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Eddy Current Testing Methods and Design for Pipeline Inspection System: A Review

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Eddy Current Testing Methods and Design for Pipeline Inspection System: A Review

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Abstract. Non-destructive testing and complex systems integration are commonly used in transportation, aircraft, automotive, manufacturing, petrochemical, and defence. Eddy current testing (ECT) is a common non-destructive evaluation technique, especially in the coating, nuclear, and oil and gas industries. However, the eddy current testing method must continue to focus on the probe's construction and application. It ascribed noisy data to inadequate detection and a severe false alarm problem. Nonetheless, only few academics have elaborated on the intelligent ECT crack detection method. This study provides an overview of the eddy current testing technique and the probe structure design elements that influence fracture detection accuracy. The first section describes the Eddy current testing by encircling coil system for a differential probe (ECDP) and an encircling coil for an absolute probe design (ECDP). The explanations focus mostly on the probe's creation and detection in Rotating electromagnetic field eddy current (RoFEC). The advantages and disadvantages of eddy current testing surrounding probes are analysed. In addition, a summary of prior studies investigating testing samples of ferromagnetic pipe, steel rod, and wire rope is presented. The second segment focuses on Eddy current testing employing a Giant Magnetoresistance (GMR) sensor system, with a particular emphasis on sensor arrays, GMR, and conventional eddy current coils for crack identification. Finally, a comprehensive overview of eddy current testing methods and design for non-destructive pipeline inspection systems is presented.

1. Introduction

Modern nondestructive testing technology is developing towards fast and non-stop testing. It is of great significance to study the rapid and large area testing technology without damaging the tested components (external coating, thermal insulation layer and protective layer) and establish an effective and perfect evaluation system. The pulsed eddy current testing signal contains rich frequency components, including not only the high-frequency components for detecting surface defects, but also the low-frequency components for detecting deep defects, thus avoiding the limitations of traditional eddy current testing. It has the advantage of acquiring multi-level defect information once testing, and also has the characteristics of electromagnetic non-contact coupling. Therefore, it is expected to become a rapid, large-area nondestructive testing technology [1]. Numerous NDT procedures, including as thermographic testing, electromagnetic acoustic testing, radiographic testing, ultrasonic testing, magnetic particle testing, penetrant testing, and eddy current testing, have been created for that purpose (EMAT) [2][3][4][5][6]. The mentioned methods each have advantages and disadvantages in determining the location of cracks in the pipe and plate surface. Radiographic testing for example is one of the best methods but it is time consuming, expensive, requires a special exposure room and has a negative impact on the operator's health [7][8][9][10], Ultrasonic testing [11][12], Pipeline non-destructive testing is appropriate for testing for magnetic particles and penetration, but its use is limited by the high complexity of the detecting equipment[13][14][15]. The secondary electromagnetic field is composed of the primary electromagnetic field directly coupled from the coil and the secondary electromagnetic field generated by the eddy current field induced from the component, and the latter contains the thickness or defect information of the component itself. The information l of the component to be tested can be obtained by measuring the secondary field with appropriate methods and detection elements and analyzing the measurement signal. Different from traditional eddy current testing, pulsed eddy current testing uses square wave or step rather than sine wave excitation. The electromagnetic signal picked up by the receiving element, usually called pulsed eddy current signal, is a system pulse or step response centered on the component[16][17]. Compared with eddy current testing method, PEC testing method has the following advantages. 1) PEC signal has rich frequency components, including ultra-low frequency eddy current signal which can pass through the thin metal sheath and thick non-metallic layer to realize the deep defect detection of the tested component, extract the deeper level information of the component, and overcome the influence of skin effect in traditional eddy current testing. 2) Compared with traditional eddy current sensor, PEC sensor excites coil excitation the magnetic field amplitude is large, so the detection signal can still be obtained under large lift off; with PEC sensor covers a large area and can detect large areas of metal corrosion.

2. ECT Principal operation

2.1 History of Eddy Current Testing

Through his research on electromagnetic induction, Michael Faraday made significant contributions to the fields of science and engineering. The concept of eddy current testing can be traced back to 1831, when Michael Faraday made the finding that electromagnetic induction exists. In the early 1800s, Faraday worked as a chemist in England. He is credited with the discovery of a number of different phenomena, including diamagnetism, electromagnetic induction, electromagnetic rotations, the magneto-optical effect, and the magneto-optical effect. In the year 1879, another scientist by the name of Hughes documented how the characteristics of a coil changed when it was brought into contact with metals that varied in their conductivity and permeability. However, these effects were not put to practical use for evaluating materials until after the Second World War. Prior to that time, no such testing had been done. During the 1950s and 1960s, a significant amount of progress was made, notably in the aerospace and nuclear sectors. Testing using an eddy current is now an inspection method that is both common and well understood.

