"KIP Clean Mix", a Segregation-free Powder-Premix*

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1 Introduction

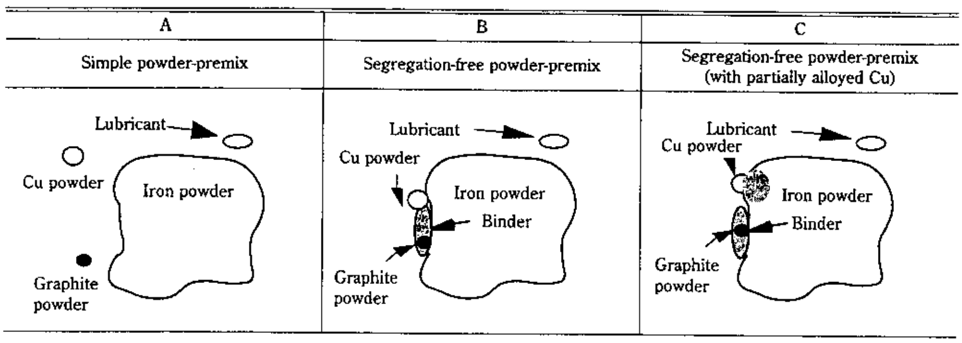
Iron powder metallurgy is a process for efficiently producing parts of complicated shape by performing sintering after pressing iron powder in a die. For this reason, this process is widely used in the manufacture of PM automobile parts. In the manufacture of such parts, powder of zinc stearate as a solid lubricant is usually mixed with iron powder in order to reduce the friction among iron powder particles and between iron powder particles and the die. In addition, powders of alloying elements such as graphite and copper are usually added to iron powders with the above lubricant powder in order to increase the strength of the material by causing these alloying powders to diffuse into the iron powder during sintering. As a result, all these powders are used as a mixture as shown in schema A of **Fig. 1**.

However, the particles of these additive powders differ from iron powder particles in density and particle size. For this reason, segregation occurs, that is, additive powders will segregate from iron powder particles when a mixture is transported, transferred to a press for pressing, or fed from a hopper into a die. When graphite powder segregates and emits dust, the working environment for the production of sintered parts is impaired, and changes in the graphite and copper powder content occur between parts pressed in the initial period of pressing and those pressed in the latter period in a continuous pressing process. As a result, the mechanical properties of sintered parts and dimensional change during sintering vary, deteriorating the quality of sintered parts and lowering the yields of raw material powders and sintering parts.

In order to solve these problems in the conventional powder-premix, Kawasaki Steel developed a segregation-free powder-premix in which, as shown in schema B of Fig. 1, graphite powder and copper powder are adhered to the surface of an iron powder particle using a binder. The company has manufactured and sold this product under the trade name of "KIP Clean Mix" since 1989. KIP Clean Mix has gained a reputation since it appeared on the market because of (1) low dust emission from graphite, (2) improved yields of raw material powders and sintered products, and (3) the elimination of the need for mixing by users.

The above-described zinc stearate as solid lubricant powder is widely used in iron powder metallurgy because it improves the flowability of a mixture when the mixture is filled into a die. However, the greater part of zinc oxide formed by the decomposition of zinc

Fig. 1 Schematic description of powder-premix



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stearate during the removal of the solid lubricant by heating in a sintering furnace, accumulates in low-temperature portions of the furnace. The rest of the zinc oxide is discharged into the air. For this reason, in a sintering furnace for mass production, it is necessary to remove buildups in the furnace by periodically stopping furnace operation, resulting in lowered productivity of the sintering process. Moreover, this zinc oxide can contaminate the surfaces of sintered compacts, lowering the quality of sintered parts.

To solve these problems, a wax-based powder of an organic compound not containing metallic elements is sometimes used as a solid lubricant. However, this method has not been widely adopted because the flowability of a mixture is less than when zinc stearate is used.

Thus, Kawasaki Steel developed "KIP Clean Mix KWAX," which provides the same flowability as conventional solid lubricants containing zinc stearate, but uses a wax-based lubricant instead. Also, the company developed "Cu-Segregation-free Clean Mix," which provides an improved segregation-preventing effect for copper powder, which segregates more readily than graphite powder. The company has already started marketing these products.

2 KIP Clean Mix KWAX

2.1 Flowability

In the production of sintered parts, the flowability of a raw material mixture is important for improving the production speed, the uniformity of density of sintered parts and the consistency of dimensional changes ascribed to this uniform density. As shown in schema B of Fig. 1, a segregation-free powder-premix is a mixture of multiple powders. It is known that especially the flowability of a mixture containing a wax-based lubricant is governed by the adhesive force among powders. This adhesive force is greatly influenced by liquid bridge force, electrostatic force and van der Waals force. On the basis of these findings, the company developed a new product called "KIP Clean Mix KWAX."

