New Products & Technologies

Calcined Hard Ferrite Powder*

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1 Introduction

Ferrite magnets are more economical and more widely used than any other type of permanent magnets. Kawasaki Steel has shipped high-quality calcined hard ferrite powders under the trademarks **KF-SR** (strontium ferrite) and **KF-BA** (barium ferrite) to many magnet manufacturers in Japan and abroad, and these products have earned a high reputation.

These calcined powders have the following features:

(1) Diverse quality requirements of users can be met.
(2) High-performance (high Br and high $_{I}Hc$) ferrite is available.
(3) Quality is stable.

2 Manufacturing Process of Calcined Powders

An outline of the calcined powder manufacturing process is given in **Fig. 1** and the appearance of a rotary kiln is shown in **Photo 1**.

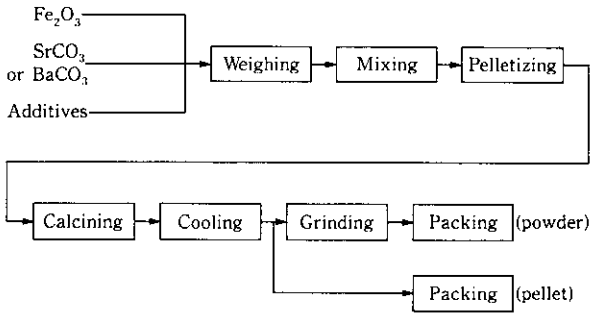

Fig. 1 Manufacturing process of calcined powder

This process has the following features:

(1) This process is direct-coupled with the production equipment (hydrochloric acid recovery plant) of iron

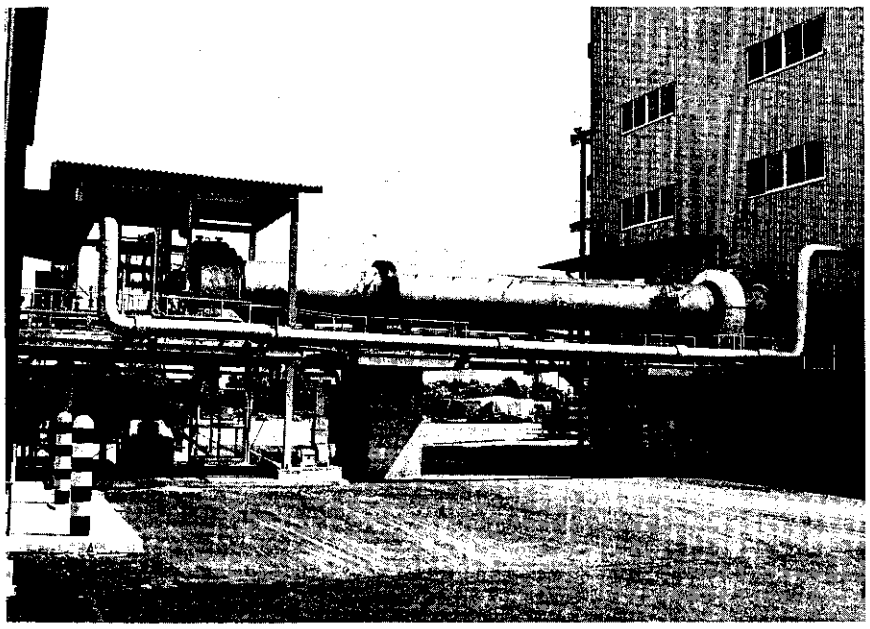

Photo 1 Rotary kiln for calcining

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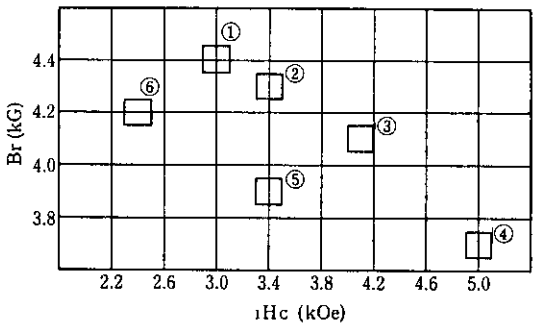
Table 1 Properties of hematite

Components								Powder properties	
Fe_2O_3 (%)	Cl (%)	SO_4 (%)	SiO_2 (ppm)	Mn (ppm)	Ca (ppm)	Na (ppm)	K (ppm)	Mean dia. (μm)	Compressed density (g/cm³)
99.2～99.3	≦0.10	≦0.10	≦200	≦3000	≦350	≦100	≦15	0.8～1.0	2.7～2.9

Table 2 Properties of KF-SR and KF-BA

Brand \ Properties of magnet			Sh-D (%)	Br (kG)	$_BHc$ (kOe)	$_IHc$ (kOe)	$(BH)_{max}$ (MGOe)
①KF-SR	Wet press, anisotropic	Standard	13.4	4.3	3.3	3.4	4.3
②KF-SR		High Br	13.9	4.4	2.9	3.0	4.5
③KF-SR		High $_IHc$	12.8	3.7	3.6	5.0	3.3
④KF-SR		High Br and $_IHc$	13.0	4.1	3.8	4.1	4.0
⑤KF-SR	Dry press, anisotropic	Standard	14.9	3.9	3.3	3.4	3.4
⑥KF-BA	Wet press, anisotropic	Standard	11.8	4.2	2.3	2.4	4.0



① KF-SR－High Br products (Wet press, anisotropic)
② KF-SR－Standard products (Wet press, anisotropic)
③ KF-SR－High Br and $_IHc$ products (Wet press, anisotropic)
④ KF-SR－High $_IHc$ products (Wet press, anisotropic)
⑤ KF-SR－Standard products (Dry press, anisotropic)
⑥ KF-BA－Standard products (Wet press, anisotropic)

Fig. 2 Properties of magnets

oxide, which is the main raw material for calcined powder, and the quality of iron oxide and calcined powder integrally controlled. This enables the production of iron oxide with properties suitable for the required calcined powder. Quality characteristics of the iron oxide raw material are shown in **Table 1**.

