DEVELOPMENT OF NON-GRAIN ORIENTED SILICON STEEL GRADE M310-50K WITH HIGH PERMEABILITY AND LOW ENERGY LOSS

ABSTRACT
The development of motor engines with improved efficiency is driving the adoption of non-oriented steel grades with lower power loss and high permeability. In this frame NGO grades M310-50K and M920-50K are increasingly requested by the market. The current work presents the development of the semi-processed grade M310-50K, based on a 2.0 wt% Si non-oriented electrical steel, at Marcegaglia Carbon Steel through the optimization of the microstructural characteristics of final product by means of the thermo-mechanical processing (TMP) conditions and the following cold rolling, annealing cycle and skin-pass processes. Microstructure and ODF analysis were carried out on hot rolled sample, cold rolled and annealed and after final decarburization and secondary recrystallization annealing. The results confirmed that to develop the favorable texture and achieve the target magnetic properties a thorough understanding of texture evolution along the manifold processing steps is required. The current contribution presents the results of the M310-50K product development carried out by means of optimization of the texture evolution through the selection of the best hot and cold rolling processing parameters. Microstructure and texture evolution was characterized by means of optical microscopy and XRD analysis on hot rolled sample, after cold rolling and batch annealing till to the laboratory decarburization and secondary recrystallization treatment. Tailoring the texture of the final product requires an optimized processing strategy, which involves a thorough understanding of texture evolution along the manifold processing steps. The ideal texture of a soft iron core for motor engines is the one that maximizes the density of <100> crystal directions in the plane of the sheet. Therefore, for rolling in addition to the well-known Goss component (110)[001], the orientations of the cube fibre for which the (001) planes are parallel to the rolling plane are also desired (Fig. 6).

MATERIALS AND METHODS
The chemical compositions used for the industrial production of NGO electrical steels grade M310-50K is reported in the following Table 1. In Fig. 1 is reported the phase diagram of the steel tested. As can be noted there is no reverse phase transformation during the hot rolling temperature range.

<table>
<thead>
<tr>
<th>C</th>
<th>Si</th>
<th>Mn</th>
<th>Al</th>
<th>P</th>
<th>S</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.005</td>
<td>0.4</td>
<td>0.5</td>
<td>0.013</td>
<td>&lt;0.01</td>
<td>&lt;0.005</td>
<td></td>
</tr>
</tbody>
</table>

Table 1: Steel chemical composition (wt%)

Tailoring the texture of the final product requires an optimized processing strategy, which involves a thorough understanding of texture evolution along the manifold processing steps. The current contribution presents the results of the M310-50K product development carried out by means of optimization of the texture evolution through the selection of the best hot and cold rolling processing parameters. Microstructure and texture evolution was characterized by means of optical microscopy and XRD analysis on hot rolled sample, after cold rolling and batch annealing till to the laboratory decarburization and secondary recrystallization treatment. Tailoring the texture of the final product requires an optimized processing strategy, which involves a thorough understanding of texture evolution along the manifold processing steps. The ideal texture of a soft iron core for motor engines is the one that maximizes the density of <100> crystal directions in the plane of the sheet. Therefore, for rolling in addition to the well-known Goss component (110)[001], the orientations of the cube fibre for which the (001) planes are parallel to the rolling plane are also desired (Fig. 6).

RESULTS
Microstructure
Fig.2 illustrates the whole manufacturing route of the product. The slabs were reheated to 1200 °C and kept in the furnace for a soaking time of 90 minutes, and then hot rolled to 2.0 mm. The finishing rolling process started at temperature 1050 °C and finished at 860 °C.

After hot rolling, the strip was cooled at 680 °C. The hot rolled strip was pickled and cold rolled down to 0.5 mm and then annealed in a bell furnace. The annealing conditions are of paramount importance for the enhancement of the target texture. The annealing atmosphere consists of 100% H2 to obtain a smooth surface without oxidization, and the dew point was kept under -50 °C. The final process is the skin-pass with a typical elongation ranging between 4-8%.

For measurement of hysteresis curves and losses of soft magnetic steels the standardised 30cm Epstein frame is measuring equipment was adopted according to IEC 60404-2 norm. In the Table 2 are reported the results of the measurements in terms of power loss and polarisation carried out with the Epstein frame. As can be noted the losses Ps at B=1.5T and 50Hz are quite good and fits well the requirements of the steel grade M310-50K.

<table>
<thead>
<tr>
<th>Ps (50Hz, B=1.5T)</th>
<th>J (Hs=2500A/m)</th>
<th>J (Hs=5000A/m)</th>
<th>J (Hs=10000A/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;3.1</td>
<td>&gt;1.55</td>
<td>&gt;1.64</td>
<td>&gt;1.76</td>
</tr>
</tbody>
</table>

Table 2: Power loss measured by Epstein frame.

CONCLUSIONS
In the present paper the results of the industrial development of the non oriented grade M310-50K at Marcegaglia Carbon Steel (Ravenna plant) has been presented. The magnetic properties of electrical steels such as magnetization curves, permeability and specific losses are, to a large extent, correlated with the microstructure and crystallographic texture. The maximisation of these properties depends on the optimisation between the thermomechanical process (TMP) adopted and the following cold processing of the strip and the need of cost reductions. Of course this optimisation is strictly related to the specific chemical composition adopted. The results confirmed that the best magnetic performances were achieved with the TMP conditions consisting of slabs reheated at 1200°C, finish rolling hot at 860 °C and cooling at 680 °C. The following process consisted in cold rolling with a reduction of 75%. The fine tuning of batch annealing and skin-pass conditions (4-8%) allowed to achieve power loss below 3.1W/kg and J50H=1.44T.