2.2 Basic Principles of Eddy Current Inspection

The phenomena of electromagnetic induction are utilised by electromagnetic sensors. A time-varying current running through an excitation coil will generate an electromagnetic field, as seen in Figure 1. (EMF). According to Faraday's Law, if an electrically conductive substance is in the vicinity of this electromagnetic field, an eddy current will be produced in the material. The induced eddy current will create an electromagnetic field that opposes the coil's primary magnetic field. The interplay between these fields generates a back EMF in the coil, resulting in an apparent change in the coil's impedance.

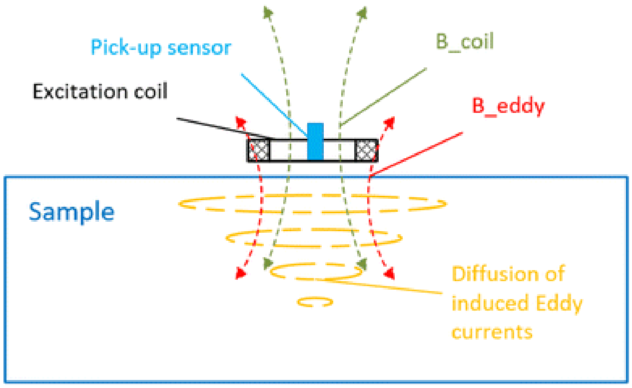


Figure 1. Illustration of the working principle of ECT [18]

The eddy current method for a sample is an important issue for testing in NDT techniques. This is due to the density and penetration factor for the eddy current which at the same time limits the penetration rate of the eddy current and will directly reduce the rate of penetration of the depth of the eddy current in an exponential manner. This can be represented by 1/e as the density change and d as the penetration depth that occurs as in the formula below

$$.\sigma = \sqrt{\frac{1}{\pi f \mu \sigma}} \quad (1)$$

Where:

μ =Magnetic Permeability (H/m)
f =Test Frequency (Hz)
σ =Electrical Conductivity (Siemens/m)
δ =Standard Depth of Penetration (m)

3. Eddy current testing by encircling coil system

There are many benefits inspect, examine or analyze the defects without causing any damage for checking steel tubular constructions in avoiding the damage due to crack propagation. Some researchers used the conventional methods in setup the research experiment to solve that problem. There are many conventional coil arrangements and turning configuration had been proposed. Rotating electromagnetic field eddy current (RoFEC) testing approach has received a lot of attention. However, the majority of the relevant research used feed-through probes, which are frequently ineffective for identifying outer wall faults and to identify defects in the inside walls of metal pipes.

3.1 Design of Coil Probe Eddy Current

To generate the excitation magnetic field, a cooper coil with 100 turns and a 0.1mm diameter was constructed. A'in Nadzri et al., 2020 utilized a combination of coil winding and two fluxgate sensors (DRV425 Texas Instrument) spaced apart by a 2-mm in their research experiments to discover the back-side cracks in metal structures[19], [20]. To complete the system, it also comprises a power supply, a DAQ card, and a desktop for data collecting and analysis. An experiment in Figure 2 was carried out utilising a sample with artificial slits of varying depths, ranging from 768 µm to 929 µm. The magnetic field's frequency for excitation in this experiment was set at 70 Hz, 110 Hz, 160 Hz, 210 Hz, and 310 Hz.

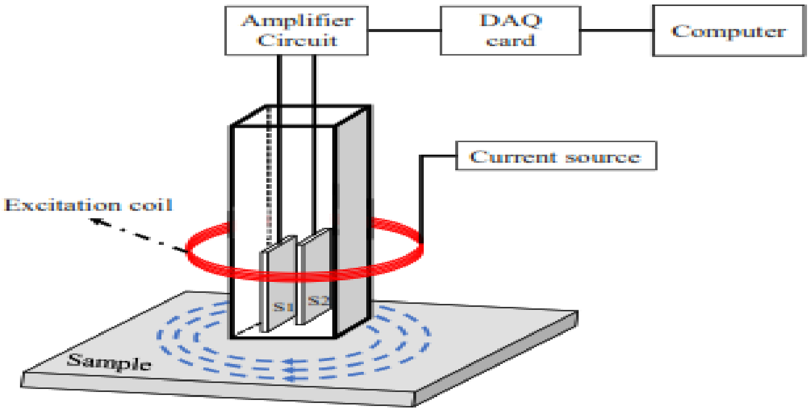
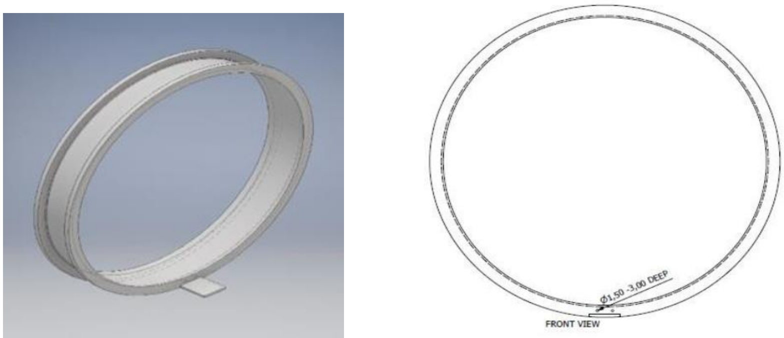


