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The application of the vacuum degassing technique in steel plant in order to obtain new quality grades in non-oriented magnetic steel sheet

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In the light of the author's more recent publications and previous research work, this paper seeks to review the progress made in the iron and steel manufacturing processes, and the new quality grades obtained in the field of non-oriented magnetic steel sheet as a consequence of eliminating impurities by applying the modern technique of vacuum degassing in steel plant.

1. Introduction

It is a well-known fact that the growing increase in costs, especially since 1974, has led to energy saving becoming a particularly important factor. In order to save energy, it has become necessary to bring conventional iron and steel manufacturing processes up-to-date by incorporating new techniques. One of the more preferable techniques is that of vacuum degassing in steel plant. The application of this technique has resulted in higher quality grades of non-oriented magnetic steel sheet.

2. Physical–metallurgical principles

It is of common knowledge that the presence of impurities in solid solution, such as C, O, N and S, together with their precipitates, gives rise to significant stress and irregularities in the crystal lattice which disturb the movement of the Bloch wall[1–5] and thereby render magnetic reversal more difficult. They also cause an increase in the level of losses[6–10]. At the same time, the presence of impurities implies a magnetic dilution of the material with a subsequent decrease in the saturation induction value and permeability, as a result of local demagnetization.

Figure 1 shows the influence that these impurities have on the values of the core losses and coercive force.

It should also be pointed out that the greater or lesser incidence of these impurities, both with regard to core losses as well as to magnetic aging, does not only refer to the quantitative aspect, but is also closely linked to the morphology and distribution of the precipitates[11–13].

Therefore, eliminating these impurities by means of modern vacuum degassing techniques in steel plant[14,15] to levels of: C—0.01–0.02%; O—0.001–0.003%; N<0.003%, respectively, not only allows the negative effects of these impurities on the magnetic properties to be minimized, but also allows the process to be optimized, thereby at the same time obtaining new quality grades.

3. Results obtained by applying this technique. New quality grades

3.1. Decarburized electrical steel sheet for electrical applications. Decarburizing of this kind of material is traditionally carried out at the decarburizing annealing stage of the process using continuous or open-coil decarburizing annealing installations. By means of the former, and due to the lack of silicon, decarburizing is very slow and there is a simultaneous production of a columnar grain structure[16,17] which gives rise to negative magnetic characteristics. On the other hand, the open-coil annealing process[18,19], prevents this kind of columnar grain structure from forming, although it implies the use of very long annealing cycles.

These problems may be avoided by the use of the vacuum degassing technique[20] which allows a final, high-productivity, non-decarburizing annealing process to be carried out on the material (760–815°, HNX, 2 min), obtaining magnetic characteristics (W^{15}_{50}=10.4 W/kg, μ^{15}_{P50}=1560 Gauss/Oe) similar to the results obtained by applying the conventional process[21,22], but at a considerably lower cost.

3.2. Non-oriented grain magnetic steel sheet. By incorporating these vacuum techniques into the manufacturing process of these materials it is possible to minimize the effects of the impurities on the magnetic properties, and at the same time:

(a) to reduce the rate of decarburizing during the continuous annealing process, thereby achieving higher productivity on the line, and allowing the partial elimination of the sublayer of oxide, responsible for high core losses; this sublayer is generated in the gas-metal interphase[23,24] during the above mentioned process;

(b) to favour adequate grain growth (ASTM 3–5) by means of eliminating the process which would normally prevent such growth[25,26].

3.3. Texturized, non-oriented grain magnetic steel sheet. As a result of using these techniques and the subsequent elimination of

