Compensating for Variations in Material Properties in Remote Field Testing of Heat Exchanger and Boiler Tubes.

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Abstract

Material compensation technique has been developed for RFT inspection. It is useful whenever difference in material property and/or wall thickness exists between calibration sample and actual tubes or pipes. A new "Material Compensation" software program can help operators of RFT equipment to adjust their wall-loss predictions in the presence of magnetic permeability changes and/or wall thickness variations. The new software is described and several case studies would be presented.

Introduction

It is well known that the properties of carbon steel tubes change with such things as applied stresses, (which affects the magnetic permeability of the tube), tubes that have become bent in service, (such as bent boiler tubes), tubes that have been bent during manufacturing (such as return bends) and tubes that have been bent during handling (such as the outer rows of exchanger tubes removed for cleaning every shutdown) can give signals that can be mistaken for wall loss. Quite often, it is difficult to find calibration sample that is identical to actual tubes/pipes in both material properties and geometry (thickness in particular). Material property variation could be due to manufacturing process or the use of different tube types while tube geometry variations could be due to manufacturing tolerance or availability of calibration tubes. On the other hand, tubes in a bundle may originate from different manufacturers or in extreme cases such as when tubes are mixed with different types and grades when heater exchangers were manufactured. Difference in either material properties or tube wall thickness requires material compensation before defects can be quantified. It is a better solution to use material compensation technique than to prepare all types of calibration tubes to calibration all possible tube types that may exist in a tube bundle. This article shows the feasibility of using material compensation to take into account material and wall thickness difference between cal tube and actual tube in the process of RFT data analysis.

RFT theory and material compensation

RFT data analysis is usually done through voltage plane polar plot [1]. RFT data analysis can also be done in the same way as conventional eddy current analysis [2].

Let’s assume that defect trace angle is θ, and the RFT defect depth in radians is φ. Then θ and φ are related to each other as follows:

$$\tan \theta = e^{\varphi} \sin \varphi / (1 - e^{\varphi} \cos \varphi), \quad (1)$$

where θ and φ are illustrated in Fig. 1. φ is a linear function of defect depth while θ is slightly non-linear with respect to defect depth, as shown in Fig. 2. It is a first order approximation to assume that θ is a linear function of defect depth with an offset of 45 degrees at nominal wall area.

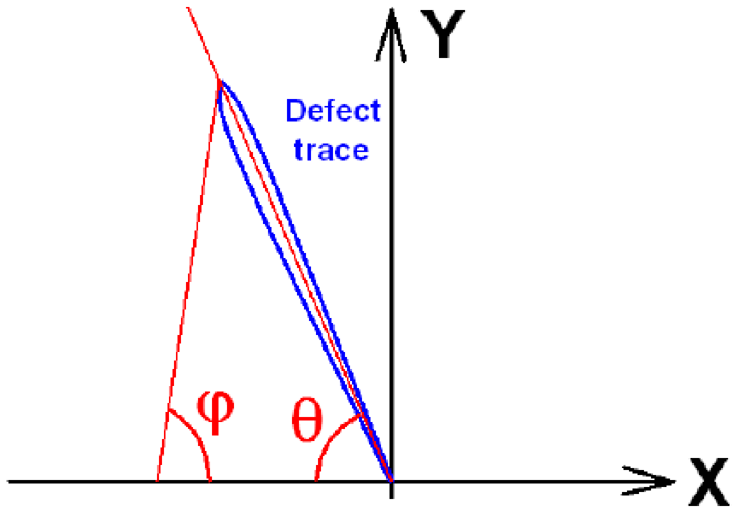

Figure 1. Illustration of relationship between defect trace angle θ and RFT defect depth φ.

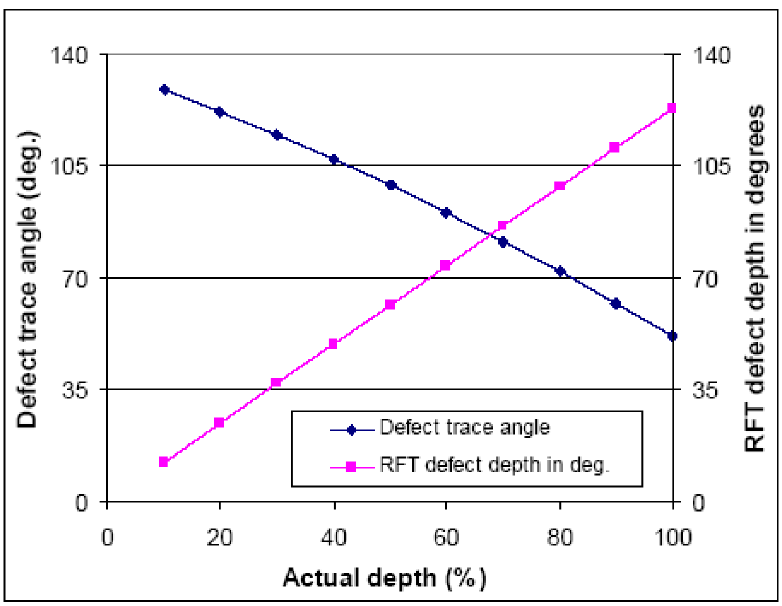

Figure 2. Typical plot of defect trace angle and RFT defect depth in degrees as a function of actual defect depth in percentage.