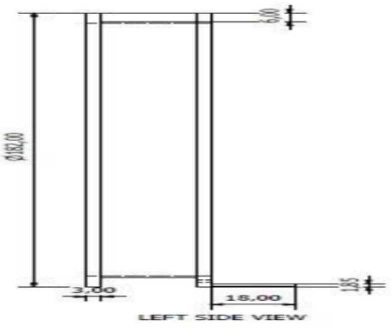
Figure 2. Excitation coil and fluxgate sensor experiment setup

3.2 Design of an encircling coil for a differential probe

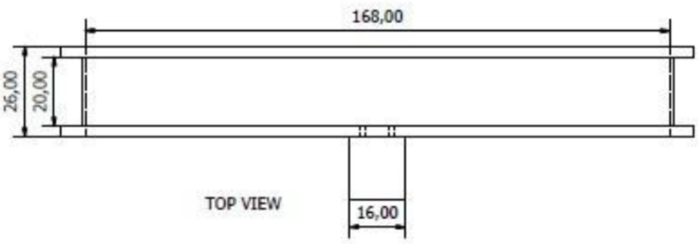
Pipeline systems, such as those used to transport oil and natural gas, are often buried in the ground or laid out across the ocean floor, making them susceptible to corrosion and pressure degradation. In the oil and gas sectors, corrosion behind the insulation of process piping is a major problem that is sometimes undetectable until it has already caused significant damage. The primary objective of this study is to evaluate the relative merits of two different types of encircling coils for use with AC multi-frequency excitation signals: the encircling coil for a differential probe (ECDP) and the encircling coil for an absolute probe (ECAP). Excitation signal influence on crack measurement as a function of examination depth for plates and pipes. Voltage and current signals were employed alongside ECDP and ECAP to measure defects. Both the ECDP and ECAP probes relied on coil turns for their designs, with 20-turn coils being the norm. The output and excitation signals can be measured via a USB port located on the housing. The surrounding probe is designed with the help of 3D printing. As can be seen in Figure 3(a), the encompassing probe housing was fabricated using Acrylonitrile Butadiene Styrene (ABS). The front aspect of the encircling coil probe housing is shown in Figure 3(b). With a gap of less than 3mm and a thickness of 1.5mm, the enclosing casing is attached to the sampling pipe as per the specification. The top view is shown in Figure 3(d), while the sides of the shell, which has an outside diameter of 182mm, are shown in Figure 3(c). The method of measuring involved the integration of ECDP and ECAP. The excitation frequencies between 30 kHz and 60 kHz are recommended for quality assurance testing.[21][22][23][24][25].



(a) (b)



(c)



(d)

Figure 3. Eddy current coil casing (a) Default view, (b) Front View, (c) Side View, (d) Top view

4. Detection theoretical model

In order to solve the above problems, researchers simplified the modeling, and analyzed the electromagnetic phenomena and processes in the detection with electromagnetic theory. According to the different electromagnetic theories used, the theoretical models of PEC detection can be divided into circuit model and electromagnetic field model. The circuit model is equivalent to the circuit composed of ideal power supply, resistance element, inductance element and capacitor element, and it is analyzed with the theory of "circuit"; The core of the electromagnetic field model is to solve Maxwell's equations 61 under certain solution conditions, generally boundary conditions or initial conditions. Among them, the electromagnetic field model can more clearly express the change law of electromagnetic field with space and time, which is helpful for the in-depth understanding of electromagnetic phenomena and processes. Therefore, it is widely used in PEC detection, especially in the rapid inversion of defects. According to the different methods of solving Maxwell equations, the electromagnetic field model can be further divided into analytical calculation model and numerical calculation model. Among them, the analytical calculation model obtains a closed form solution that explicitly represents the relationship between the PEC detection signal and the detection parameters through strict formula derivation, which has the advantages of clear physical significance, fast calculation speed, and high accuracy, and is an important part of the theoretical research of PEC detection.

