Abstract:

JFE Steel has been seeking for low iron loss technologies of grain oriented electrical steels since starting the production of grain oriented electrical steels in 1959. A low iron loss grain oriented electrical steel "JGSD™" was developed in 1994, and then a low iron loss grain oriented electrical steel for stacked core transformers "JGSE™" has been recently developed. These materials are making a substantial contribution to global society through energy conservation of transformers.

1. Introduction

Grain-oriented electrical steel is used mainly as a core material for transformers, and its iron loss properties have a large effect on transformer energy efficiency. Therefore, JFE Steel has vigorously promoted technical development of low iron loss technologies for grain oriented electrical steel.

This paper describes the history of development of grain-oriented electrical steel at JFE Steel and the company's product line-up. The level of magnetic properties achieved in recent highest grade products is also introduced, together with the characteristics of transformers using those products.

2. History of Development of Grain-Oriented Electrical Steel

2.1 Needs of Times for Energy Saving

The rise in social needs for energy saving in transformers begins with the 1st Oil Crisis in 1973. More recently, strict regulations have been applied to transformers from the viewpoint of preventing global climate change; these include the Top Runner Program in Japan, the Department of Energy (DOE) regulations in the United States and the Ecodesign Directive in Europe.

In Japan's Law Concerning the Rational Use of Energy, equipment in which improvement of energy consumption efficiency is deemed necessary is designated as "specified equipment." The "target fiscal year," which is the fiscal year when regulations take effect, and "energy consumption efficiency," which is the standard value to be achieved, are provided in "criteria, etc. for judgment of improvement of performance of specified equipment by manufacturers and others," and manufacturers and importers of the specified equipment concerned are obligated to make efforts to achieve those standards. In the "1st judgment standard," which was announced in December 2002, oil-filled transformers were subject to regulations from fiscal year (FY) 2006 and molded transformers were subject to regulations from FY 2007. Under these regulations, transformers conforming to the "1st judgment standard" (Top Runner transformers) realized an energy saving of 32.8% in "energy consumption efficiency (in case of transformers, total iron loss; unit: W (watt)) " in comparison with the former products. Low iron loss in grain oriented electrical steel is indispensable for achieving high efficiency in transformers, and improvement of grain oriented electrical steel made a large contribution to the Top Runner transformers. Following the "1st judgment standard," further increases in the efficiency of iron cores and winding materials and improvement of processing tech-

nologies were studied, and in March 2012, the “2nd judgment standard” was announced. The total iron loss of transformers conforming to the “2nd Judgment Standard” (Top Runner transformers 2014) achieved a 12.5% improvement in comparison with transformers conforming to the “1st Judgment Standard” and an improvement of 39.4% in comparison with the former products manufactured before the “1st Judgment Standard,” which account for the majority of transformers currently in operation. This has made an important contribution to both protection of the global environment and energy conservation. Grain oriented electrical steel with further improved performance was also used in Top Runner transformers 2014, contributing to energy conservation and suppression of increased external size and mass of the equipment.

Introduction of Top Runner transformers has had an extremely large effect in reducing CO_2. As of the end of FY 2012, cumulative shipments of Top Runner transformers by transformer companies belonging to the Japan Electrical Manufacturers’ Association (JEMA) were 535 thousands units with a total capacity of 116 GVA. The effect of reduced energy consumption on the environment calculated from these actual shipment results is 1 800 million kilowatt hours per year, and the CO_2 reduction effect reaches 1 mi

Eddy current loss (W_e) is Joule heat which is caused by the eddy currents generated in a steel sheet by the action of electromagnetic induction when the steel sheet is magnetized by an alternating current.

Classical eddy current loss (W_{ce}) is the eddy current loss when the magnetization in a wh ɵ Min ġ ɪ t0 i Nen heron et ٦ þ 0 abyusalntur ican by an

iron loss grain oriented electrical steels with excellent iron loss characteristics for use in stacked core type transformers.

It should be noted that only representative products are shown in Fig. 5. Designations such as “35JG135” indicate the sheet thickness, grade and guaranteed value of iron loss ($W_{17/50}$). For example, in the case of “35JG135,” “35” indicates the sheet thickness, “JG” indicates the grade and “135” indicates the guaranteed value of iron loss ($W_{17/50}$).