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Dimensional Change During Sintering of Samples of the Fe-Cu System

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Abstract: In this study we examine powder metallurgical material from Fe-Cu system. In sintering the samples of this system as a result from the processes of deletion of internal porosity and separation of supersaturated solid solutions occurs a significant change in the size of the initial preparations. Detected the influence of the copper amount, density of samples and the sintering temperature on the occurring dimensional changes of the starting billet, and the results obtained are compared with those of pure samples of sintered iron under the same conditions.

Keywords: powder metallurgy; dimensional changes; iron powder ASC 100.29; electrolytic copper.

I. Introduction

Copper is an alloying element that does not applicable in classical metallurgy, but finds wide use in powder metallurgy. This is based on these important advantages:

- good mixed with iron powder;
- easy reducibility of copper oxide;
- formation of liquid phase during sintering at relatively low temperatures, etc.

Alloy of iron with copper or copper in combination with other elements makes it possible to obtain alloys with good physical and mechanical properties. [2,3,6] However, in the presence of copper sintering leads to significant changes in the starting billets. [1,4] The change in the dimensions of the billets from powder metallurgical Fe-Cu system depends on number of tech parameters, and the amount of copper in the samples, the presence of graphite and alloying elements in the matrix, technological characteristics of the starting powders, density of billets after sintering, temperature and duration of the sintering and etc.. [5,7]

This study was designed to monitor the influence of the amount of copper and sintering temperature on the amount of change of the billets in the system Fe-Cu.

II. Technical requirements

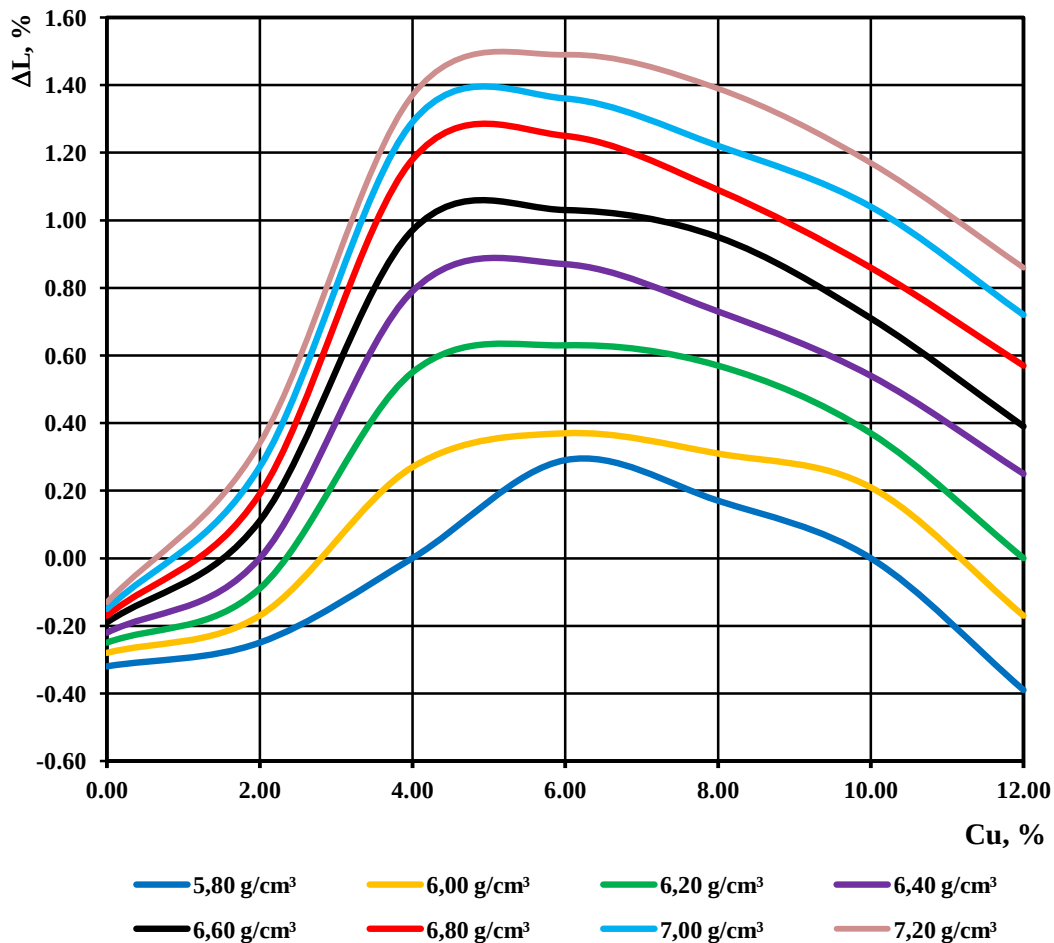
Study samples are subjected powder metallurgical based iron powder ASC 100.29. It is a representative of the water atomized powders and currently this is the best quality iron powder manufactured by "Höganäs". Characterized by very high purity. It has excellent compressibility, which is a result of the fact that the particles are at substantially spherical shape. This allows after single pressing with different effort to obtain samples having a wide range of variation of the density with a maximum from $7,20 \div 7,30 \text{ g/cm}^3$. Iron alloyed matrix is added to 12% electrolytic copper with a particle size of $63 \mu\text{m}$. After mixing, the powder billet is extruded with power of $200 \div 800 \text{ MPa}$, which allows to obtain samples having a density in the range of $5,80 \div 7,20 \text{ g/cm}^3$.

