DEVELOPMENT OF SEMI-PROCESSED STEELS FOR ELECTRICAL LAMINATION APPLICATIONS AT TATA STEEL

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ABSTRACT

Semi processed electrical steels are important materials in a verity of electrical machines. They offer better magnetization than equivalent fully processed grades and are subjected to decarburisation annealing treatment at customers' end for developing final magnetic properties. This paper reports the results of the Silicon free as well as silicon bearing semi-processed grades of cold rolled non-oriented (CRNO) steels developed at Tata Steel for electrical lamination applications. Both the grades were processed through LD steel making, secondary steel making (LF/RH), continuous casting, hot rolling, cold rolling, batch annealing followed by skin pass/temper rolling.

INTRODUCTION

Electrical steel sheets are essential components in electrical equipments [1-4]. Based on texture, electrical steels are categorized into two types namely (i) Cold rolled non oriented electrical steel (CRNO) (ii) Cold rolled grain oriented electrical steel (CRGO). Cold rolled non-oriented steel grades are mainly used for the cores of rotating machines and are processed to develope a random texture unlike the cold rolled grain oriented variety which possesses a strong Goss texture and exclusively used for transformer cores. CRNO electrical steels are supplied in (i) Fully Processed or Semi processed conditions. In case of fully processed material, final magnetic properties are achieved through annealing at the suppliers / steel producers' end and can be readily used by the equipment manufacturer. Varnish or special coatings are often applied on these grades for enhancing magnetic properties. In contrast, semi processed electrical steels are finished to the final thickness by the steel producer/supplier and final magnetic properties in the punched lamination are achieved through decarburisation annealing/stress relief annealing at the customers' end. Semi processed coils are generally temper rolled/skin passed after cold rolling and annealing to improve punchability, facilitate strain induced grain growth during decarburisation annealing. Decarb-annealing treatment of the laminations lowers carbon content, increases grain size and also eliminates the residual punching stress thereby eliminating all the deleterious factors affecting magnetic properties [5]. It may be noted that ultra low carbon (~30 ppm) based semi-processed steels may not require this treatment; a simple grain growth annealing may suffice to develop the final magnetic properties in the laminations. The aim of the present work is to study the effect of chemical composition on the final magnetic properties of the semi-processed electrical steels produced at Tata Steel.

EXPERIMENTS

Commercial heat making and rolling

Two heats of low carbon Si-free steel were commercially processed through LD-RH-LF. The continuously cast slabs were hot rolled to 2.3 mm thickness strips, cold rolled to 0.5 mm sheets, annealed in batch annealing furnaces and were subsequently given ~ 2 % deformation at skin pass mill. One commercial heat of silicon bearing electrical steel was processed in a similar way. The chemical composition of the steel is shown in Table 1. The hot rolled strips thickness were cold rolled to 0.5 mm thickness, annealed in batch annealing furnace and temper rolled (7% deformation in two passes).

Table 1 : Chemical composition of the steels under present investigation

Sl. No.	Grade	C	Mn	Si	P	S	Al
1	Si-Free- 1	0.020	0.35	0.21	0.012	0.013	0.002
2	Si-Free-2	0.025	0.35	0.31	0.088	0.005	0.003
3	Si-bearing	0.010	0.31	0.48	0.074	0.008	0.30

Laboratory decarb-annealing

Decarb annealing experiments of skin passed/ temper rolled samples was carried out in a controlled atmosphere (N2-8%H_2) muffle furnace. Too high a temperature leads to the sticking of the laminations while a low temperature is undesirable for slow grain growth and decarburisation kinetics [6]. Thus the temperature was maintained at 780°C with about an hour of holding. Bluing operation was also performed during cooling at 450°C for about half an hour.

Characterization

Epstein test specimens (300 x 30 x 0.5 mm) were prepared from the samples of each grade for the testing of the magnetic properties using an AMH-20 Magnetic Hystersis graph generator. Magnetic properties (specific core loss and permeability at 1.5T, 50Hz) were determined before and after decarb-annealing treatments. Residual carbon content after decarb-annealing was determined by optical emission spectroscopy. Grain sizes of the samples before and after decarb-annealing experiments were observed under optical microscope.

