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UNIVERSITI TEKNOLOGI MARA

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2 ND INTERNATIONAL SCIENCE, ENGINEERING AND TECHNOLOGY COLLOQUIUM

THE POWER OF SCIENTIFIC INNOVATION

INTELLIGENT SOLUTIONS FOR A SUSTAINABLE WORLD

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PREFACE

Welcome to the 2nd International Science, Engineering and Technology Colloquium 2025 (ISETC 2025)!

It is with great pleasure that we present this year's colloquium, a distinguished gathering of scholars, researchers, and professionals dedicated to the advancement of applied sciences. Held virtually on 9th July 2025, ISETC 2025 serves as a platform to highlight cutting-edge research, foster meaningful networking, encourage collaborations, and explore innovative solutions to global challenges.

This year's theme, "The Power of Scientific Innovation: Intelligent Solutions for a Sustainable World" highlights our shared goal to solve global challenges through applied science. It celebrates innovation as a key to building a more sustainable and resilient future. We're proud to feature keynote speakers and presenters who bring fresh insights, bold ideas, and breakthroughs shaping tomorrow's world.

We would like to extend our heartfelt appreciation to the Faculty of Applied Sciences, Universiti Teknologi MARA, Perak Branch, Tapah Campus, for their outstanding support and assistance throughout the planning and execution of the event. Their dedication has been instrumental to the success of this colloquium. We would like to sincerely thank all participants and researchers for their valuable contributions. We also appreciate the reviewers for their careful evaluations and helpful feedback. Your hard work and support mean a lot to us.

As editors, we are proud to present this collection of proceedings. It is an honour to bring together the interesting and meaningful work of our speakers and authors. We hope the ideas shared will lead to new discoveries, encourage more research, and help solve global challenges through science and innovation.

Warm regards,

Dr. Emi Norzehan Mohamad Mahbob
Dr. Saiyidah Nafisah Hashim
Ms. Lili Widarti Zainuddin
Ms. Nurul Nazwa Mohammad
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ISETC 2025 Proceedings Editors

DESIGN AND DEVELOPMENT OF COERCIVITY METER FOR NON-DESTRUCTIVE DETECTION IN MAGNETIC MATERIALS: A PROPOSED METHOD

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Abstract: This paper presents a proposed design and development of a portable coercivity meter for nondestructive defect detection in ferromagnetic materials. Coercivity, a key magnetic property reflecting the internal microstructure and stress state of a material, is highly sensitive to mechanical damage, fatigue, and heat treatment anomalies. Leveraging this sensitivity, the proposed device uses a controlled magnetic excitation system coupled with high sensitivity magneto resistive sensors to measure the coercive field accurately. To enhance reliability, particularly under field conditions, the system incorporates simultaneous inductance measurement to correct for lift-off variations (air gaps). Calibration and validation are performed using standard steel samples with known hardness and stress levels, and results are benchmarked against conventional nondestructive testing (NDT) techniques such as magnetic particle inspection and eddy current testing. Results on the coding development capability to detect early-stage fatigue damage and subsurface defects, even through protective coatings. The developed system offers a cost-effective, real-time, and portable solution for structural health monitoring in industrial environments.

Keywords: *Coercivity, non-destructive testing (NDT), magnetic material, defect detection, magnetic sensor*

INTRODUCTION

Magnetic materials play an essential role in modern technologies, especially in electromechanical systems such as motors, transformers, and sensors, where their performance is closely tied to their magnetic properties (Cullity & Graham, 2011). Over time or under mechanical stress, these materials may develop defects such as micro-cracks, voids, or stress-induced anomalies that can significantly degrade their magnetic behavior and, ultimately, their functional reliability (Jiles, 1998). Therefore, the detection of such defects is crucial for ensuring the structural and operational integrity of magnetic components.

Traditional nondestructive testing (NDT) methods like ultrasonic, radiographic, or eddy current testing are widely used but can be cost-intensive, limited by geometry, or insensitive to certain subsurface features (ASTM E1444, 2016). In contrast, magnetic property-based diagnostics—particularly coercivity measurement—offer a promising, indirect approach for defect identification. Coercivity, defined as the reverse magnetic field required to reduce magnetization to zero, is highly sensitive to microstructural changes within the material (Aharoni, 1996). Defects alter domain wall motion and pinning, which results in measurable deviations in coercivity (Nakamura & Hayashi, 2005).

