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New Products & Technologies

New Grain-Oriented Electrical Steels for Transformer Cores with Extremely Low Iron Losses*

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1 Introduction

The production of grain-oriented silicon electrical steels, which are used mainly as the materials for transformer cores, is increasing with the increase in demand for electrical power supply. An improvement is sought for iron loss in electrical steels used to make the iron cores of electrical equipment, especially the transformers used for power transmission.

Kawasaki Steel has developed new grain-oriented electrical steels that have extremely low iron loss rates when used as the core material of transformers. They combined technologies with (1) a new component system and the development of a production process suitable for this system[1-3], (2) a new domain refining process[4-6] applicable to both materials used for wound-core transformers and for stack-core ones, and (3) the development of equipment able to run these technologies.

This report expresses the characteristics of recently developed grain-oriented electrical steels having extremely low iron losses and examples of how to apply them to transformers.

2 Concepts of the Development

As iron loss in electrical steels consists of hysteresis loss and eddy current loss, both kinds of losses need to be reduced independently. This was achieved by applying the following two concepts.

(1) Decrease in hysteresis loss by applying a high alignment technique to the grain orientation of the materials with thinner gauges

(2) Decrease in eddy current loss by applying a heat-proof domain refining technique to the materials with thinner gauges

3 Distinctive Features of New Products

(1) 23RGH090N

The technique of high orientation alignment was applied to the thinner gauge materials, for which high induction and extremely low losses are characteristic. These materials can be used for both stacked-core transformers and wound-core ones, especially since they have excellent magnetic properties in the higher fields. Moreover, their good magnetostrictive properties are particularly suitable for meeting the strong demand in reducing transformer noise.

(2) 23RGHPD085N, 27RGHPD090N

These products were developed by applying a heat-proof domain refining technique[4-6] to the above materials. During this process, grooves are formed a certain distance apart on the steel surface through electrolytic etching after final cold rolling, reducing the eddy current loss remarkably through the demagnetizing effect of the grooves. These materials can be used for both stacked-core transformers and wound-core ones. They have fewer high harmonic magnetostrictive components than the materials irradiated by the plasma jet flame[7,8], thus are suitable to be used as transformer materials with low loss and low noise rates. Especially the 27RGHPD090N has an extremely low loss rate in the materials with this gauge. It has therefore the advantage of improving the efficiency of the stacking process.

4 Characteristics of New Products

The typical magnetic values of the new products are shown in **Table 1**, and **Fig. 1** compares the iron loss curves of the new products to the conventional low loss material of Kawasaki Steel (conventional one: RGH). The iron loss of each new product is extremely low, and the $W_{17/50}$ of 23RGHPD085N especially is reduced by almost 25%.

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Table 1 Typical magnetic properties of new materials and conventional one

Material	Grade	Iron loss (W/kg)						Induction
		$W_{13/50}$	$W_{15/50}$	$W_{17/50}$	$W_{13/60}$	$W_{15/60}$	$W_{17/60}$	B_8(T)
New RGH	23RGH090N	0.43	0.63	0.86	0.62	0.82	1.13	1.93
	23RGHPD085N	0.42	0.57	0.77	0.56	0.75	1.00	1.89
	27RGHPD090N	0.45	0.61	0.84	0.60	0.81	1.11	1.89
RGH[1)]	30RGH105	0.56	0.75	1.03	0.85	0.99	1.37	1.89

[1)]Conventional material with high permeability

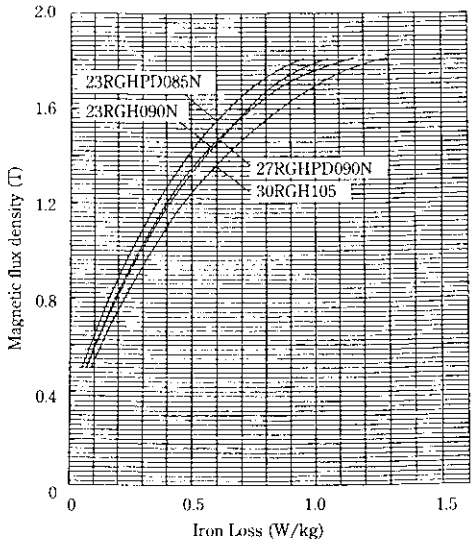


Fig. 1 Iron loss curves of new materials comparing with conventional one, measured at 50 Hz

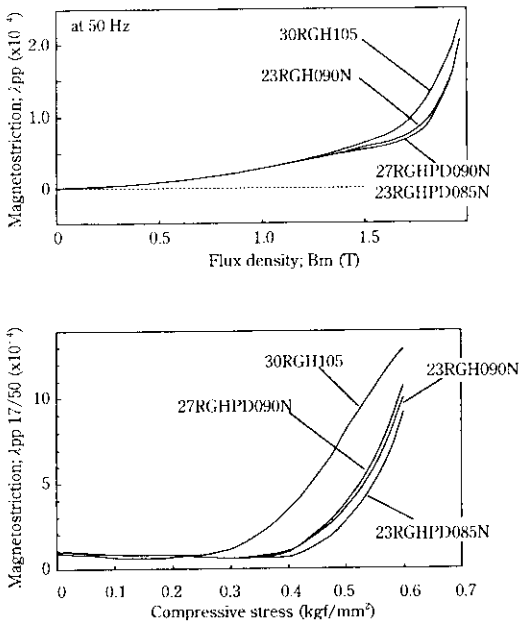
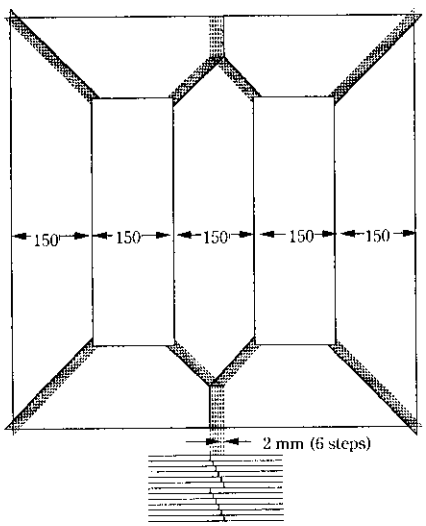


