KAWASAKI STEEL TECHNICAL REPORT
No.42 (May 2000)

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Kawasaki Steel has developed two kinds of copper segregation-free premixed iron powders. One is "binder treated type" segregation-free iron powder, in which fine copper powders are adhered on surface of iron powder by the binder and the other is "partially alloyed type" segregation-free iron powder. The characteristics of these two types of powders such as compressibility, Rattler value and ejection force are almost equal to those of conventional segregation-free iron powder, and the properties of sintered products, including tensile strength, Charpy impact value and dimensional change, are almost equal to those made of conventional segregation-free iron powder. The "partially alloyed type" segregation-free iron powder reduces the segregation of copper by 70% and improves dimensional accuracy by 20% compared with conventional segregation-free iron powder.

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1 Introduction

In iron powder metallurgy, graphite powder, other alloying powders such as copper powder and nickel powder, and lubricant are normally mixed with the iron powder, and the mixture is then compacted and sintered.

Because the specific gravity of the graphite powder which is added to the iron powder differs greatly from that of the iron powder, the graphite tends to separate and segregate from the iron powder during transportation in "simply mixed powders," which are prepared simply by mixing without other treatment to adhere graphite powder and the alloying powder to the surface of iron powder. This not only causes dusting, which deteriorates the working environment, but also leads to deviations in the graphite content, even when powders in the same mixing lot are compacted. As a result, deviations in the dimensions of the sintered parts and in mechanical properties can easily become large.[1)]

Fe-Cu-C system, in which copper powder and graphite powder are added to iron powder as alloying elements, account for more than 90% of sintered iron products. With this composition system, carbon swelling; diffusion of the graphite powder into the iron powder (γ phase) and copper swelling; penetration of the molten copper into iron particles occur continuously during sintering.[2)] For this reason, segregation of the graphite and copper deteriorate the final dimensional accuracy of the sintered product. In order to solve this problem, the premixed powder has been developed, in which graphite powder is adhered to surface of iron powder by binder.

No premixed powders virtually which prevented copper powder segregation had been developed, with the exception of those in which copper powders were partially alloyed with iron powder.

Kawasaki Steel developed two types of premixed iron powder, in order to prevent segregation of copper and graphite simultaneously. In one type, called the "binder treated type," fine copper powder and graphite powder are made to adhere to the iron powder, while in another, called the "partially alloyed type," copper powder is made to adhere to iron powder by partially alloying. This report describes the properties of these copper segregation-free premixed iron powders and the effect of copper segregation on dimensional accuracy of sintered steel.

* Originally published in *Kawasaki Steel Giho*, **31**(1999)2, 135–138

2 Experimental Procedure

2.1 Degree of Adhesion of Copper to Iron Powder, Powder Characteristics, and Mechanical Properties of Developed Powders

Segregation-free iron powders were prepared by mixing 0.75% zinc stearate as a lubricant with Fe-2%Cu-0.8%C. Three types of copper powder were used, a 10% partially alloyed powder, a fine copper powder, and electrolytic copper as a comparison material.

The flowability and apparent density of the sample powders, and the green density, ejection force, and Rattler value after compacting at compacting pressures of 392, 490, and 588 MPa were measured. In order to investigate the degree of segregation of the copper powder, Cu analysis were performed at each particle sizes 60# mesh to 325#. As a measure of graphite segregation, the degree of graphite adhesion was evaluated as defined by the following equation.

Degree of graphite adhesion (%) = {(Analysis value of C in segregation-free premixed iron powder sieved with −100#/+200#)/(Analysis value of C in segregation-free premixed iron powder)} × 100 ···························· (1)

The sample powders were compacted to a green density of 6.85 Mg/m^3, and were then sintered at 1 130°C for 20 min in a RX gas atmosphere. After sintering, tensile strength, the Charpy impact value, and dimensional change were measured.

2.2 The Measurement of Cu Segregation in Premixed Powder and Dimensional Accuracy of Sintered Steel

One ton of segregation-free premixed iron powder with a composition of Fe-2%Cu-0.8%C and a 0.75% mixture of zinc stearate was manufactured. 10% partially alloyed powder and electrolytic copper powder were used as copper powders.