This work proposes the design and development of a portable coercivity meter tailored for defect detection in ferromagnetic materials. By capturing and analyzing the B-H hysteresis loop of test samples, the system aims to identify subtle changes in coercive force that indicate the presence of internal or surface defects. The goal is to develop a cost-effective, real-time diagnostic tool that complements or enhances existing NDT techniques.

MATERIALS AND METHODS

The coercivity meter is composed of several key components designed to facilitate accurate and efficient measurement. A magnetizing coil is used to generate the required external magnetic field for cyclic magnetization of the sample. A sensing or pickup coil is positioned to detect the induced voltage, which corresponds to changes in the magnetic flux within the sample. The system is controlled by a microcontroller (which is an Arduino Uno R3), which manages the excitation signals and performs real-time data acquisition. To ensure signal clarity, a signal conditioning circuit is incorporated, featuring amplification and filtering stages to process the raw signals. Finally, the system includes a graphical display or user interface, which visualizes the resulting hysteresis loop and provides numerical readings of key magnetic properties, such as coercivity. During operation, the magnetic sample is subjected to cyclic magnetization, and the corresponding B-H (magnetic induction vs. magnetic field intensity) hysteresis loop will be recorded.

From this loop, the coercivity (Hc)—the magnetic field strength required to reduce the magnetization to zero—will be extracted. Variations in coercivity are indicative of changes in the microstructure of the material, often caused by internal or surface defects. To ensure measurement accuracy, the system is calibrated using defect-free reference samples. Validation is carried out using test samples with intentionally introduced flaws, such as notches or stress concentrations, to evaluate the system's defect detection capability.

The experimental procedure involves preparing samples of commonly used ferromagnetic materials, such as mild steel and silicon steel. Artificial defects are introduced using precision machining or other controlled methods to simulate real-world anomalies. The coercivity meter is then used to record and analyze the hysteresis loops of both the intact and defective samples. The data collected from these tests are compared with results obtained from established nondestructive testing techniques, such as eddy current testing, to assess the reliability and accuracy of the proposed system.

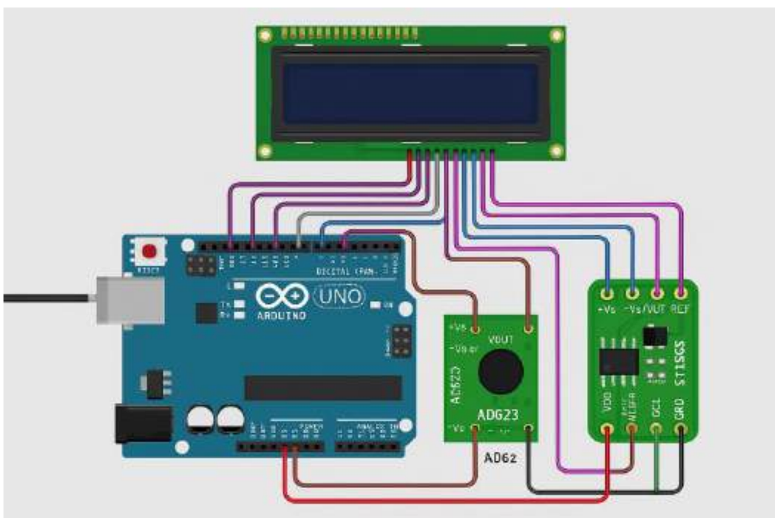

Figure 1. Circuit diagram

RESULTS AND DISCUSSION

During the experimental phase, data will be collected by measuring the coercivity values of both defect-free and artificially defected ferromagnetic samples. Each sample will be subjected to cyclic magnetization using the developed coercivity meter, and the resulting hysteresis loops will be recorded. The primary data points will include magnetic field intensity, magnetic flux density, and the corresponding coercivity (Hc) values (Jiles, 1998; Cullity & Graham, 2011).