4.1 Analytical calculation model

The excitation detected by PEC is generally square wave or step. It is very difficult to directly solve the response of this excitation with Maxwell equations. The general solution idea is to decompose the square wave or step excitation into multiple harmonic excitations in the complex frequency domain or frequency domain through Laplace transform or Fourier transform, solve the response of all harmonics, and then obtain the response under square wave or step excitation through a certain inverse transform. According to the different ways of processing the excitation waveform, the analytical calculation model of PEC detection is described from two aspects of Laplace transform and Fourier transform[26].

When carrying out the Laplace inverse transformation, Bowler J et al. used the method of looking up the Laplace inverse transformation table. However, the Laplace inverse transformation table gives limited transformations, so no more solutions can be obtained. Theodoulidis T.P. (3) made a breakthrough in solving the inverse Laplace transform. He provided a simpler method to solve the time-domain expression of the analytical model of pulsed eddy current testing by solving the residues at the poles in the Laplace domain and applying the Heaviside expansion theorem. Chen Xingle et al. "applied this method to the research of non-axisymmetric pulsed eddy current testing, and obtained the time-domain analytical expression of the induced voltage at both ends of the testing coil and the eddy current distribution in the pipe wall when the placed coil is located at any position outside the ferromagnetic pipe[27].

Although the time domain solution of the pulsed eddy current model obtained by using the inverse Laplace transform has high accuracy, its expression is complex. In contrast, the inverse Fourier transform method is easier to calculate and can be programmed by MATLAB, Mathmatics and other mathematical software, so it is more widely used.

Common numerical calculation methods, such as finite difference time domain method (FD-TD), boundary element method (BEM), and finite element method (FEM), have been used in pulsed eddy current testing calculation. The finite element method can be used to segment areas with grids of arbitrary shape, It has a good adaptability to the shape of the region, so it is often used to solve the problem of pulsed eddy current testing with complex shapes of components or sensors.

When the finite element method is used to solve the pulsed eddy current testing model, one method is to solve the model directly in time domain. At present, the commonly used finite element commercial software, such as Comsol, ANSYS and Ansoft, can conveniently obtain the time domain solution of electromagnetic problems by loading the time domain waveform and setting the time step, so it is used to analyze various kinds of pulsed eddy current testing problems. Cheng W et al. used the finite element method to study the eddy current distribution in the component, and determined the coverage area of the sensor according to the eddy current distribution, providing a basis for the optimization of the sensor. Zhang Yuhua et al.26 established the calculation model of three-dimensional transient eddy current problem by using the finite element method, and studied the rectangular coil tangential placed above the flat conductor. The results show that the size change of the excitation coil will affect the flow mode of the induced eddy current in the conductor. Thou D.Q. et al. studied the influence of rectangular coil size proportion on pulsed eddy current testing signal with three-dimensional finite element model to guide the design and selection of sensors under different testing conditions. Gu Zengtao et al. numerically simulated the influence of the component thickness and lift off height on the thickness measurement when the sensor is located at different positions of the ferromagnetic component edge, and gave the fitting formula to eliminate the edge effect; Wang Jian et al. aiming at the interference of surrounding pipelines to the detection results when detecting the corrosion of pipes with cladding, a simulation model was established that the interference tubes are parallel to the detection tubes on both sides of the detection tubes, and the influence of the distance between the interference tubes and the detection tubes on the detection results was analyzed.

The other method is similar to the solution method of the analytical calculation model. First, the response under harmonic excitation in the frequency domain is solved by using the finite element method, and then the time domain solution under square wave current excitation is obtained by superposition of all harmonic responses. By comparing with the experimental signal, et al. found that the error of the result obtained by this method is smaller than that obtained directly in the time domain, and when the excitation waveform is steep, the result obtained by this method is closer to the experimental value; Xie Shejuan et al. applied the idea of interpolation to this method to reduce the calculation time; Then Xie Shejuan applied this method to the simulation analysis of pulsed eddy current flaw detection, and introduced Toshiyuki's fast calculation method based on data benchmark to realize the fast calculation of pulsed eddy current flaw detection simulation.

4.2 Circuit model

The circuit model is simple and intuitive without deriving complex electromagnetic field formula, and is easy to be applied in engineering. Therefore, it has also been applied in the analysis of pulsed eddy current testing. In 1976, Loos F.R. proposed a simple circuit model - eddy current ring theory based on the "principle of equivalence". The basic principle of eddy current ring theory is that the eddy current in the component is equivalent to the current flowing in the imaginary coil with a certain size, and the coupling relationship between the excitation coil and the component is equivalent to the coupling relationship between the excitation coil and the imaginary coil, as shown in Figure 4. So, the complex electromagnetic field model is simplified into a circuit model. The eddy current ring theory is used to model the pulsed eddy current testing signal of non-ferromagnetic materials, but the model has two problems: 1) the component is directly equivalent to the inductance coil, lacking the corresponding theoretical analysis; 2) The eddy current in the component is equivalent to a coil, so the order of the model established is low. When the component is made of thick wall non ferromagnetic materials and ferromagnetic materials, the signal fitting effect is poor[28][29] [30].