The sample powders were transported to a height of 2 m at a rate of 25 kg/min by a tube conveyor. Samples of 1 kg were taken at each 25 kg portion during conveying and used as sample powders. Each of the samples was compacted into 5 ring shaped pieces $\phi 38 \times \phi 25 \times h10$, with a density of 6.85 Mg/m^3, and the green compacts were sintered at 1 130°C for 20 min in a RX gas atmosphere. After sintering, the dimensional changes of each sample were measured and analysis of Cu contents were carried out.

3 Results and Discussion

3.1 Degree of Adhesion of Cu to Iron Powder

The Cu contents of the samples are shown at each

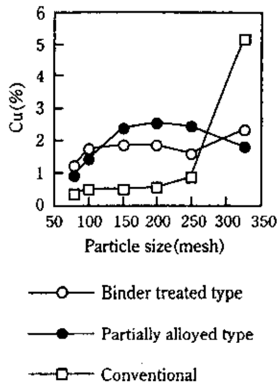

Fig. 1 The effect of kinds of copper resource on Cu contents of segregation-free iron powders sieved

particle size range in **Fig. 1**. Figure 1 shows that, the Cu content of the conventional segregation-free iron powder, is less than 0.5% in the particle size range larger than the 325 mesh, which is almost equivalent to a Cu powder particle diameter of 47 μm, but increases dramatically, to 5.3%, in the range smaller than 325 mesh. On the other hand, the effects of particle size on Cu contents are smaller, both the binder treated type and diffusion alloyed type. The Cu content in the particle size range under 325 mesh is as small as 2–3%, which is copper content in pre-mixed powder used of.

The particle size of the copper powder is under 47 μm (325 mesh). Because the copper powder which does not adhere to the iron powder will pass through a 325 mesh during sieving, the Cu content increases with particle sizes under 325 mesh, when Cu powder does not adhere to the iron powder. Accordingly, with both the binder treated type and the partially alloyed type, it is concluded that the copper powder adhered to the iron powder. On the contrary, with the conventional powder, there is a large amount of copper powder which does not adhere to the iron powder, and the segregation-free effect is slight.

Photos 1 and **2** show SEM images of the conventional segregation-free iron powder and the binder treated iron powder. With the conventional type, the copper powder cannot be captured on the surface of the iron powder because the diameter of the copper powder used is larger than that of the concave areas on the surface of the iron powder. For this reason, an extremely strong binder is needed indispensably to prevent segregation of copper powder. The adhesive force of the binders, which are normally used, is not capable of preventing segregation of the copper powder. However, the use of strong binders cannot be considered desirable, because strong binders deterioate the flowability of the segregation-free premixed powder, and in addition, are difficult to be removed during sintering.

Photo 2 shows that, with the binder treated type, the

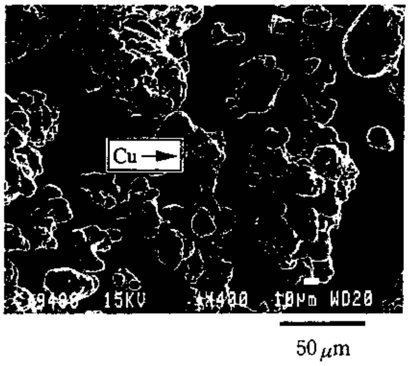

Photo 1 SEM image of conventional segregation-free iron powder

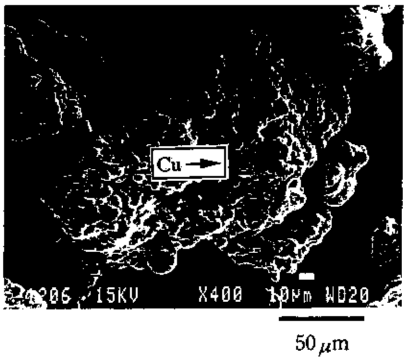

Photo 2 SEM image of newly developed segregation-free iron powder with the fine copper powder