RESULTS AND DISCUSSION

The magnetic properties obtained before and after decarb-annealing treatments for each grade along with the residual carbon content and grain size observed under each condition are presented in Table 2. The silicon bearing grade, in spite of having higher amount of temper rolling deformation, is observed to have a lower specific core loss value as compared to the silicon free grades before decarb-annealing treatment. This is clearly due to the favorable effect of silicon and aluminum in decreasing the core loss value. The effect of these alloying elements on the magnetic properties of the electrical steels has been studied quite extensively [7-9]. These alloying additions have been shown to increase the resistivity of the steel thereby reducing the eddy component of the total core loss value. The silicon free steel containing higher amount of phosphorus displays a lower specific core loss value than the other variety. This is also due to the beneficial effect of phosphorus in increasing the resistivity. Thus it seems that the chemical composition of the steel has a great effect on the specific core loss value obtained.

Table 2 : Magnetic Properties, grain size and carbon content before and after laboratory decarb-annealing treatment

Grade	Skin pass/ temper rolled condition				Decarb-annealed condition			
	Sp Core loss, W/kg*	Perm., G/Oe*	C, Wt. %	Grain size µm	Sp Core loss, W/kg*	Perm., G/Oe*	C, Wt. %	Grain size µm
Si-Free-1	14	729	0.020	30-40	5.6	1902	0.0023	170-180
Si-Free-2	12	750	0.025	30-40	5.0	1750	0.0020	160-170
Si-bearing	10	712	0.010	10-30	3.9	1500	0.0020	150-160

Magnetic properties reported here are at 1.5 T & 50 Hz.

The specific core loss values after decarb-annealing treatment for each of these grades decreases markedly to a very low value from that obtained before decarb-annealing. The beneficial effect of the alloy content is also reflected in the specific core loss values obtained after decarb-annealing. The silicon bearing grade showed a specific core loss of 3.9 W/kg as compared to the silicon free steels with phosphorus recording 5 W/kg while the silicon free steel with lower amount of phosphorus displays 5.6 W/kg. Decarb-annealing treatment coarsens the grain size and lowers the carbon content as shown in Table 2. A typical microstructure after decarb-annealing is presented in Figure 1. Coarsening of grain size and lowering of carbon content are beneficial for the easy magnetization thereby reducing the specific core loss and increasing the permeability values [10]. Thus decarb-annealing treatment of the semi-processed electrical steels can yield superior magnetic properties depending on the chemical composition of the steel.

CONCLUSIONS

1. Decarb-annealing of semi-processed electrical steels results in superior magnetic properties.
2. Increasing phosphorus content lowers the specific core loss in silicon free steels.
3. Silicon bearing steels display lower specific core loss (3.9 W/kg) than the silicon free steels both before and after decarb-annealing treatment.

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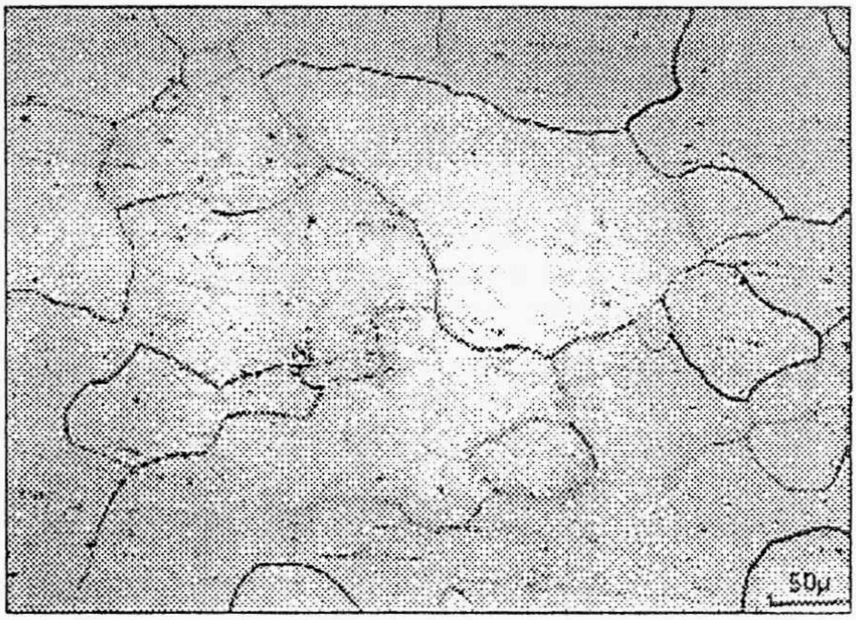

Fig. 1: A typical microstructure of silicon free steel after decarb annealing treatment

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