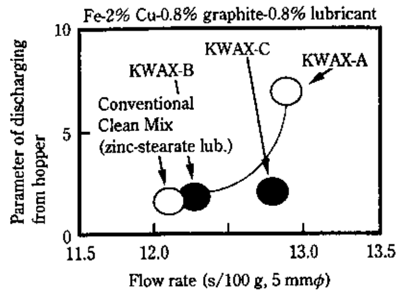

Fig. 2 Flowability of Clean Mix powders with wax lubricant

Figure 2 plots the flowability of KIP Clean Mix KWAX as flow rate and dischargeability from a hopper. The dischargeability from the hopper was evaluated by an index of flow blocking obtained until the segregation-free powder filling the test hopper was discharged from a 2.5 mm orifice provided in the bottom of the test hopper with a size of 100 mm × 100 mm × 100 mm. In the figure, KWAX-A is a conventional Clean Mix containing a wax-based lubricant. The new product, KWAX-B, has the same dischargeability from a hopper and flow rate as a conventional Clean Mix powder containing a zinc stearate lubricant. However, the new product unlike the conventional one, can prevent the sticking and accumulation of the lubricant inside the conveyor during the transfer by a screw conveyor. Another new product, KWAX-C, which does not contain any metallic element in the lubricant, has excellent dischargeability from hopper equal to that of the conventional Clean Mix powder containing zinc stearate.

2.2 Properties of Powders and Sintered Compacts

The properties of powders and sintered compacts of the new products are shown in **Table 1**. The new products KWAX-B and KWAX-C have apparent densities higher than that of the conventional Clean Mix containing a zinc stearate lubricant. The tensile strength and impact value of sintered compacts and their dimensional change during sintering are comparable to those of the

Table 1 Properties of powders and sintered compacts of Clean Mix powders with wax lubricant

Powders	Apparent density (Mg/m^3)	Tensile strength (MPa)	Impact value (J)	Dimensional change during sintering (vs. die cavity) (%)	Features
KWAX-C	3.25	434	10	0.40	With wax lubricant only
KWAX-B	3.39	430	11	0.38	Without luburicant sticking with wax lubricant
KWAX-A	3.20	422	10	0.40	Conventional Clean Mix with wax lubricant
Conventiomal Clean Mix	3.25	435	10	0.34	With zinc-stearate lubricant

Composition: Fe-2% Cu-0.8% graphite-0.8% lubricant
Specimen: $\phi 38 \times \phi 25 \times 10$ t
Green density: 6.85 Mg/m^3
Sintering conditions: 1 130 °C × 20 min in endothermic gas

Table 2 Properties of powders and sintered compacts of the Cu segregation-free Clean Mix powder

Powders	Apparent density (Mg/m³)	Tensile strength (MPa)	Impact value (J)	Dimensional change during sintering (vs. die cavity)	
				Dimensional change (%)	Standard deviation, σ (%)
Cu segeragation-free Clean Mix	3.35	467	11	0.39	0.016
Conventional Clean Mix	3.35	469	11	0.38	0.020

Composition: Fe-2% Cu-0.8% graphite-0.8% lubricant
Specimen: $\phi 38 \times \phi 25 \times 10$ t
Green density: 6.85 Mg/m³
Sintering conditions: 1 130 °C × 20 min in endothermic gas

conventional product. Moreover, in KWAX-C, the variation in the weight of green compact during continuous pressing is reduced by as much as 60% or more of that of KWAX-A in terms of standard deviation. Thus, the productivity and quality of sintered parts can be significantly improved by using these new products.

3 Cu-Segregation-free Clean Mix

3.1 Prevention of Cu Segregation

As shown in schema C of Fig. 1, in a particle of the new Cu-segregation-free Clean Mix, copper powder is adhered to the surface of an iron powder particle by thermal diffusion and it is possible to obtain a segregation-preventing effect higher than with the conventional adhesion by a binder. **Figure 3** shows the scattering of the copper content in compacts when 1 t of segregation-free powder of Fe-2Cu-0.8C is transported by a screw conveyor. In the new Cu-segregation-free Clean Mix powder, the standard variation of analytical values of copper is reduced 70%, from 0.080% to 0.024%, compared to the conventional segregation-free powder.

3.2 Properties of Powders and Sintered Compacts

As shown in **Table 2**, the properties of powders and sintered compacts of the new product, such as apparent density, tensile strength and impact value, are comparable to those of the conventional powder. Moreover, the dimensional change of the new product is equal to that of the conventional segregation-free powder, but the variation in dimensional change is reduced 20% from 0.02% to 0.016% compared to the conventional segregation-free powder. Thus, the variation in dimensional change can be substantially reduced without a change in the material characteristics by using the new product.

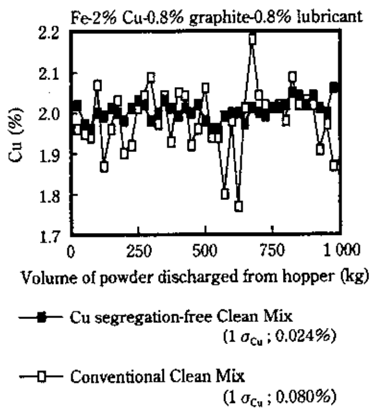

Fig. 3 Scattering of Cu content in compacts made from the powders discharged from a hopper

4 Concluding Remarks

KIP Clean Mix is a highly-acclaimed product that can meet high-level requirements for consistency in quality variations, such as composition, dimensional change and product weight; improvements in productivity, such as pressing speed and maintenance of sintering furnaces; improvements in the environment; and basic properties required of future PM automobile parts.

At Kawasaki Steel, the capacity of the Clean Mix production facilities was expanded in 1999 to meet future technological and quantitative demands of customers.

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