+1.5%Cu	0.48
4	DWP 200.28+2%Cu	0.62
5	DWP200.28+2.4%Cu	Still not broken
6	DWP 200.28+3%Cu	Still not broken

For the fatigue resistance, it can be seen that it doesn't follow any of tensile strength or elongation trends. Until 2.4% cooper added, tensile strength is increasing while elongation is decreasing, and for higher cooper contents, these properties are changed. It means that fatigue resistance is determined by both this properties. So, the fact that the best fatigue behaviour is achieved for higher tensile resistance and elongation is confirmed.

Conclusions

All this theoretical and experimental results are leading to the following conclusions:

- The cooper addition increases the tensile resistance, even double it;
- Adding cooper, the Young modulus is increasing while elongation is decreasing;
- Cooper addition increases the fatigue resistance for ferrous sintered materials, due to the liquid phase formation, which also increase the density and produce more round pores;
- Sintered powder materials fatigue strength is very much depending to their tensile resistance and elongation.

References:

1. Palfavi A., Powder Metallurgy (Metalurgia pulberilor), Ed. Tehnică, Bucureşti, 1988, p. 11-77.
2. Colan H., Science of Metals (Studiul metalelor), Litografia IPCN, Cluj-Napoca, 1978, p. 252.

3. Colan H., Cercetări privind influenţa şi difuzia cuprului în oţeluri şi aliaje de fier – carbon sinterizate, Teză de doctorat, IPCN, Cluj, 1971, p. 171.
4. *** Prospecte – S.C. Ductil S.A. Buzău România, 8-09-2002.
5. Md. Hamiuddin – Correlation Between Mechanical Proprieties and Porosity of Sintered Iron and Steels – A Review, Powder Metallurgy International vol 18, no. 2, 1986.
6. Tina M. Cimino, Amie H. Graham and Thomas F. Murphy – The Effect of Microstructure and Pore Morphology on Mechanical and Dynamic Proprieties of Ferrous PIM Materials, International Conference on Powder Metallurgy & Particulate Materials May 31-June 4, 1998 Las Vegas, NV USA.
7. Rapport for research nr. 7003/1997: Research regarding the fatigue behaviour of the sintered metallic materials (Protocol Contract de cercetare nr. 7003/1997: Cercetări asupra modului de comportare la solicitări variabile (oboseala) a materialelor metalice sinterizate – Etapa a II-a Determinarea influentei parametrilor tehnologici ai formării si sinterizării asupra comportării la oboseala a materialelor din pulberi metalice sinterizate), Director de contract: Reader Dr. Eng. L. Brânduşan.
8. C. Pavel, L. Brânduşan, R. Mureşan – Study regarding the fatigue behaviour of the sintered iron powder materials (Studii privind comportarea la oboseală a materialelor sinterizate din pulberi de fier), Tehnica şi Ingineria, Lucrările celei de a II-a Conferinţă Naţională „Prof. Dorin Pavel – fondatorul hidroenergeticii româneşti”, Sebeş, 2002, vol. II, p. 581-586.