The samples are sintering into a horizontal laboratory muffle furnace in an atmosphere of dissociated ammonia - NH_3 . A proportion of nitrogen and hydrogen in the working space of the crucible was 75 % H_2 and 25 % N_2 . Sintering is conducted at temperatures of $850 \div 1350^\circ \text{C}$ while controlling the rate of the incoming gas, and its dew point for 60min. Sintering billets were placed in a covered ceramic boats and backfill of $75\% \text{Al}_2\text{O}_3 + 15\% \text{FeMn} + 10\% \text{C}$. Backfilling helps to minimize the loss of mass and the change in dimensions of samples due to oxidation of the iron powders at high temperature sintering.

The change in the linear dimensions of the billet size $10 \times 10 \times 50$ after sintering at different concentration of copper in them and different density is given in Table №1, and graphical interpretation in figure 1. From the figure it can be seen that increasing copper concentration from 0 to 12% linear change of the samples was read with curves with a maximum fixed at a concentration of copper $4 \div 8\%$. For small values of copper concentration in the samples - less than 5%, and the sintering temperature 1150°C increase in the billets is determined by both the processes of bulk diffusion and the diffusion of molten copper on the borders of the iron grains.

Table 1 Size changes depending on the density – T=1150°C

№	ρ , g/cm ³	ΔL , %						
		0%Cu	2%Cu	4%Cu	6%Cu	8%Cu	10%Cu	12%Cu
1	2	3	4	5	6	7	8	9
1	5,80	-0,32	-0,25	0,00	+0,29	+0,17	0,00	-0,39
2	6,00	-0,28	-0,17	+0,27	+0,37	+0,31	+0,21	-0,17
3	6,20	-0,25	-0,09	+0,55	+0,63	+0,57	+0,37	0,00
4	6,40	-0,22	0,00	+0,79	+0,87	+0,73	+0,54	+0,25
5	6,60	-0,19	+0,11	+0,97	+1,03	+0,95	+0,71	+0,39
6	6,80	-0,17	+0,19	+1,18	+1,25	+1,09	+0,86	+0,57
7	7,00	-0,15	+0,27	+1,29	+1,36	+1,22	+1,04	+0,72
8	7,20	-0,13	+0,34	+1,37	+1,49	+1,39	+1,17	+0,86

Figure 1 Size changes depending on the density – T=1150°C

As a result of these processes copper forms solid solutions with iron, and released its porosity volume form determined by the effect of Kirkendal, which also leads to further expansion of the samples.

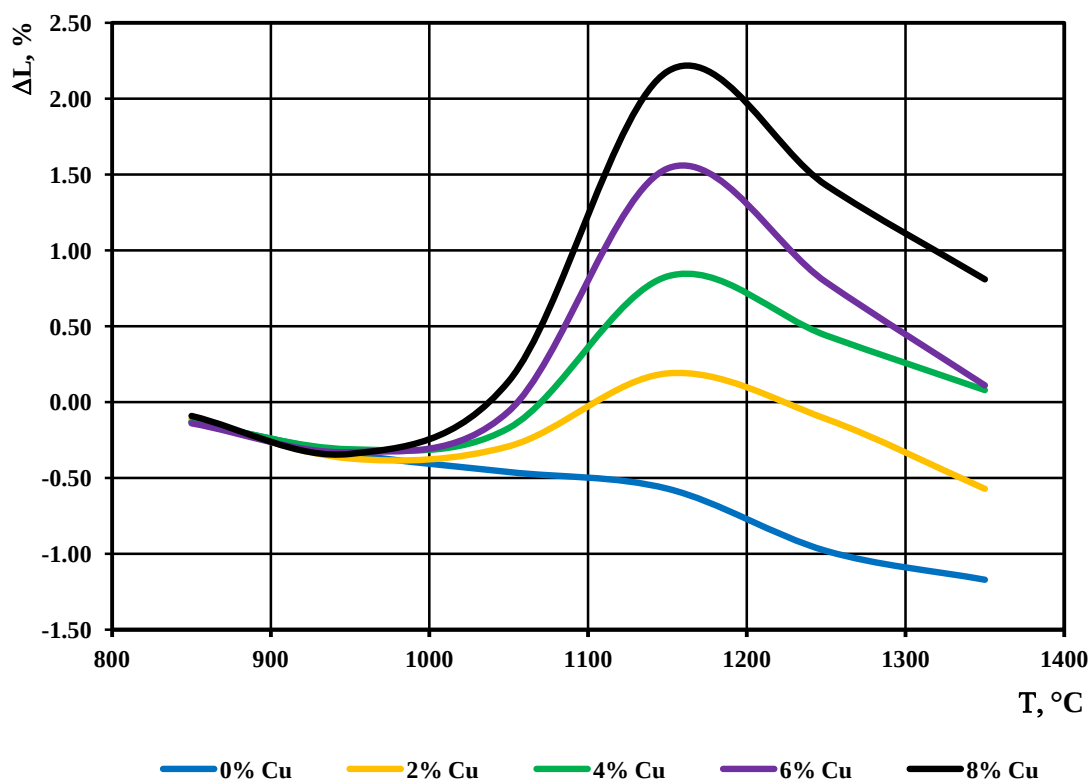
The limited volume diffusion coefficient of copper in Fe_y [2] determines the limited penetration and incomplete alloying of copper with iron particles by volume diffusion. Therefore it can be concluded that the influence of the density distribution to increase the size of the iron-copper bars is negligible and only in the concentration range 4÷6% copper. Above this concentration, the process of sintering is implemented completely in the presence of a liquid phase from a guaranteed insoluble iron in copper. It promotes sintering the iron particles to be realized even under pressure from comprehensive liquid phase. As a result, a process of coalescence of

