Aging Behaviour of FeCuNbSiB Nanocrystalline Materials for Fluxgate Current Sensors Applications

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The increasing demand for miniaturization in electrical systems results in higher operational frequencies, which require magnetic cores that remain stable at high temperatures and over time (aging). This paper addresses the aging of nanocrystalline cores used in fluxgate current sensors. The nanocrystalline materials are exposed to high temperatures in the presence of an AC magnetization generated by the fluxgate electrical circuit. The study focuses on monitoring macroscopic magnetic properties. The impact of magnetic aging on the performance of fluxgate sensors is then examined by monitoring gain errors and linearity errors of the sensor.

Keywords: Nanocrystalline materials, magnetic aging, fluxgate sensors, anisotropies.

1. Introduction

Nanocrystalline (NC) materials exhibit exceptional magnetic behaviour at high frequencies[1][2]. These properties make NC materials suitable for a wide range of applications in electrical and magnetic systems. One significant application of NC materials is in fluxgate current sensors, which rely on the magnetic properties of the core to detect small variations in current.

In this paper, we investigate the aging of $Fe_{73.5}Si_{15}B_7Nb_3Cu_1$ NC cores at high temperatures (110°C and 200°C) while exposing them to an AC (22 kHz) magnetic field generated by the fluxgate sensor's electronics. The evolution of magnetic properties (dynamic and static) is monitored. The fluxgate measurement accuracy is then by measuring the gain error and linearity error of the sensor, before and after, aging of these NC cores.

2. Results and discussion

Figure 1 shows the evolution of dynamic hysteresis loops measured at ambient temperature during aging at 200°C. The dynamic hysteresis loops do not show significant changes.

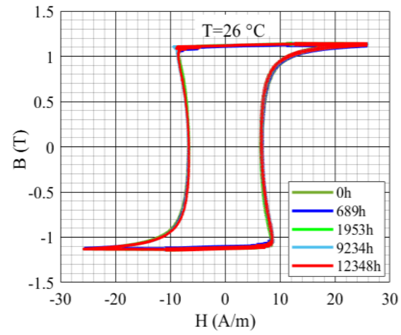

Figure 1: Evolution of dynamic B-H cycles (22kHz) of NC material during aging at 200°C.

To isolate and evaluate the evolution of the gain error independently from any offset drift, the characteristic curve of the fluxgate current sensor was plotted with offset compensation (Figure 2).

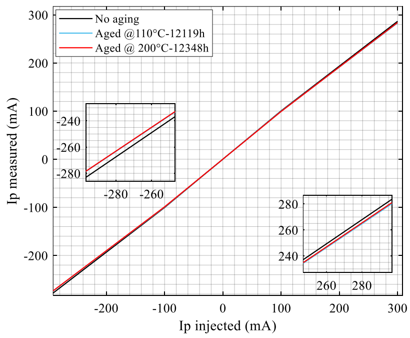

Figure 2: Evolution of gain error during NC aging at 200°C.

The results indicate that the gain remains remarkably stable throughout the aging process. The change corresponds to a variation of approximately 0.9% after aging at 200 °C for ~12000 hours.

On the other hand, the linearity error during aging appears to be closely linked to an increase in sensor offset. This offset drift correlates well with the rise in remanence (Br) observed in the static B-H loops. However, the linearity error remains within acceptable limits, (<1mA for Ip = [-5,5] mA), even after 12000 hours of accelerating aging

These findings demonstrate the robustness of the sensor’s design, and the thermal stability of the magnetic core materials used.

References

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