Detection of wall thinning of carbon steel pipe covered with insulation using Pulsed Eddy Current technique

Duck-Gun Park [a*], M.B. Kishore[a] , D. H. Lee [a]
[a] *Nuclear Materials Development Division , Korea Atomic Energy Research Institute, Taejeon, South Korea -305-353,*
[*] *Corresponding author: dgpark@kaeri.re.kr*

Abstract

Local wall thinning in pipelines affects the structural integrity of industries like nuclear power plants (NPPs). In the present study a pulsed eddy current (PEC) technology to detect the wall thing of carbon steel pipe covered with insulation is developed. The test sample is a ferromagnetic carbon steel pipe having different thickness, covered with a 10 cm plastic insulation laminated by 0.4 mm Al plate to simulate the pipelines in NPPs.The PEC Probe used for the wallthinning detection consists of an excitation coil and a Hall-sensor. The excitation coils in the probe is driven by a rectangular bipolar current pulse and the Hall-sensor will detects the resultant field. The Hall sensor output is considered as PEC signal. Results shows that the PEC system can detect wall thinning in an insulated pipeline of the NPPs.

Key words: Pulsed eddy current (PEC), single core probe, wall thinning, insulation.

1. Introduction

The pipelines of power plant and heat exchanger are covered with thermal insulator in order to decrease the heat loss. During long-term services, corrosion might occur on the outer side of the pipe as corrosion under insulation (CUI) [1], or on the inner side of pipe as flow accelerated corrosion (FAC)[2], and develops into wall thinning of pipelines, which may finally results in catastrophic failure. Therefore, local wall thinning is a point of concern in almost all steel structures such as the pipe lines, usually the pipelines are covered with a thermal insulator which is made up of the materials having low thermal conductivity (fiberglass or mineral wool); hence the NDT methods which are capable to detect the wall thinning and defects without removing the insulation are necessary. There are several noncontact electromagnetic NDT methods in use, such as the eddy current technique (ECT). The conventional eddy current technique (ECT) which operates with single frequency sinusoidal excitation has gained a wide acceptance in the field of NDT but this technique suffers from a limitation i.e., penetration depth or skin depth. The skin depth equation is given by $\delta = \sqrt{1/\pi\mu\sigma f}$ where μ is the permeability, σ is the conductivity and f is the frequency of excitation, the penetration depth δ depends on excitation frequency f [8]. The PEC technique uses repetitive pulses having short duration in time instead of a sinusoidal wave with a single frequency. Since the Fourier transform of a pulse contains multiple frequency components, a pulsed excitation generates numerous frequencies simultaneously in the work piece. The pulsed eddy current (PEC) technique offers an alternative to these conventional techniques because of its potential advantages such as less susceptible to interference, less power consumption because of using short pulses which is more desirable specification in development of portable instruments. In order to apply the PEC in the ferromagnetic sample, the excitation frequency has to be sufficiently lowered and bipolar pulse waves are employed. The induced signal is measured by Hall-sensor at the same time and.

2. System Development

The PEC system consists of a pulse amplifier, the probe having a driving coil with a magnetic field detecting sensor (Hall-sensor), a sensitive differential amplifier with variable gain to amplify the output voltage from the Hall-sensor, A/D converter, and a computer with signal processing software. During a defined time a DC-current (pulse having definite pulse width) is applied to the exciting coil causing a stable magnetic field in the pipe or vessel wall. After switching off the current, the magnetic field drops rapidly to zero generating eddy currents within the material under examination. The density of the eddy currents, within the enclosed magnetic field, is directly related to the thickness of the material. The PEC response to varying metal thickness was measured at various thicknesses cover with insulation and shielded with steel. The PEC probe was scanned on the tested sample insulated and shielded with the plastic and galvanized steel respectively. The strength and measurable duration of the eddy current depend on the strength of the magnetic field and as well as the conductivity and permeability of the material. These properties are all being monitored and measured by the PEC system. The exciting signal frequency and duty cycle can be adjusted by the waveform generator depending on experimental requirements. The PEC probe characteristics are determined by the combination of measuring environments such as induced current, insulation thickness, sample thickness. Excitation coil in the probe is driven by a bipolar rectangular current pulse; the time domain features of the detected pulse, such as ‘peak value’ and ‘time to zero’ were used to describe the wall thinning in the tested sample. A real time LabVIEW program was developed for the data acquisition and scanning the probe on the insulated sample. The scanning results were continuously displayed on the computer monitor.