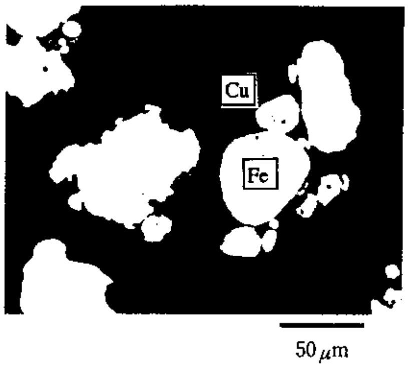

Photo 3 Optical micrograph of cross section of newly developed segregation-free iron powder with the copper partially alloyed powder

Table 1 The apparent density and flow rate of segregation-free iron powders

The kinds of segregation-free iron powders	Apparent density (Mg/m³)	Flow rate (s/100 g)
Binder treated type	3.23	11.9
Partially alloyed type	3.35	11.6
Conventional	3.35	11.6

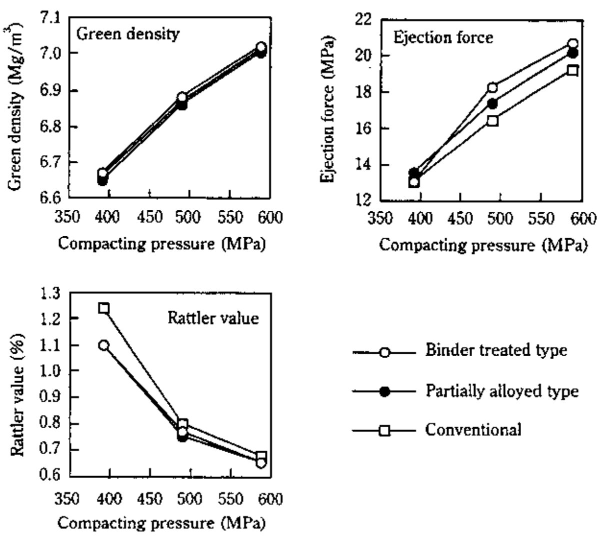

Fig. 2 Green density, ejection force and Rattler value of the segregation-free iron powders

fine copper powder is fixed in the concavities on the iron powder by the binder, resulting in free segregation of copper.

Photo 3 shows an optical micrograph of the cross-section of the partially alloyed iron powder. This photograph indicates that the copper powder has been partially alloyed to the surface of the iron powder.

3.2 Properties of Developed Powders

Table 1 shows the apparent density and flowability of the sample powders. The apparent density of the binder treated type, in which fine copper powder is made to adhere on the surface of the iron powder, is approximately 0.12 Mg/m^3 smaller than that of the conventional segregation-free powder, while the apparent density of the partially alloyed type is the same as that of the conventional product. Moreover, the flowability of both the binder treated type and partially alloyed type is similar to that of the conventional powder.

As shown in **Fig. 2**, the compressibility (green density), ejection force, and Rattler value of the binder treated type and the partially alloyed type are substantially the same as each of the respective properties of the conventional product.

The powder characteristics of the newly developed binder treated type and partially alloyed type, in which Cu is partially alloyed to the iron powder, are on the same level as those of the conventional powder.

3.3 Mechanical Properties of Sintered Parts

Table 2 shows the values of the tensile strength,

Table 2 The tensile strength, Charpy impact energy and dimensional change of segregation-free iron powders

The kinds of segregation-free iron powders	Tensile strength (MPa)	Charpy impact value (J)	Dimensional change (%)
Binder treated type	458	10	0.42
Partially alloyed type	467	11	0.39
Conventional	469	11	0.38

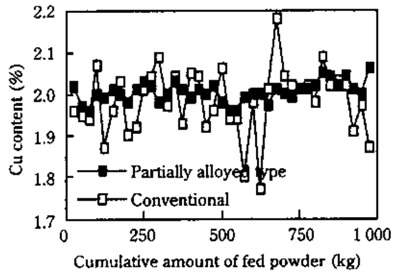

Fig. 3 Difference of scatters of Cu content during feeding between newly developed segregation-free iron powder with the copper partially alloyed powder and conventional segregation-free iron based powder with a composition of Fe-2Cu-0.8C

Charpy impact energy, and dimensional change during sintering (mold standard) of sintered parts made from the sample powders. The both sintered steels made from the binder treated type and the partially alloyed type have tensile strength and Charpy impact values similar to those of the conventional product. Dimensional change of sintered steel made from the binder treated type has 0.04% larger than that made from the conventional product, but that made from the partially alloyed type is virtually the same as that made from the conventional powder.