Huang Chen et al. dispersed the square wave current into harmonics of multiple frequencies, equivalent the eddy current induced by each frequency harmonic to an eddy current ring, and established a multi eddy current ring coupling model by using the mutual coupling between eddy current rings to equivalent the interaction between harmonic eddy currents. The circuit model corresponding to this model is shown in Figure 5. The multi vortex ring coupling model is a modification and supplement to the vortex ring model.

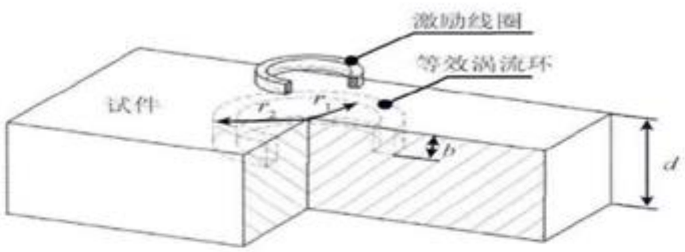


Figure 4. Equivalent coil coupling model

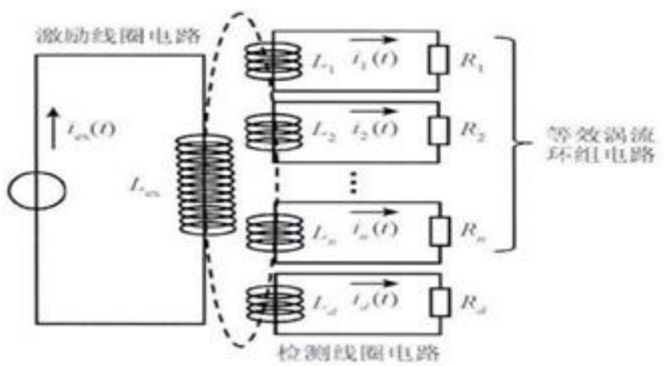


Figure 5. Equivalent circuit model for PEC

5. Eddy current testing using Giant Magnetoresistance (GMR) sensor system

Many attempts have been made in recent years to increase the dependability of sensors and sensor systems while lowering the cost of manufacturing. Cubells-Beltrán et al., 2016 [31]summarise a number of successful cases of GMR sensor integration with heterogeneous complementing elements to report on innovative domains of application of GMR sensors [31].

The suggested device is capable of identifying minute surface and subsurface flaws such cracks, metal loss, and other mechanical flaws [32]. In order to get beyond the limitations of coil-based sensors, magnetic sensors including giant magnetoresistance (GMR), Hall sensors, and superconducting quantum interference devices (SQUID) have been developed. The most used sensors for sensing magnetic fields are hall sensors. Hall sensors can gauge the strength of magnetic fields and are reasonably priced. However, compared to GMR and coil sensors, Hall sensors are less sensitive. 50 mm long and 0.3 mm broad artificial cracks can be found using a SQUID-based probe. SQUID sensors cost more than GMR sensors, aside from probes that need substantial mechanical components to function[33].

5.1 Design of GMR sensor Probe

The paper written by Sasi et al., 2018 discusses the detection sensitivity of induced magnetic field components for deep seated flaws under varying lift-off conditions by using integrated EC-GMR sensor. The experiment measurements and Finite Element Model done on 8.0 mm thick AISI type 316 stainless steel plate with machined surface and subsurface notches at various depth locations were investigated. The artificial cracks ranges from 2mm to 7mm depth were selected in these studies. The Figure 6 and Figure below shows the setup of the experiment and the artificial crack developed by the scholar[1].

