Bending angle influence of grain-oriented silicon steel on iron loss and domain patterns

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This paper presents bending angle influence of grain-oriented silicon steel on the iron loss and domain patterns. The silicon steel is widely used for transformer cores where it is wound and stacked to form a magnetic circuit. In that process, the stress, which is induced by forming wound cores, sharing the sheets, and binding the laminations, is one of the deteriorate elements for the iron loss in the cores. Particularly, bending the sheet is unique process because it exists the plastic and elastic strain transversely across the magnetic circuit, especially, at the low curvature radius. The result shows the bending makes more losses and it needs to avoid the extra bending in the core corner, which is caused by the spring back of the steel sheet.

Keywords: bending angle; domain patterns; grain-oriented silicon steel

1. Introduction

The grain-oriented silicon steel is a soft magnetic material, and it is mainly used for the transformers core. Since the high efficiency is required for the transformers, it must have low iron loss characteristics. The iron loss is influenced by the stress, which is made by forming, welding, cutting. Particularly, bending the sheet is unique process because it has the plastic and elastic strain transversely across the magnetic circuit [1,2], especially, at the low curvature radius.

In this work, bending angle influence on the iron loss is evaluated and discussed, which is caused by the spring back of the steel sheet for the enforced adjustment to fit along the core frame.

2. Experiment

Samples used in this work are grain-oriented electrical steel with the thickness of 0.23 mm. The samples are bent in 35° to 45°and settled along the octagonal shaped frame, which has 8 angles of 45° bent to fit along the core frame. This core is measured for iron loss, hysteresis loss, and eddy current losses.

The magnetic domain patterns in the samples are observed using Magnetic Optical sensor. The samples are DC-magnetized to observe the variation of the domains caused by the bending stress. The stress distribution near the bending line is analysed by FEM to evaluate the stress distribution and compared to the domain patterns.

3. Results and discussion

Table 1 shows the iron losses which depend on the bending angle of the silicon steel sheets to fit along the core frame. The iron loss increases 31% at bending angle of 10°, compared to the angle of 0° . Figure 1 shows the domain patterns where one is saturated near bending edge magnetized at 0.46 T. Figure 2 shows the DC magnetic field and saturation area of the domain patterns. The bending angle at 10° is easier to saturate near the bending edge. Therefore, the result shows the bending makes more losses and it needs to avoid the extra bending in the core corner,

Table 1: Bending influence on the iron loss separation of silicon steel.

Bending angle (°)	0	5	10
Hysteresis loss (W/kg)	0.147	0.150	0.201
Eddy current loss (W/kg)	0.143	0.178	0.179
Iron/Total losss (W/kg)	0.290	0.328	0.380

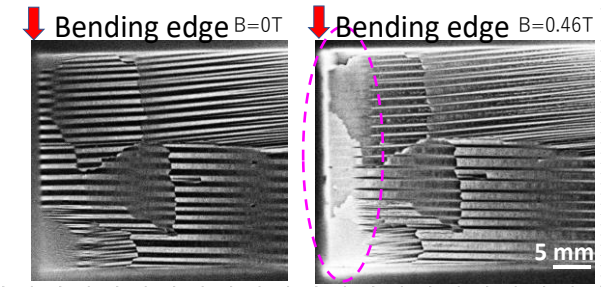

Figure 1: Domain patterns near bending edge at demagnetized (right) and at magnetized (left): B=0.46T, H=11A/m,

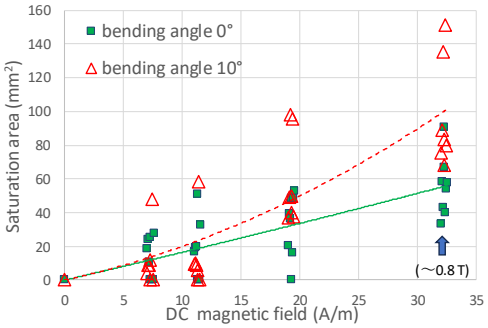

Figure 2: Bending angle and domain saturation area in silicon steel.

References

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