APPLICATION OF THE BARKHAUSEN EFFECT FOR THE QUALITY ASSESSMENT OF Fe-Si PLATES FOR ELECTROTECHNICS

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Abstract

Highly important utility parameters of Fe-Si plates for electrotechnics depend not only on their chemical composition and production technology employed, but also on their condition after mechanical processing into the shape of pressings at the electrical machinery manufacturer’s plant. An important quality parameter - specific losses $\rho_{Bi}$ represents an influence of mechanical stresses introduced during primary production technology and also processing of the pressings used in the magnetic circuits of electrical devices. This, above all, represents the area in the vicinity of stamping trace and influence of winding and straightening equipment. Reinforcement of the affected area leads to the increase of coercivity $H_C$ and thus also to the change of dynamic $B$-$H$ loop shape and subsequently of specific losses $\rho_{Bi}$ as well. Through measurement of Fe-Si plate samples (strip with dimensions of 280 x 30 x 0.5/0.3 mm) using gauge for recording Barkhausen jumps, we determined profile charts with substantial differences in levels of Barkhausen noises in the areas of mechanical interference (around cuts) prior to heat treatment \cite{1,2}. Experimentally determined correlation between specific losses and BN level allows assessment of quality of these plates during input and in-process control by the manufacturer of electrical machinery. Methodology of Fe-Si plate condition review based on Barkhausen noises is suitable both for non-oriented (NO) and grains oriented (GO) Fe-Si plates too \cite{4,5,6}. Magnetic Barkhausen noise method appears to be very effective for non-destructive determination of magnetic anisotropy, which can quantitatively characterize the plastic properties steel plates after metal forming and heat treatment.

Key words: Barkhausen noise, specific losses, plastic deformation

1. UTILIZATION OF THE BARKHAUSEN EFFECT FOR THE QUALITY ASSESSMENT OF Fe-Si PLATES FOR ELECTROTECHNICS

Important utility parameters of Fe-Si plates for electrotechnics depend not only on their chemical composition and production technology employed, but also on their condition after mechanical processing into the shape of pressings at the electrical machinery manufacturer’s plant. An important quality parameter - specific losses $\rho_{Bi}$ represents an influence of mechanical stresses introduced during processing of the pressings used in the magnetic circuits of electrical devices. This, above all, represents the area in the vicinity of stamping trace and influence of winding and straightening equipment. Reinforcement of the affected area leads to the increase of coercivity $H_C$ and thus also to the change of dynamic $B$-$H$ loop shape and subsequently of specific losses $\rho_{Bi}$ as well. Through measurement of Fe-Si plate samples (strip with dimensions of 280 x 30 x 0.5/0.3 mm) using gauge for recording Barkhausen jumps, we determined profile charts with substantial differences in levels of Barkhausen noises in the areas of mechanical interference (around cuts) prior to heat treatment. Chemical composition of samples measured is specified in table 1. NO plates are used for production of electrical motors and electrical generators, while GO plates are used for transformers, suppressors and alternating electromagnets.
Stress in the sample was subsequently reduced through the heat cycle (HTA i.e. 8 hours at 400 °C + 820 °C/2 min.), which lead to a significant increase of BN levels. This new fact also corresponds to a decrease of specific losses in magnetic material measured by the compensation ferrometer. Removal of internal and surface tension in the sample for HTA is not complete. Relaxation (tempering) occurs only partially. Different results for various classification levels of non-oriented plate grades (NO) were observed by comparison of magnetic materials with higher grade M553-50A and with lowest grade M800-50A. In case of alternating magnetizing M530-50A shows lower specific losses $\rho_{B/f}$ and also lower BN levels. Low grade M800-50A shows higher BN levels at higher $\rho_{B/f}$ values. Both materials were produced by the same technology “full finished”. In order to ensure comparison, figure 1 also includes a profile chart of oriented plate (GO) with Goss texture M140-30S. BN levels prior and after HTA are higher compared with NO, however, only slight increase of BN level occurs. This can be explained by a different technology of GO plate production using which very low $\rho_{B/f}$ values are achieved. For oriented plate only very small reduction of $\rho_{B/f}$ due to HTA was indicated, which does not correspond to the increase of BN levels, see table 2.

### Table 2 Comparison specific losses $\rho_{B/f}$ and BN levels.

<table>
<thead>
<tr>
<th>Samples</th>
<th>after die-cutting, before HTA</th>
<th>after HTA</th>
<th>change</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$\rho_{1.5/50}$</td>
<td>BN [\mu V]</td>
<td>$\rho_{1.5/50}$</td>
</tr>
<tr>
<td>M800-50A (NO)</td>
<td>7,467</td>
<td>167,22</td>
<td>6,585</td>
</tr>
<tr>
<td>M530-50A (NO)</td>
<td>5,987</td>
<td>59,16</td>
<td>5,113</td>
</tr>
<tr>
<td>M140-30S (GO)</td>
<td>0,794</td>
<td>366,55</td>
<td>0,790</td>
</tr>
</tbody>
</table>

### 2. MAGNETIC ANISOTROPY

An important parameter affecting the quality Fe-Si plates for electronics is their state of stress after manufacturing rolling operations steel sheets. Anisotropy properties of steel strips determined by the plastic stain ratio by destructive tensile tests (according to ISO 10113) are unsuitable for continuous production. Exceeding the limits will lead to a defect of the "bulge", which increases the magnetic losses. Nondestructive highly effective tool to evaluate the anisotropy of the Fe-Si sheets appears to be the Barkhausenova noise. Vengrinovich et al. [3] outlined some typical texture of stress when observing Barkhausenova noise. Evaluation of magnetic anisotropy was performed on the material M150-35S (GO), thickness = 0,35 mm and dimensions of 950x2000 mm. Figure No. 2 and No. 3 shown curves for BN wide steel plate in the rolling direction in place with and without defect. Figure No. 3 and No. 4 shows the steel plate with location of
defects and textures stress diagram on the same plate. Comparison of Barkhausen noise (BN) on the sheet with and without defect is done in Fig.5. Figures 2-5 very clearly identify place with the possibility of unacceptable defects.

**Fig. 1** Barkhausen noise (BN) measurement thermal relaxation convertor steel plate.

**Fig. 2** Dependence of Barkhausen noise (BN) width plate with defect (belt 3, side B, in the rolling direction).
3. CONCLUSION

Experimentally determined correlation between specific losses and BN level allows assessment of quality of these plates during input and in-process control by the manufacturer of electrical machinery. Methodology of Fe-Si plate condition review based on Barkhausen noises is more suitable for non-oriented Fe-Si plates of qualities M270-35A up to M800-65A. After modification of the measuring equipment it can be used also for Fe-Si plates with oriented grains. Using Barkhausen noises allows non-destructively determine the scope of the plastic anisotropy of electrical steel strips and lets specify a location undesirable defects.
REFERENCES


[3.] VENGRINOVICH, V. L., TSUKERMAN, V. L. Stress and texture measurement using Barkhausen Noise and angular scanning of driving magnetic field, 2006