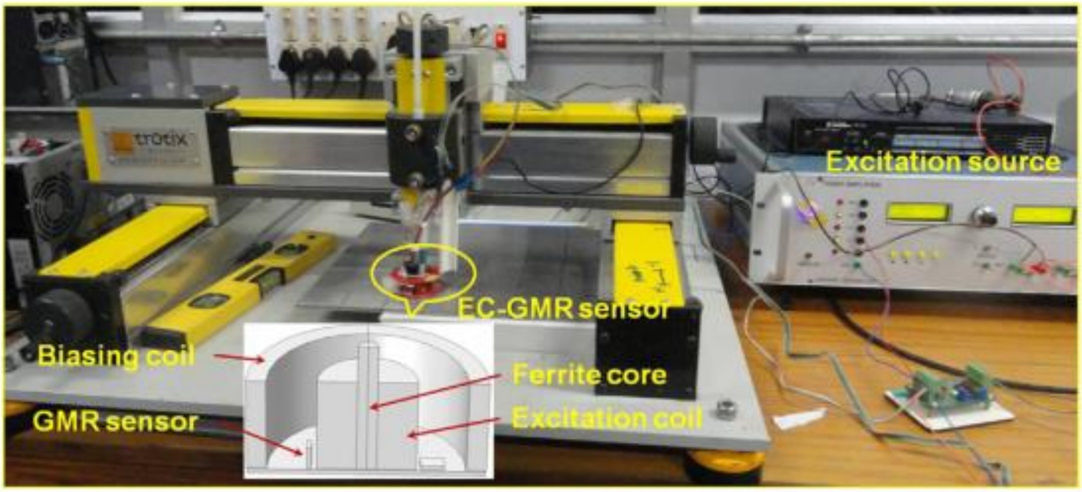


Figure 6. Experiment setup with GMR Integrated probe

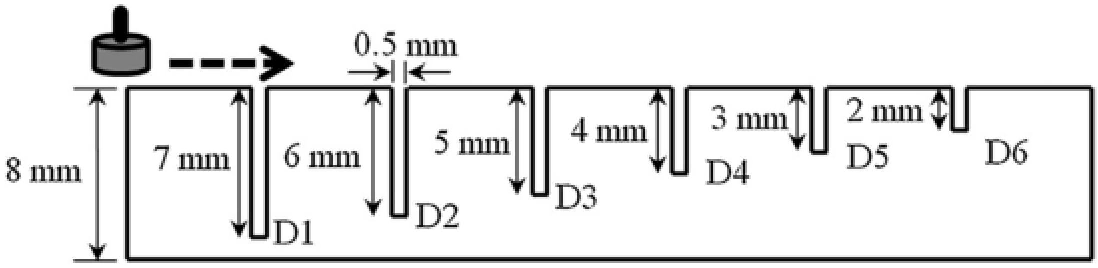


Figure 7. The artificial crack investigated

GMR-based configuration was also proposed in [34], [6] developed an experimental EC system that discusses the effect of symmetry-asymmetry on GMR-based EC probe sensitivity and the effect of excitation coil dimensions on GMR-based EC probe sensitivity. The block diagram of the EC system that is typically utilized in EC experiment setup is shown in Figure 8. The millimeter screw and GMR holder made up the asymmetry setting system. A specially manufactured holder with an asymmetry setting mechanism was created, as shown in Figure 9, in order to set the value in equation 1 of the examined GMR-based EC probe.

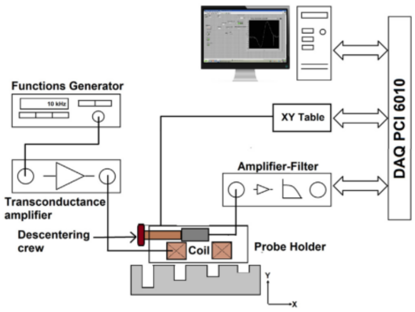


Figure 8. The block diagram of EC system

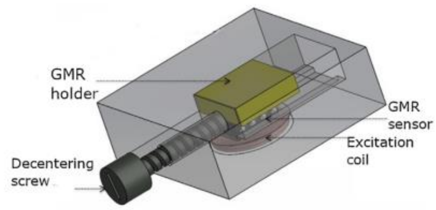


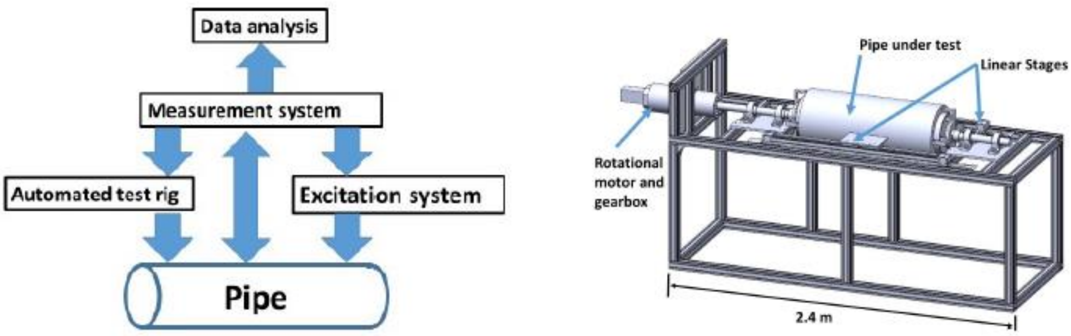
Figure 9. System used to adjust the GMR-based EC probe asymmetry with the GMR holder and the decentering screw.

