Effects of Bending and Annealing on NOES, GOES, and FeCo Magnetic Materials

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The construction of an axial flux machine rotor involves the rolling of electrical steels, which generates mechanical stresses that alter their magnetic properties. This study aims to experimentally evaluate the impact of rolling and annealing on the permeability and iron losses of FeCo and FeSi sheets, both grain-oriented and non-oriented. To this end, the sheets were rolled into diameters of 200 mm, 160 mm, and 120 mm. The results show a significant degradation of magnetic performance, with a clear correlation between roll diameter and the extent of magnetic property deterioration. Additionally, annealing partially restored these properties.

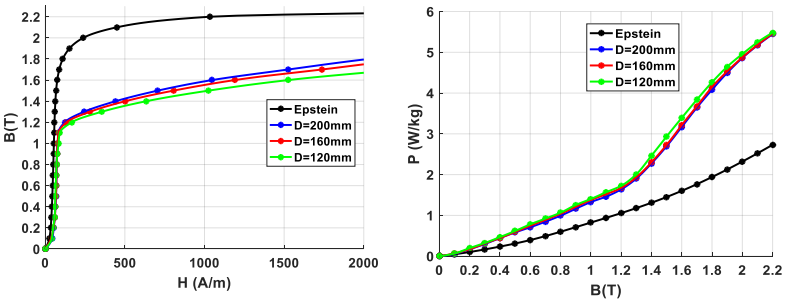
Keywords: annealing; bending stress; iron losses; electrical steel; permeability.

1. Introduction

In the context of the rapid development of electric vehicle technology, improving the efficiency of the powertrain remains a crucial goal for minimizing the environmental impact of hybrid and electric vehicles. The design of magnetic circuits, which involves steps such as cutting, punching, welding, and shrink-fitting, alters the initial magnetic properties of the materials. Magnetic circuits in axial flux machines require the rolling of electrical steels. Previous studies have shown that rolling electrical steels, which applies bending stress, can modify the alignment of magnetic domains, leading to a degradation in permeability and an increase in core losses [1, 2, 3, 4]. The severity of these effects depends on the level of stress applied. This deterioration in performance directly impacts efficiency. Annealing has been identified as a potential solution to mitigate these effects by restoring magnetic domains through recrystallization. However, while annealing offers improvements, it also introduces additional costs and processing time, necessitating a trade-off between performance recovery and manufacturing efficiency. The novelty of this article lies in the investigation of the effects of bending stress and annealing on several magnetic materials—NOES, GOES, and CoFe. The research quantifies the degradation of these materials for various diameters, which represents the innovative aspect of this study. The novelty of this article, compared to reference [5], lies in its exploration of the combined effects of bending stress and annealing on various magnetic materials—NOES, GOES, and CoFe. This study quantifies the degradation of these materials across different diameters, providing a new perspective not covered in reference.

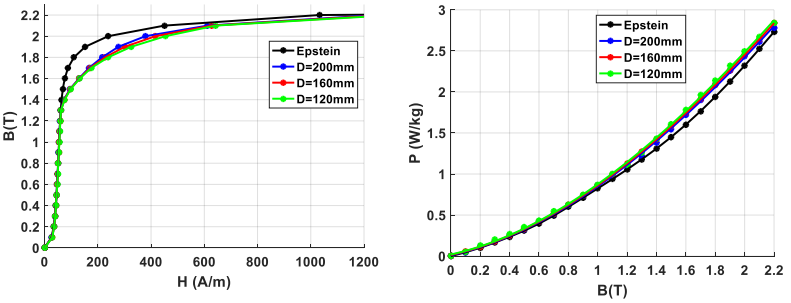
2. Results and discussion

The three toroids are fitted with a primary excitation winding and a secondary winding (B-coil), both wound in a regular pattern [5]. The BH curves and the iron losses for CoFe alloys under bending stress are displayed in Figure 1. The study demonstrates that bending stress reduces the permeability of the materials, requiring a stronger magnetic field for a given induction, with the effect being more significant for smaller toroid radii. Hydrogen annealing allowed for the recovery of the magnetic performance of the sheets after bending stress. In the final article, we will include the effect of bending stress and annealing on NOES and GOES materials.



a) B-H curves at 50Hz, b) Iron losses at 50Hz

Figure 1: Magnetic properties of CoFe under bending stress.



a) B-H curves at 50Hz, b) Iron losses at 50Hz

Figure 2: Magnetic properties of CoFe under bending stress after annealing.

3. Conclusion

Bending stress degrades the magnetic properties of CoFe, GOES, NOES, and other materials, depending on the bend radius. Annealing can restore their magnetic performance. The final article will detail the degradation, annealing characteristics, and the measurement technique for these materials.

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