Fig. 2 Magnetostriction curves of new materials comparing with conventional one, measured at 50 Hz

Figure 2 shows the magnetostrictive properties of the new products in comparison with the conventional one. The magnetostrictive properties of the new products both to flux density and to compressive stress are considerably improved. This is a great advantage in reducing the noise of transformers.

5 Ways of Applying to Transformers

The examples show how these materals have been



Joint geometry	Step lap
Lap width	2 mm × 5
Number of sheets /Unit lap	2
Sheet thickness, Number of stacked sheets	0.23 mm × 144 0.27 mm × 120 0.30 mm × 108
Core weight	ca. 100 kg

Fig. 3 The configuration of a 3-phase stacked-core model transformer

applied to stack-core transformers and wound-core ones. The new products have been tested using the model stack-core transformer with iron core structures for step laps as shown in **Fig. 3**. These results are shown in **Table 2**. Moreover, the new products have been tested in wound-core transformers with a capacity of 20 kVA and with step lap structures. These results are shown in **Table 3**. **Figure 4** compares the iron loss rates of these transformers with the new products and the conventional one. The iron loss rates for both the stack-core transformer and the wound-core transformer were improved by 15 to 25% by using these new products in comparison with using the conventional one. This is a reasonable result in improvement for the iron loss rates of the new materials.

Moreover, **Table 4** shows the results of using the new product (27RGHPD090N) and a conventional one (27RGH100) in a stack-core transformer at 110 MVA

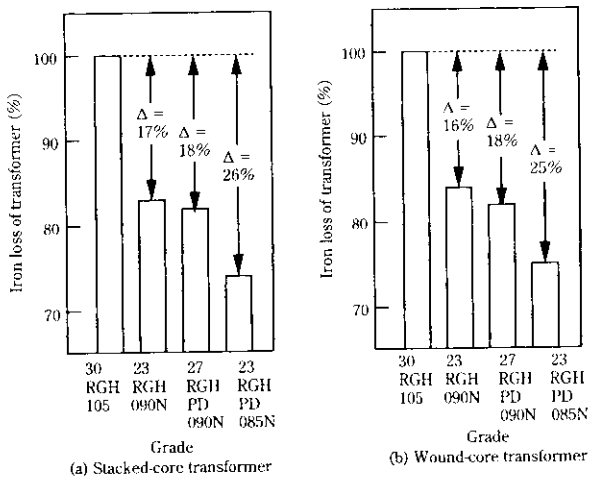


Fig. 4 Loss reduction rate of model transformers using new materials comparing with conventional one

Table 2 Magnetic properties of stacked-core model transformers

Material	Grade	Magnetic properties of materials		Magnetic properties of model transformer cores			
		B_8 (T)	$W_{17/50}$ (W/kg)	$W_{17/50}$ (W/kg)	$I_{\sigma 17/50}$ (A)	$Noise_{17/50}$ (dB)	BF[2]
New RGH	23RGH090N	1.93	0.86	1.01	0.74	52	1.17
	23RGHPD085N	1.89	0.77	0.90	0.75	52	1.17
	27RGHPD090N	1.89	0.84	0.99	0.85	53	1.18
RGH[1]	30RGH105N	1.89	1.03	1.21	0.85	56	1.17

[1]Conventional material with high permeability
[2]BF: Iron loss of transformer core/Iron loss of material

Table 3 Magnetic properties of wound-core model transformers

Material	Grade	Magnetic properties of materials		Magnetic properties of model transformer cores	
		B_8 (T)	$W_{17/50}$ (W/kg)	$W_{17/50}$ (W/kg)	BF[2]
New RGH	23RGH090N	1.93	0.86	0.87	1.01
	23RGHPD085N	1.89	0.77	0.78	1.01
	27RGHPD090N	1.89	0.84	0.85	1.01
RGH[1]	30RGH105	1.89	1.03	1.04	1.01

[1]Conventional material with high permeability
[2]BF: Iron loss of transformer core/Iron loss of material

Table 4 Magnetic properties of 3 phase-3 limb stacked-core transformers (step lap, V notch, designed flux density: 1.78 T)

Material	Grade	Magnetic properties of materials		Magnetic properties of transformers (no load, at 50 Hz)			
		B_8 (T)	$W_{17/50}$ (W/kg)	Excitation (%)	Loss (kW)	I_0 (%)	Noise (dB)
New RGH	27RGHPD090N	1.90	0.86	90	42.8	0.05	61
				100	58.9	0.12	72
				110	95.9	0.78	—
RGH[1]	27RGH100	1.90	0.97	90	47.5	0.06	64
				100	70.3	0.14	74
				110	107.4	0.89	—

[1]Conventional material with high permeability

which also shows that the iron loss rate of the transformer has been remarkably improved by using this new product.

6 Conclusion

The newly developed materials, 23RGH090N, 23RGHPD085N and 27RGHPD090N, had their magnetic properties presented and the ways they can be applied to tranceformers. By using these materials, large energy saving can be expected for transformers with their iron loss.

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