3. Results

In order to simulate the wall thinning of steel pipe, the mock-up of wall thinned pipe was fabricated as shown in Fig.1. Prior to measuring signal on simulated corrosion areas, signal received from intact areas of the pipe having the initial pipe thickness is recorded as reference signal. When the high level of current is applied to the exciting coil, the coil make a static magnetic field (primary magnetic field) in the sample; when the exciting current suddenly drops to a zero, eddy currents are induced in the sample; the time-varying magnetic fields (secondary magnetic field) generated by the decaying eddy currents is captured by the Hall-sensor as a voltage signal. The strength and duration of induced pulse signal resembles the average wall thickness can be measured. The duration of the eddy currents will have an effect on the transition period of the detected pulse.

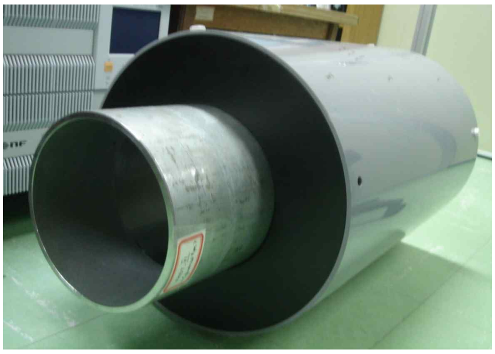

Fig. 1. The configuration of sample mock-up. The tube was separated with different thickness region with 2.5, 5, 8 mm.

Fig.2. shows the hall sensor detected voltage corresponding to the excitation pulse for various thickness changes. The thicker part of the sample shows the less pulse amplitude and decreases to minimum at faster rate which means that the eddy currents induced in that thicker part decays at faster rate and moreover the change of eddy currents magnitude is considerably more hence it has a higher impact on the hall sensor detected pulse as the sample thickness is decreasing. The magnitude and the transition are also changed accordingly as shown in fig.2.Usually when the stainless cladding with 0.4 mm thickness was inserted between the insulation and probe, the resolution to identify the thickness variation was deteriorated. The thickness resolution can be recovered by increasing the current density. As a result, it can be concluded that the developed PEC system can effectively measures the wall thinning of carbon steel pipe without removing the thick insulator covered with galvanizing steel cladding.

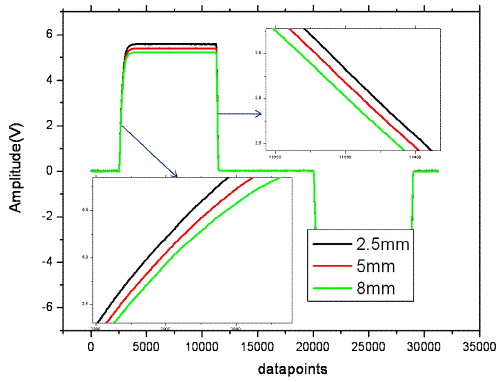

Fig.2. Comparison of signals obtained from different Wall thickness.

4. Conclusion

In order to measure the wall tinning of carbon steel pipe without removing the insulator covered with cladding, the PEC system was developed. The system was applied in the mock-up sample with various thickness region covered with 95mm thick insulator with galvanizing cladding. The system can distinguish the wall thickness of 2.5, 5, 8mm under 95mm insulation covered with 0.4mm stainless cladding.

REFERENCES

[1] S. Winnik, "Corrosion-under-Insulation (CUI) guidelines", Europaen Federation of Corrosion Publications No. 55, Woodhead Publishing Limited, Cambridge England
[2] W.H. Ahmed, Annals of Nucl. Energy, 37 (2010) 598-605, 999.