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The factors of dimensional change of Fe-Cu-C sintered objects

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Abstract Dimensional accuracy is one of the most important issues in the production of sintered parts. The iron-copper-carbon system is commonly used alloys in sintered structural parts production. The dimensional control of these alloys, however, is not easy because of their complex sintering behavior. This study is an effort to clarify the influence of common factors on dimensional change of Fe-Cu-C sintered structural parts. We determined the effect of such various parameters as chemical composition, particle diameter, compact density, sintering temperature and sintering time on dimensional changes. Consequently, we obtained a useful formula to predict the final dimension in function of these parameters. The effect of typical impurities in copper powder on the dimensional change of sintered parts has also been described.

1. Introduction

While dimensional accuracy is one of the most important features of powder metallurgy, the dimensional change of iron based sintered objects is complicated due to phase transformations, and additives diffusion and sintering. Typical dilatometric curve of a iron-copper-carbon powder compact during sintering is illustrated in Fig. 1. The final value of dimensional change has been influenced by carbon diffusion, copper swell and sintering which had sequentially occurred during sintering process.

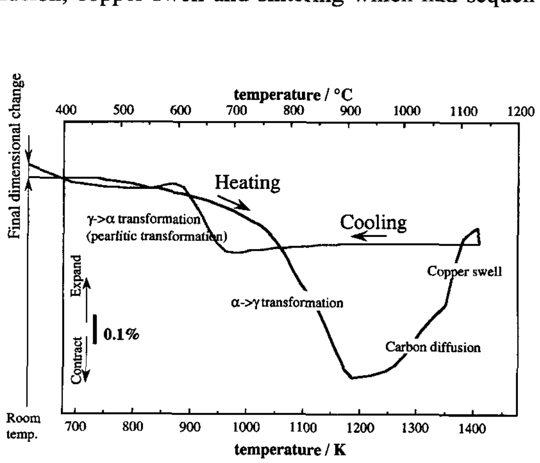

Fig. 1. Schema of dilatometric curve of iron-copper-carbon powder compact.

Han, et al[1] studied the mechanism of copper swell. Styskin determined the effect of additives amount on dimensional change in iron-copper-carbon-nickel sinter alloys.[2] Griffo, et al. and Kohno, et al. examined the effect of various process factors on dimensional change in iron-carbon-copper sinter alloys.[3-5] These works have provided the individual effect of various factors on dimensional change in iron-copper-carbon sinter alloys; however, it is difficult to predict the dimensions of these sinter alloys. On the other hand, little information has been published on the effect of impurities in additives.

The object of this study is to determine an empirical formula of the dimensional change of iron-copper-carbon sinter alloys, and to clarify the influence of impurities on the dimensional change. We focused on very common impurities of tin in atomized copper powder and lead in electrolytic copper powder.

2. Experimental Procedure

The powders for the study were water atomized iron powder, Kawasaki steel KIP 300A, electrolytic and water atomized copper powders, and natural

Table 1. Experimental conditions

Composition of powder mixture	
Copper	1.0 to 3.0 wt%
Graphite	0.4 to 1.2 wt%
Compact density	6.4 to 7.1 g/cm³
Sintering conditions	
Holding temp.	1393 to 1413 K
Holding time	0.6 to 1.8 ks
Atmosphere	Endothermic gas

flake graphite powder. Zinc stearate was used for lubrication. Mean diameter of copper and graphite powders were determined by Microtrac 7997 laser scattering analyzer. The powders were mixed for 15 minutes in a V blender. The powder mixtures were compacted into $\phi 78 \times \phi 35 \times 15$ mm rings using a 5000 kN hydraulic press. The powder compacts were sintered in a mesh belt furnace under an endothermic gas (RXgas) atmosphere. Experimental conditions are shown in Table 1.

Several test pieces were quenched from 1368K, just above the copper melting point, for study of diffusion phenomena by using an electron probe micro analyzer.

3. Experimental Results

The formula which indicate the relationship between process parameters and dimensional change has been obtained by regression of experimental data as shown below.

$$DC = -4.59 \times 10^{-1} C_{Gr} + 3.51 \times 10^{-2} C_{Cu} - 6.43 \times 10^{-2} C_{Lub} - 9.86 \times 10^{-4} \frac{d_{Gr}}{d_{Cu}} - 2.75 \times 10^{-5} T_s - 1.44 \times 10^{-3} \log \tau_s + 2.51 \times 10^{-3} \rho_g + 3.96 \times 10^{-2} \quad (1)$$

where DC: dimensional change, C_{Gr}: graphite content, C_{Cu}: copper content, C_{Lub}: lubricant (Zinc stearate) content, d_{Gr}: mean diameter of graphite powder (mm), d_{Cu}: mean diameter of copper powder (mm), T_s: holding temperature (K), τ_s: holding time (s) and ρ_g: compact density (g/cm^3). The correlation coefficient of the formula was 0.985. This formula clarify the influence of process parameters on dimensions of iron-copper-carbon sinter alloys.

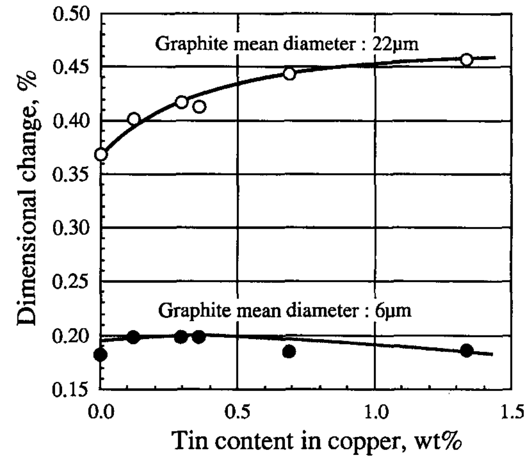

Fig. 2. Effect of tin impurity in copper powders on the dimensional change of Fe-Cu-C alloys.