3.4 Segregation-free Effect and Improvement in Dimensional Accuracy of the Partially Alloyed Type Copper Segregation-free Premixed Powder (Graphite Particle Size: 12 μm)

Figure 3 shows the scatter in the analysis values of Cu in sintered parts by the order of compaction (cumulative amount of powder fed), when 1 t of a conventional powder and the new partially alloyed type powder were transported by a tube conveyor. In comparison with the conventional powder, the scatter of the analysis values of Cu was small, and the standard deviation (1 σ) was reduced by 70%, from 0.080% to 0.024%.

Figures 4 and **5** show the scatter of dimensional change of sintered steel. The deviation in dimensional change of sintered steel using the partially alloyed type premix powder reduces by 20%, from 0.020% to 0.016% compared with that using conventional one.

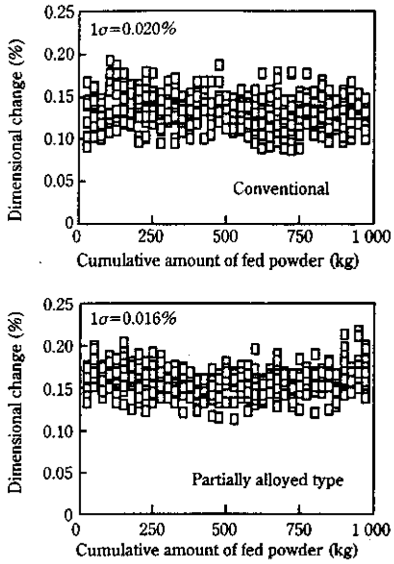

Fig. 4 Difference of scatters of dimensional change during feeding between newly developed segregation-free iron powder with the copper partially alloyed powder and conventional segregation-free iron powder with a composition of Fe-2Cu-0.8C

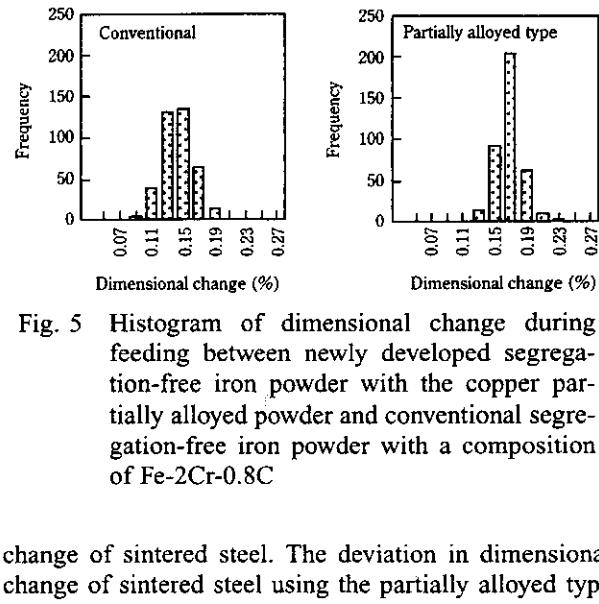

Fig. 5 Histogram of dimensional change during feeding between newly developed segregation-free iron powder with the copper partially alloyed powder and conventional segregation-free iron powder with a composition of Fe-2Cr-0.8C

The newly developed partially alloyed type segregation-free iron powder cause copper segregation to reduce by 70% and to improve dimensional accuracy by 20% in comparison with the conventional premix powder.

4 Conclusion

(1) Two types of copper segregation-free premixed iron powder were developed. These powders simultane-

ously suppress the segregation of copper and graphite simultaneously, which had been difficult with conventional segregation-free powder. The new powders are a binder treated type, in which fine copper powder is made to adhere to the surface of the iron powder by using binder, and a partially alloyed type, in which the copper powder is partially alloyed to the surface of the iron powder.

(2) The powder characteristics, of the two newly developed types of powder, mechanical properties, and dimensional change of sintered parts made of these powders which are important for manufacturing sintered parts, are substantially the same as those of the conventional one.

(3) The partially alloyed type powder causes copper segregation to reduce by 70% and improve dimensional accuracy by 20% compared with the conventional premixed powder.

References

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