In addition to the GMR sensor used by the researcher, Tunnel MagnetoResistance (TMR) sensors are also used to replace the original induction coils mentioned by Fan et al., 2022[35]. In order to evaluate the influence of altered magnetic induction intensity at the test site, a current dipole model is first suggested, followed by a method for quantitatively monitoring subsurface cracks. The sensor's finite element model is then created in order to study how fracture propagation affects eddy current at various excitation frequencies. Finally, investigations on crack monitoring at various depths in the surface and subsurface are conducted. The outcomes of the experiment demonstrate that numerical monitoring of fracture propagation is possible.

5.2 Design on Combination with Giant Magneto Resistive Sensors A Test Rig

Corrosion is the most frequent cause of metal building deterioration. One of the popular non-destructive procedures used to assess the current state and forecast the remaining lifetime and potential failure of the device is excitation with a variable magnetic field and detecting the change of the magnetic field owing to eddy currents in the device under test [36]. Signals will be significantly suppressed by a substantial distance between the excitation source, magnetic sensors, and the test object because of the magnetic field's quick decay. Giant magneto resistive sensors were used in the construction of an evaluation rig that can scan a pipeline with a combined weight and length of no more than 100 kg and

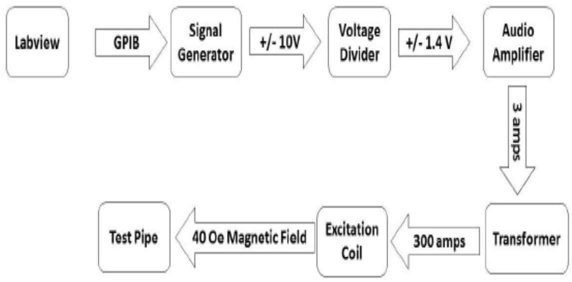
1.3m. A schematic layout of the entire experimental apparatus is shown in Figure 10(a). It is a mechanical rig that supports and adjusts the pipe's outer surface while rotating the pipe and moving the excitation unit and sensor module along the pipe on liner stages. Figure 10 displayed the CAD drawing of the mechanical rig arrangement (b). The sensor module investigated the pipeline's typical 700 mm and 360 degree surroundings with a resolution of 5 mm and 5 degrees. The GMR sensors, along with additional commercially available hardware that measures the magnetic field, connects the device to the main LabVIEW software, and offers support electronics, are housed in a sensor module that is installed immediately above the pipe as part of the measuring system. The excitation system is flexible in terms of excitation current and frequency and is equipped to create an osculating magnetic field. The corresponding magnetic field readings are then produced by processing the raw sensor data using Labview code[37].

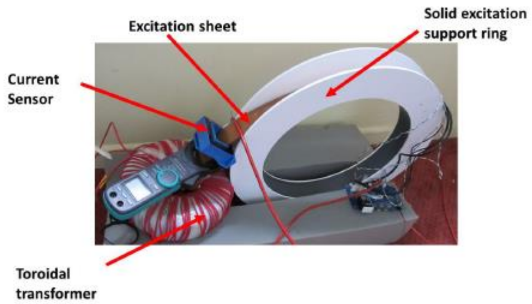


(a) (b)

Figure 10. a) experimental setup process b) mechanical setup

The fundamental outline of the excitation system is illustrated in Figure (a). The excitation coil, shown in Figure 11(b), is connected to the secondary of a toroidal transformer with a turns ratio of 106:1. 3 b). To keep the audio amplifier from overheating, the turns ratio was designed to keep the impedance it had to drive close to its rated value of 4 ohms. The encircling coil geometry was selected because it guarantees a uniform magnetic field around the entire pipe's circumference, has the largest ratio of input power to excitation field strength, and is the most flexible coil configuration. The enclosing coil is constructed from a stack of 40 mm wide, 4.2 mm thick copper strips. An expansive cross-sectional area was provided by the stack sheet design to lessen resistance while keeping the structure's pliability. The total resistance was found to be 126 μΩ when testing with just one joint. Maxwell 3D simulations were used to determine the excitation sheet's impedance, which was found to be 563 μH in the absence of a pipeline and 63 763 μH with one. These parameters allowed for a high current of up to 600 A at 20 HZ, with just a 40oC rise in temperature. Due to their low 1/f noise, GMR sensors are ideal for low frequency eddy current testing, where their high sensitivity shines. Excitation setup, sensor alignment and locations, and the influence of various excitation and sensor setup characteristics, as well as the device under test, were all evaluated via finite element analysis. In light of these findings, a laboratory apparatus was constructed to investigate the impact of key measurement factors [38][39][40][41].