The expected outcome is a noticeable shift in the hysteresis loop characteristics between defect-free and defective samples. Specifically, materials containing defects are anticipated to exhibit reduced or altered coercivity values compared to intact samples (Nakamura & Hayashi, 2005). This shift results from microstructural disruptions that influence magnetic domain motion and domain wall-pinning-effect (Aharoni,1996).

A representative graph (see Figure 1) will be used to visualize these differences, showing side-by-side comparisons of hysteresis loops for defective and non-defective samples. The data will also be statistically analyzed to establish correlations between defect presence, defect size, and coercivity changes. Results from the coercivity meter will be cross validated with conventional nondestructive testing methods, such as eddy current inspection, to confirm measurement reliability (ASTM E1444, 2016).

These findings are expected to confirm the system's ability to detect subtle defects by monitoring changes in magnetic properties, thereby demonstrating its effectiveness as a nondestructive testing tool for ferromagnetic materials.

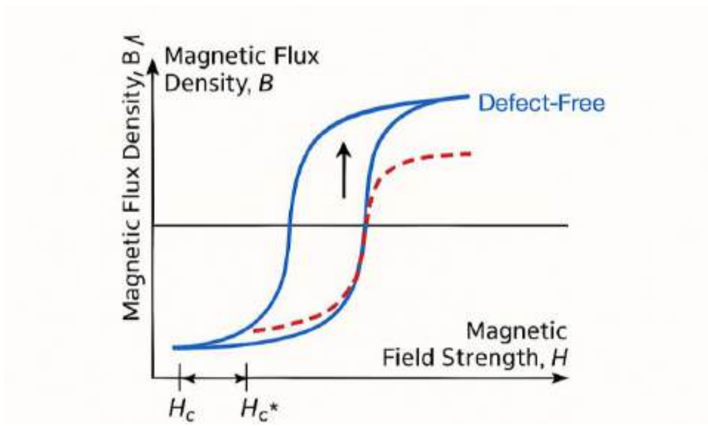

Figure 2. Comparison of hysteresis loops for defect-free and defective samples

Anticipated outcomes involve collecting and graphically representing data points of coercivity and correlating these with the presence of defects in the materials tested, A visually distinguishable shift in the hysteresis loo-p, illustrated by an increase in coercivity due to defects, serves as the key finding, reinforcing the system's proficiency in defect detection.

The preliminary results and analysis of the hysteresis loops suggest that coercivity is a sensitive parameter for identifying microstructural defects in magnetic materials (Nakamura & Hayashi, 2005). The observed shifts in coercivity values—particularly the narrowing or widening of the hysteresis loop—support the hypothesis that structural discontinuities affect domain wall motion (Aharoni, 1996). This aligns with theoretical expectations where defects act as pinning sites, altering the energy landscape required for magnetization reversal.

The developed coercivity meter not only provides a direct method for measuring coercive force, but also presents a practical and cost-effective alternative to traditional nondestructive testing techniques (Jiles, 1998). Its portability and real-time visualization features make it well-suited for industrial environments where fast defect identification is essential. However, environmental variables like temperature and electromagnetic noise may affect measurement accuracy and should be minimized in future prototypes (Cullity & Graham, 2011).

Furthermore, the system's sensitivity to different types and sizes of defects suggests potential for refinement. While preliminary tests with artificial defects show promising results, testing on naturally occurring irregularities will be necessary to fully assess field applicability. Future development may include integrating machine learning models for automatic pattern recognition and classification of hysteresis loop profiles, thereby improving defect diagnosis capabilities (Wun-Fogle et al., 2000).

In summary, the discussion supports the coercivity meter's capability as a compact, reliable, and scalable tool for nondestructive defect detection in ferromagnetic materials.

CONCLUSIONS

In conclusion, the development of the coercivity meter demonstrates the feasibility of using magnetic property analysis as a reliable nondestructive technique for defect detection in ferromagnetic materials. The system's sensitivity to microstructural variations and its compact, affordable design makes it a promising tool for real-time inspection and quality control in industrial settings. Further refinement and field testing are recommended to optimize the device for various application scenarios.

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Setuju.

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