(2) High-accuracy equipment is used in each process to obtain stable quality. For example, a high-accuracy automatic weighing system is installed in the weighing process, contributing to stable mol ratio (Fe_2O_3/SrO) of calcined powder. In addition, a vibrating mill is adapted in the mixing process to ensure sufficient mixing.

(3) The whole production system is automated and is controlled by only one operator.

3 Features of Products

The representative quality characteristics of KF-SR and KF-BA are shown in **Table 2**. The properties required for magnets, including control ranges, are shown in **Fig. 2**.

High-performance magnet, which meet the rigid specifications for automotive starter motors, provide the excellent characteristics of Br 4100 G and $_IHc$ 4100 Oe.

The production of powder for high-performance magnet has been made possible by Kawasaki Steel's vigorous development efforts and is the result of improved techniques ranging from the raw material preparation process up to the sintering process. The greatest merit, however, is that high $_IHc$ can be easily obtained by optimizing the raw material, weighing and calcining conditions.

4 Technical Evaluation of Calcined Powders

Calcined powder is formed into magnets at magnet makers by the process shown in **Fig. 3**.

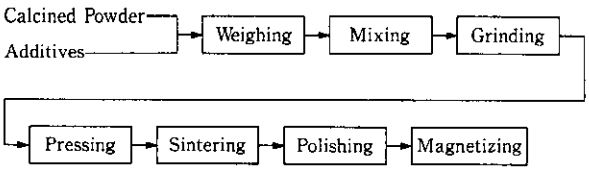


Fig. 3 Manufacturing process of magnet

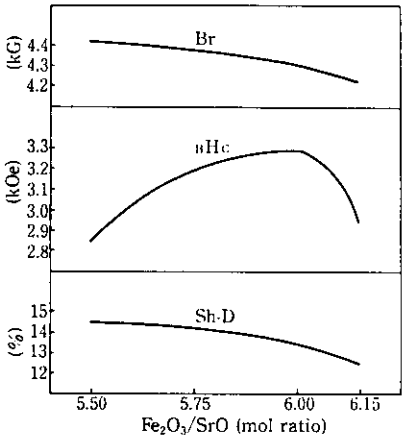


Fig. 4 Effects of molar ratio on Br, $_BH_C$ and Sh-D

In recent years, quality requirements for ferrite magnets have become increasingly rigid and diversified. To respond to these requirements, calcined powder makers have had to evaluated their calcined powders as the magnet makers do. For this purpose, Kawasaki Steel has installed ultramodern testing equipment, test plants and possesses techniques for conducting magnet-making tests and inspections.

Design factors which affect magnet quality include the mol ratio (Fe_2O_3/SrO), calcining conditions, additives, atomizing conditions, pressing conditions, and sintering conditions. In quality design, a shrinkage ratio suited to the molds of the user is first determined by combining the above-mentioned factors after which the properties of the magnet are studied. Various relationships among the mol ratio, additives, and principal characteristics are shown in **Figs. 4, 5** and **6**.

In addition to these principal characteristics, atomizing capability, density, and size of calcined powder are also important and Kawasaki Steel has possesses control techniques for these items also.

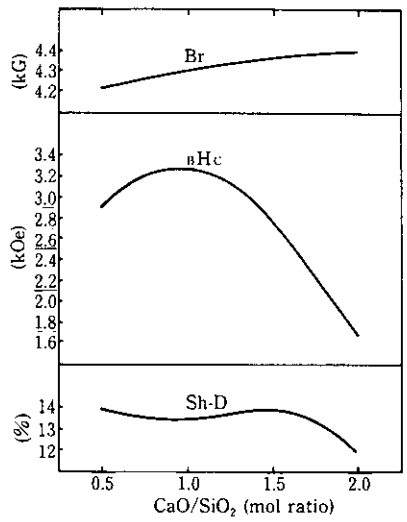


Fig. 5 Effects of additives on Br, $_BH_C$ and Sh-D

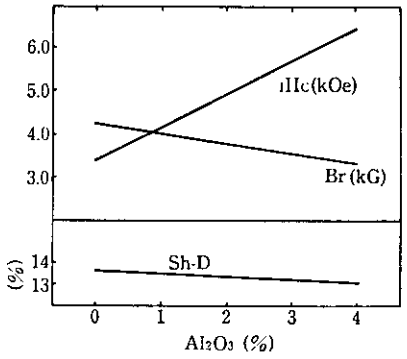


Fig. 6 Effects of additives on Br, $_IH_C$ and Sh-D

5 Concluding Remarks

The calcined hard ferrite powders KF-SR and KF-BA produced by Kawasaki Steel are high-quality products which meet the high performance standards adopted by users. The authors intend to continually improve quality in the years ahead.