Combined effects of tensile stress and magnetic aging on the magnetic performance of NO ES

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This study tackles the combined effect of elastic tensile stress and magnetic aging on the magnetic performance of non-oriented (NO) iron silicon (FeSi) electrical steels (ES). An experimental study is carried out on two identical NO FeSi ES samples, one of which was aged at 200°C for 120 hours to account for the magnetic aging effects. Then, both samples, aged and unaged, were magnetically characterized at different stress levels in the range [10-120 MPa] to observe tensile stress effects. Sample experimental results are presented, and show a behavior that effectively reflects an interaction of the internal stresses induced by each the elastic tensile stress and magnetic aging. A comprehensive explanation of these phenomena will be provided in the full-length article.

Keywords: magnetic aging; elastic tensile stress; iron losses; electrical steels

1. Introduction

During their lifecycle, NO FeSi ES endure mechanical and thermal constraints due to manufacturing processes and operating conditions within electrical machines. This study examines the combined effects of tensile elastic stress and magnetic aging on their magnetic performance. The impact of tensile stress—arising from manufacturing processes (*e.g.*, cutting, stacking, shrink-fitting) or operating conditions (*e.g.*, magnetic and centrifugal forces)—has been extensively studied for over 150 years [1]. Typically, low stress levels enhance performance by favoring easy magnetization axes close to the field direction, while higher stresses can degrade the performance through increasing the demagnetizing field. On the other hand, thermal constraints, particularly prolonged high temperatures, may cause irreversible degradation due to magnetic aging, where second-phase particle precipitation hinders domain wall motion increasing the iron losses. While various studies in the literature examine magnetic aging [2-4], none explore its combined effects with elastic tensile stress. This work addresses this gap through an experimental study on aged and unaged samples under different tensile stress levels.

2. Results and discussion

This study was conducted on two NO FeSi ES samples of the same grade (M330P-35A), with identical chemical composition, which showed an identical magnetic behavior in their initial state. To analyze the impact of tensile stress before and after aging, one sample underwent isothermal heat treatment at 200°C for 120 hours. Then, both the aged and unaged samples were magnetically characterized under uniaxial tensile stress in the range of 10 to 120 MPa, applied along the rolling direction (RD) using a stress single strip tester (SST) linked to the MPG200D equipment from Brockhaus Measurements. B–H hysteresis loops were measured under a sinusoidal induction waveform at 50 Hz from the demagnetized state to near saturation. A thorough analysis has been conducted on the evolution of B-H loops, iron losses, and other magnetic properties of both aged and unaged samples under varying elastic tensile stress levels, along the magnetic field direction. Example results are shown in Figures 1 and 2. Figure 1 illustrates the B-H hysteresis loop evolution (at 1 T, 50 Hz) with magnetic aging at different tensile stress levels. This shows that the magnetic performance improves at 10 MPa and deteriorates at 120 MPa, reflected by the increase and decrease in magnetization, respectively. Regarding magnetic aging, the B-H loop area increases with aging, indicating a rise in iron losses. For the combined effects of aging and stress, it is observed that the loss increase due to aging (ΔP, between aged and unaged samples) decreases with the increase in the tensile stress. This is illustrated in Figure 2.

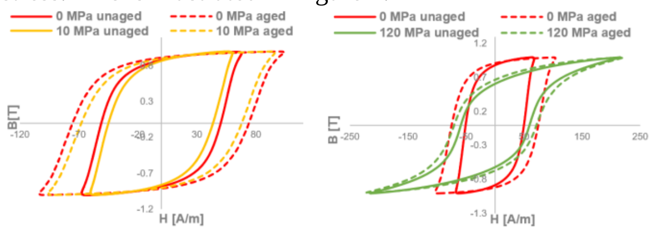

Figure 1: B-H loops at 1 T, 50 Hz for aged and unaged samples at different tensile stress levels: 0 MPa versus 10 MPa (left), 120 MPa (right).

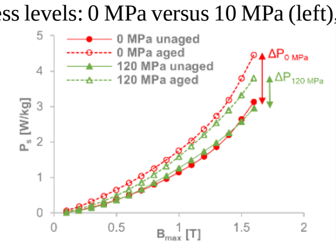

Figure 2: 50 Hz P-B curves for aged/unaged samples at 0/120 MPa.

A more detailed analysis of the combined impact of magnetic aging and elastic tensile stress examining a wider range of stress levels will be provided in the full-length article.

References

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