When actual tubes/pipes are different from calibration tubes, calibration curves such as those in Fig. 2 need adjustments through material compensation, which involves primarily calibration defect trace rotation and phase spread adjustment. The amount of trace rotation and phase spread is determined primarily by the difference of nominal phase reading between the calibration and actual samples. Free-air phase reading is needed for the compensation.

Software program description

A software program called EasyLog was developed for both RFT and EC inspection. EasyLog is a multi-functional software program. Both data acquisition and data analysis are in one single program. RFT material compensation is one of many features the program has. Fig. 3 is a screen capture of the main window of the program.
User interface for material compensation is at lower left corner area of the screen, as shown in Fig. 3.
Two parameters are required by material compensation: RFT signal phase for probe in the free air and in the nominal tube wall area of the calibration tube. These values at given frequency can be obtained through EasyLog's instrument settings wizard, which is part of instrument setup process.

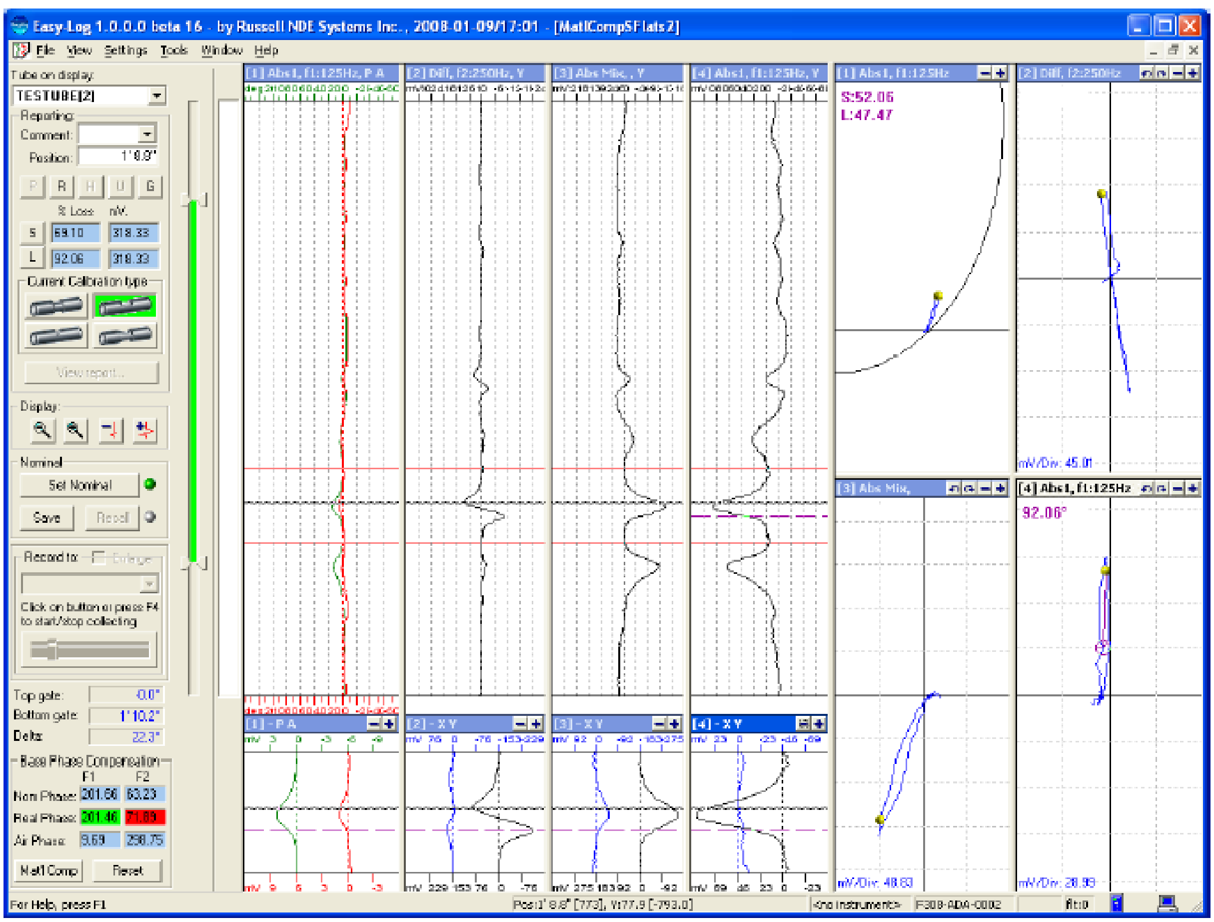

Figure 3. A screen capture of EasyLog program.

Experimental verification of material compensation

Material compensation has been successfully applied to both tubes and pipes. The defect depth calls are improved after material compensation. Without material compensation, it is difficult and sometimes even not possible to size defects in tubes that are significantly different from cal tubes in wall thickness and material properties (magnetic permeability and electric conductivity). Case studies for tubes would be presented during the conference paper session.

Summary

RFT Material compensation has been successfully applied to test tubes which are different from calibration tubes in terms of tube material type and/or tube wall thickness. Defect types that have been material compensated include flats, full circumferential grooves and flat bottom holes. The EasyLog software program with material compensation algorithm has been developed.

References

1. Mackintosh, D.D., D.L. Atherton and S. P. Sullivan, *Materials Evaluation*, Vol. 51, No. 3, April, 1993, pp.492-495.

2. Cecco, V.S., G. Van Drunen, and F.L. Sharp, *Eddy Current Manual* AECL-7523 Rev. 1, Atomic Energy of Canada Ltd., 1983.