



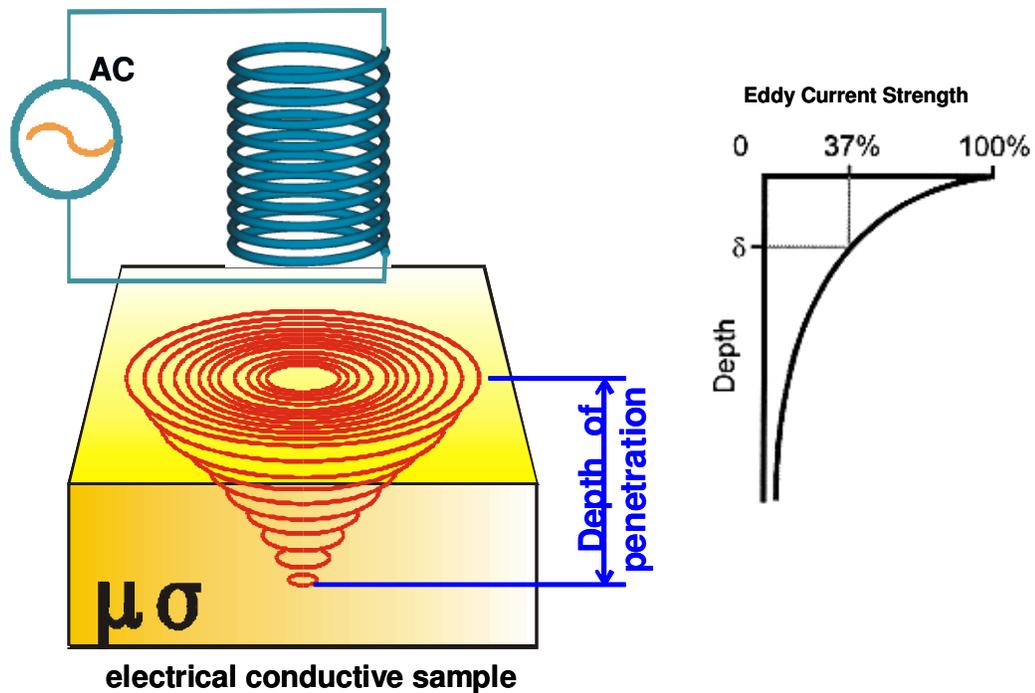
EDDY CURRENT THEORY



Eddy Currents are closed loops of induced current circulating in planes perpendicular to the magnetic flux. They normally travel parallel to the coil's winding and the flow is limited to the area of the inducing magnetic field.

Eddy Currents concentrate near to the surface adjacent to an excitation coil and their strength decreases with distance from the coil i.e. Eddy Current density decreases exponentially with depth. This phenomenon is known as the skin effect and the explanation is shown in Diagram 1

Diagram 1: Eddy Current Field Depth of Penetration & Density



Skin effect arises when the Eddy Currents flowing in the test object at any depth produce magnetic fields which oppose the primary field, thus reducing the net magnetic flux and causing a decrease in current flow as the depth increases.

Alternatively, Eddy Currents near the surface can be viewed as shielding the coil's magnetic field, thereby weakening the magnetic field at greater depths and reducing induced currents.

Eddy Current is used in the inspection of ferromagnetic and non-ferromagnetic materials. The principle of Eddy Current based inspection is explained below.