(a) (b)

Figure 11. (a) System diagram of the excitation system, (b) excitation coil coupled to toroidal transformer

6. Summaries of encircling coil system and Giant Magnetoresistance (GMR) sensor system

According on Table 1 show the previous design and method used in Eddy Current Testing (ECT) inspection. In each research show that the method and advantage according on the design used. The detail of finding and method purpose deeply explain in table below.

Table 1. Summaries of both design including encircling coil and GMR sensor system

Author	Research Area	Finding	Method Purpose
A'in Nadzri et al., 2020 [19], [20]	Creation of an ECT Probe for Back Side Crack Assessment	Development of an ECT probe using Antistrophic Magneto-Resistive (AMR) sensors to detect flaws in galvanized steel plates	When the AMR sensors detect something, a lock-in amplifier is used to apply a phase-sensitive detection approach.
A. J. Mohamad et al., [21]	Design of an encircling coil for an absolute probe and one for a differential probe (ECDP) (ECDP)	ECDP (with longitudinal and transverse coils) is quite effective in measuring the different sorts of flaws in the frequency ranges by comparing the generated signal between the probes	Evaluate the relative merits of two different types of encircling coils for use with AC multi-frequency excitation signals: the encircling coil for a differential probe (ECDP) and the encircling coil for an absolute probe (ECAP)
M. Le et al.,[24]	Design of Electromagnetic Testing of Rod Cluster Control	The system can inspect man-made SCGs, SWs, and CCs up to depths of 20%, 30%, and 40% of the thickness of the cladding tube (0.47 mm), respectively.	Integrated system with 24 encircling Hall sensor array (EHaS) probes. Each EHaS consists of 16 Hall sensor elements spaced at 22.50 m apart on a cylinder supporter of 11.2 mm in diameter (2.2 mm)
M. Liu et al., [27]	Design of Detecting Distance of Testing Device for Wire	The experiments show that it is possible to find flaws from a long way away. The method has also been used to find	Method is based on the principle of electromagnets to magnetise the wire rope

	Rope Based on Open Magnetizer	broken wires in wire ropes at high speeds. It can find broken wires with a diameter of 1 mm	with an energised excitation coil, and the second method uses a permanent magnet to magnetise the steel wire rope.
Z. Liu et al., [30]	Design of bidirectional-excitation eddy-current sensor with magnetic shielding	The experiments demonstrate that it is able to efficiently detect the notch defects on the surface of a plate made of stainless steel with a thickness of 10 mm at a distance of 7 mm. It was found that the change in impedance amplitude, phase difference, and depth of subsurface faults all had a linear connection with one another	The excitation coil of a bidirectional-excitation EC sensor has 400 turns, and the reception coil's excitation and reception coils are magnetically shielded.
J. Bailey et al., [38]	Design on Combination with Giant Magneto Resistive Sensors A Test Rig	In light of these findings, a laboratory apparatus was constructed to investigate the impact of key measurement factors	Encircling coil geometry was selected because it guarantees a uniform magnetic field around the entire pipe's circumference, has the largest ratio of input power to excitation field strength, and is the most flexible coil configuration
X. Yuan et al., [42]	Design Bobbin coil probe with sensor arrays for imaging and evaluation of longitudinal cracks.	Using the bobbin coil with TMR sensor arrays on the inside, you can see the inner-wall longitudinal crack on the inside of the aluminium tube. The detection sensitivity of the Bxin and the distance between the peaks of the Bzin can be used to get a good idea of the crack's depth and length	TMR sensor arrays are used to pick up the distorted magnetic field so that the inner-wall longitudinal crack can be seen and evaluated

7. Conclusion

Each inspection method is based on the excitation frequency used and the type of receiver. According to previous researchers there are two methods used in ECT inspection by using coil as transmitter and receiver or using GMR sensor as a receiver. For most industries, the use of coils as transmitters and receivers is still applicable to the main ECT inspection system. The most products on the market still use coil probes ECT even though there are many weaknesses existing. Accuracy of data is the most importance and also the ability to detect various types of defects including corrosion for the inspections carried out. Therefore, based on the latest technological developments and the latest research trends on ECT, there has been an inspection method that is carried out using the GMR sensor. The ability of the GMR sensor probe to detect various types of defects on material are giving an advantage, besides the size of the GMR sensor probe is small compared to the coil probe used. This allows the GMR sensor probe to be used in small workplaces in addition to providing high data accuracy. The review specifically examined technique and design compensation based on their primary characteristics/structures, strengths, and weaknesses. To remove the lift-off error, the methodologies and design from the hardware and software have been examined. GMR sensor outperforms and achieves superior accuracy when compared to both technique design hardware compensations.

8. Acknowledgement

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