released volume of diffused copper and decrease dimensions of the billets. This reduction is more markedly at higher copper concentrations in the iron pieces.

Table 2 Size changes depending on the temperature of sintering – $\rho=6,60\text{g/cm}^3$

№	T, °C	$\Delta L, \%$				
		0%Cu	2%Cu	4%Cu	6%Cu	8%Cu
1	2	3	4	5	6	7
1	850	-0,13	-0,11	-0,13	-0,14	-0,09
2	950	-0,34	-0,37	-0,31	-0,33	-0,34
3	1050	-0,46	-0,29	-0,17	-0,06	+0,14
4	1150	-0,57	+0,19	+0,83	+1,54	+2,18
5	1250	-0,98	-0,11	+0,44	+0,79	+1,43
6	1350	-1,17	-0,57	+0,08	+0,11	+0,81

Figure 2 Size changes depending on the temperature of sintering – $\rho=6,60\text{g/cm}^3$



The increase in the density of the samples of $5,80$ to $7,20\text{g/cm}^3$ also favors “copper growth”, as in a billets with high density is easier to diffusion of copper and iron is present in a large versatile pressure of the formed liquid phase. As a result, minor amounts of copper - less than 2%, are able to compensate for the shrinkage of the iron preparations with a density of $7,20\text{g/cm}^3$.

The influence of sintering temperature on the dimensional changes of the Fe-Cu billet is traced on samples of uniform thickness - $6,60\text{g/cm}^3$, and the concentration of copper in them $0\div 8\%$. Experimental results of these tests are presented in Table 2, a graphical interpretation of them – fig.2. From the results obtained in the experiments can be seen that increasing the sintering temperature from 850 to 1350°C causes the compression of specimens of pure iron with $1,0\div 1,5\%$. The addition of copper to iron pieces compensates its shrinkage, as this compensation starts at temperatures of sintering about 1100°C . This is because the melting point of copper is 1094°C and sintering temperature conditions are available for implementation of the sintering in the presence of a liquid phase. [2, 5]

The increase of temperature at the billets continues until $1150\div 1200^\circ\text{C}$, where in the solubility of copper in Fe reaches $10\div 15\%$. Above these temperatures the diffusion of copper in the iron has been completed as a result of

which the temperature rose to implement solid phase sintering and shrinkage of the billets as a consequence of the processes of coagulation freed from copper diffuses into the interior volume of the billets.

III. Conclusion

In a study of the linear changes of the samples sintered at 1150°C for 1h with a density of 5,80÷7,20 g/cm³ and a copper concentration of 2 ÷ 12% is established,

- Has been shown that an increase in the copper concentration of from 0 to 12% linear change of the samples was read with curves with a maximum at a fixed concentration of copper 4 ÷ 8% ;
- It was found that for small values of copper concentration- less than 5%, sintering temperature 1150°C increase in the billets is determined by both the processes of bulk diffusion and the diffusion of molten copper on the borders of the iron grains.
- It was found that the influence of bulk diffusion on the growing amount of Fe-Cu billet is negligible only in the concentration range 4 ÷ 6% copper.
- Has been found that the increase in the density of the samples of 5,80 to 7,20g/cm³ favors "copper growth" , as in a sample is densities it easier to diffusion of copper and iron is present in a large versatile pressure of the formed liquid phase.

Influence of sintering temperature on the dimensional change of iron - copper moldings is detected on samples with a uniform thickness - 6,60g/cm³, and a copper concentration of 2÷8%, wherein it is found that:

- Increasing sintering temperature from 850 to 1350°C leads to shrinkage of samples of pure iron with 1,0 ÷ 1,5%.
- The addition of copper to iron samples offset their shrinking as such compensation begins at the sintering temperature of 1100°C.
- Increase of billets continues to temperatures 1150 ÷ 1200°C, wherein the solubility of copper in Fe_y reaches 10 ÷ 15%.
- Above 1200°C diffusion of copper in the iron has been completed as a result of which the temperature rose to implement solid phase sintering and shrinkage of the billets as a consequence of the processes of coagulation freed from copper diffuses into the interior volume of the billets.

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