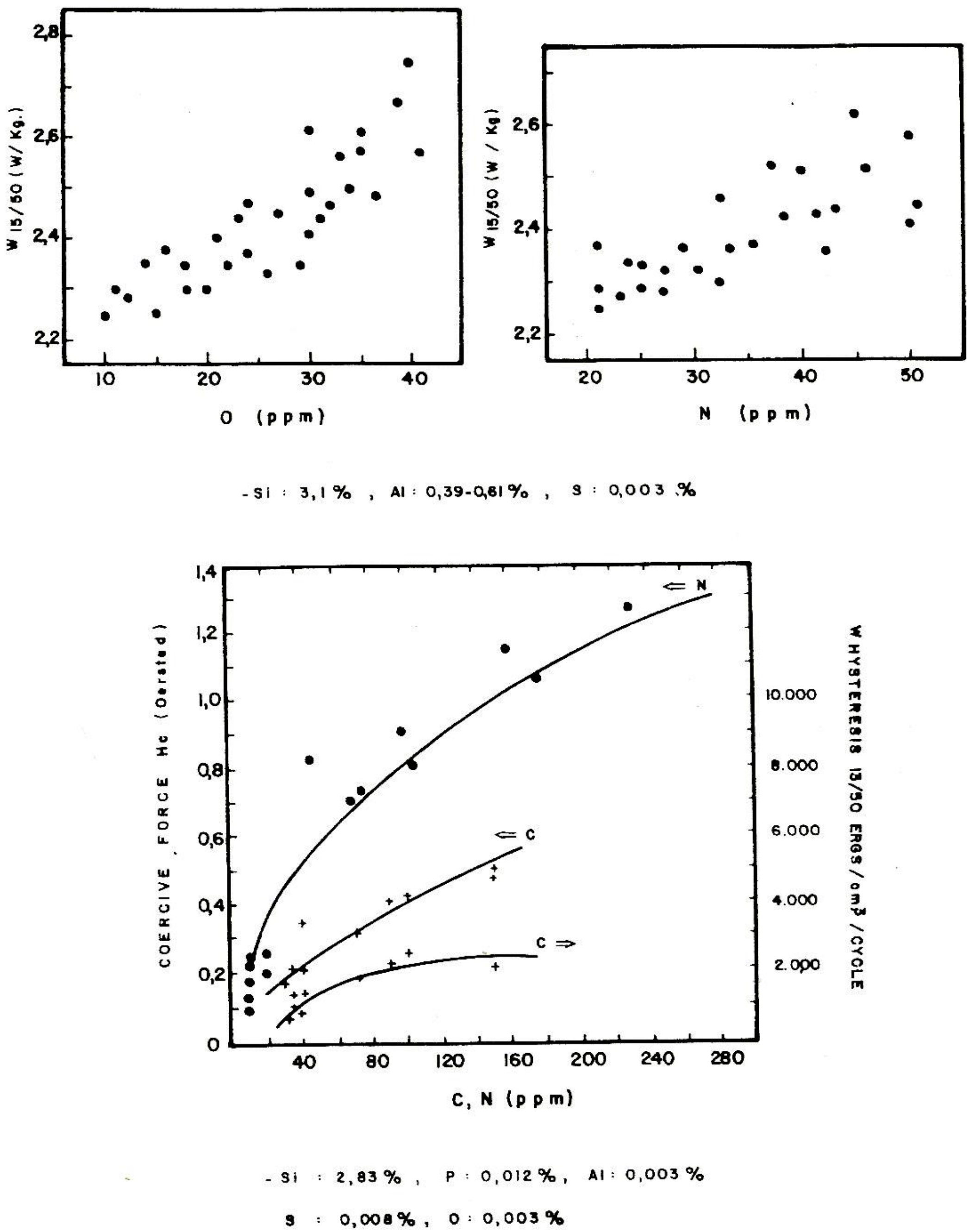

Figure 1. Effect of impurities on core losses and coercive force (refs 9 and 10).

Table 1. Magnetic characteristics of texturized, non-oriented grain magnetic steel sheet (ref 10)

Quality	Thickness	W_{50} (W/kg)		B(T)			
		10000	15000	B_{10}	B_{25}	B_{50}	B_{100}
Fully-processed	0.5	1.10	2.45	1.49	1.60	1.70	1.81
Semi-processed	0.5		2.59			1.74	

impurities up to the previously mentioned limits, the material may be provided with certain textures by using the appropriate posterior siderurgical process, {100} ⟨u v w⟩ {110} ⟨u′ v′ w′⟩ thereby producing fully- or semi-processed texturized, non-oriented grain magnetic steel sheet. This process constitutes a real technological breakthrough in the field of rotary motors, both with regard to the magnetic characteristics and the resulting industrial applications.

The magnetic characteristics are represented by the values shown in Table 1.

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