The relationship between tin content of water atomized copper powders and dimensional change of iron-copper-carbon sinter alloys is shown in Fig. 2. Two curves show the cases of different graphite mean diameters. Tin impurity increases the dimensional change in the case of regular graphite powder (22 μm of mean diameter), however, slight change of the dimension is observed in the case of fine graphite powder (6 μm of mean diameter). Fig. 3

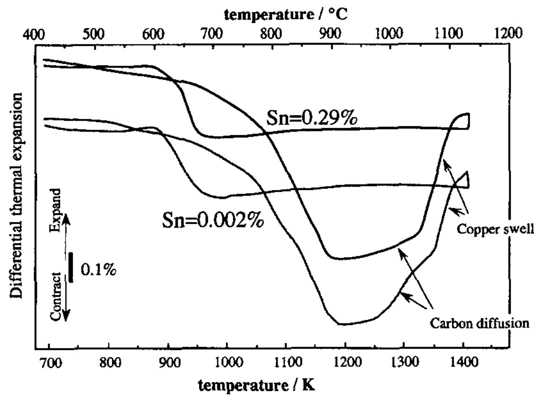

Fig. 3. Effect of tin impurity in copper powders on dilatometric curves of Fe-Cu-C alloys.

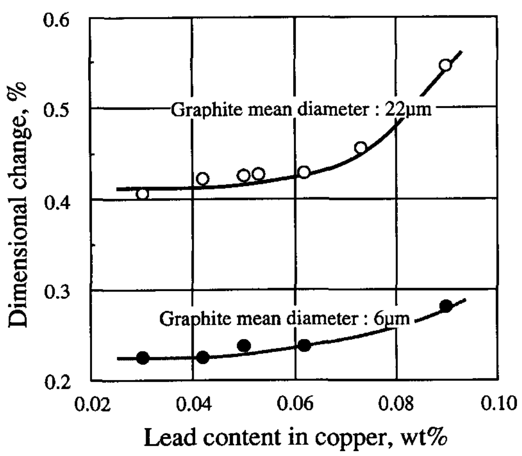

Fig. 4. Effect of lead impurity in copper powders on *the dimensional change of Fe-Cu-C alloys.*

shows the dilatometric curves for two different tin impurity contents. Two curves are apparently different in temperature range from 1150K to 1350K.

Similar phenomenon is observed with electrolytic copper powders. The influence of lead impurity content in electrolytic copper powders on dimensional change of the iron-copper-carbon sinter alloys is shown in Fig. 4. The dimensional change rapidly increases with the lead content above 700 ppm. Also in this case, the change is rather small in the case of the fine graphite powder.

4. Discussion

Regarding nominal variation range of the process parameters and coefficients of formula 1, the influence of graphite content and compact density on dimensional change of the iron-copper-carbon sinter alloys are most significant. Accordingly, to achieve small variation of the dimensions, we must eliminate the graphite segregation and deviation of compact density. Segregation free premix powders with high flow rate are suitable for this purpose.

Tin impurity in the atomized copper powders increases dimensional change of the iron-copper-carbon sinter alloys. Fig. 3 indicates that the expansion by carbon diffusion is diminished with tin impurity increase. Carbon distribution maps by the electron probe micro analyzer of the quenched test pieces are shown in Photos 1. The photos indicate that carbon diffusion decrease with tin impurity increase. The restricted carbon diffusion resulted in enhanced copper swell and increase in dimensional change. Fine graphite powder makes carbon distribution uniformly, and consequently diminishes the influence of tin impurity.

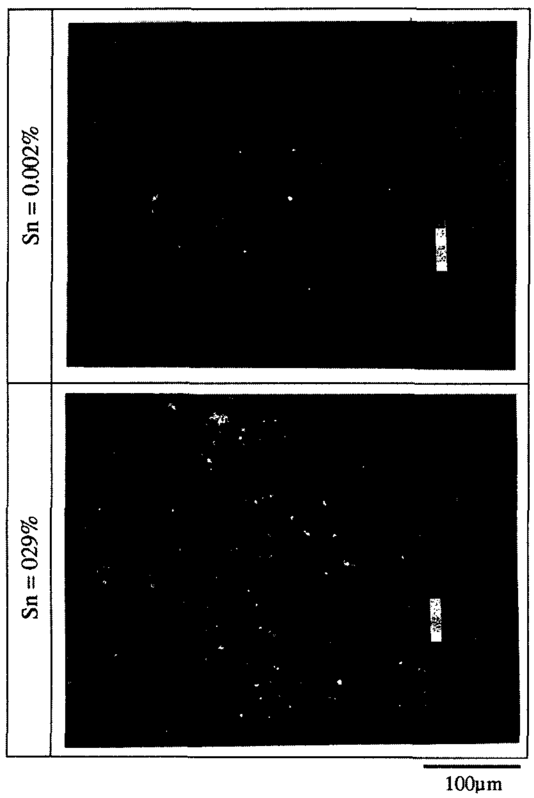

Photo 1. Carbon distribution maps of quenched test pieces containing different tin impurity of copper powders.

5. Summary

1. A formula for practical use which indicates the relationship between the dimensional change and the process parameters of the iron-copper-carbon sinter alloys is obtained.

2. Tin impurity in atomized copper powder increases the dimensional change of iron-coppercar-

bon sinter alloys on account of enhanced copper swell.

3. Fine graphite powder suppresses the influence of tin and lead impurity on the dimension of iron-copper-carbon sinter alloys.

References

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