Principle of Eddy Current

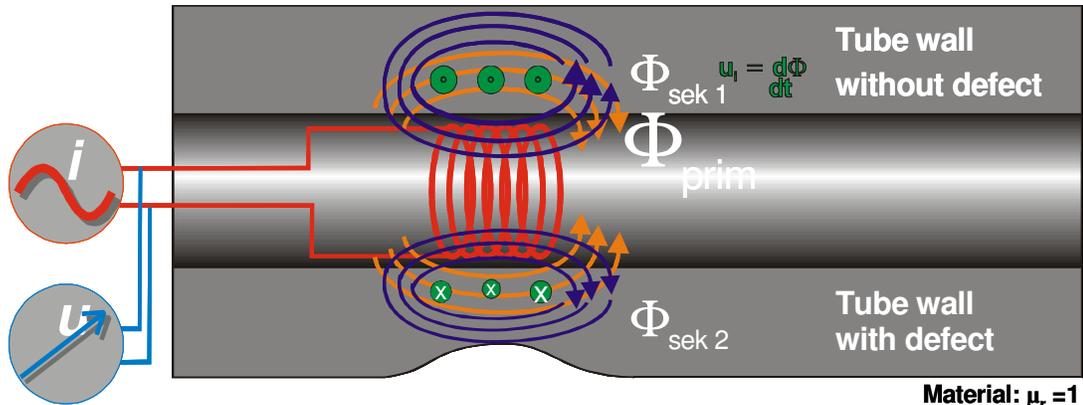
Diagram 2 shows the principle of the Eddy Current sensor inducing a primary field, according to Lenz Law, 90 degree to the original field lines of the coil.

Due to the further induction of the Eddy Current in the primary field of the electric conductive material, a secondary field is induced (again according to the Lenz law) and this has an effect to the coil impedance.

In case of a defect in the tube wall, the secondary field is changed in comparison to its origin. The change of the Eddy Current field lines causes a change of the impedance of the Eddy Current probe coil, which can be displayed in the impedance screen of the Eddy Current equipment.

The impedance screen displays the change of the coil impedance in amplitude change and phase change. This is evaluated in comparison to a calibration with known artificial defects at a calibration sample which has the same electric conductive and dimension properties as the inspected tube.

Diagram 2: Principle of Eddy Current



- Alternate current induces a primary field in a coil
- The primary field induces Eddy Currents in the tube wall
- The Eddy Currents induce a secondary field, which has an affect to the coil impedance
- Defects in the tube wall are changing the secondary field and consequently the impedance of the coil
- The change of the coil impedance can be measured in input/output phase and amplitude

The differential channel is ideal for detecting local defects while the absolute channel is ideal for detecting gradual defects. Diagram 3 shows the Eddy Current signal response of a differential and absolute coil system to local and gradual defects. The differential channel shows two sharp peaks for local defects while the absolute channel defines the local defects with a big peak.

Diagram 4 shows the phase angle analysis of defect signals with different depths.

Diagram 3: Eddy Current signal responses to local and gradual defects

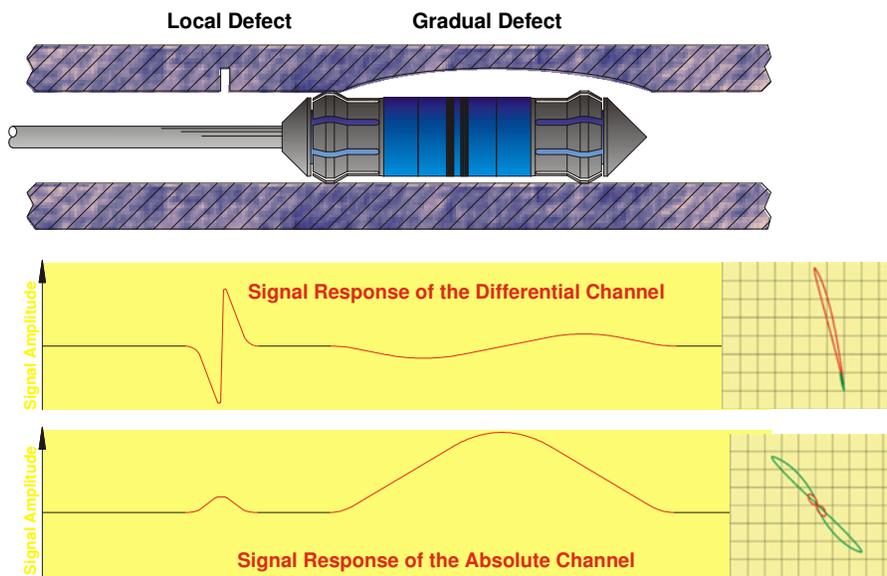
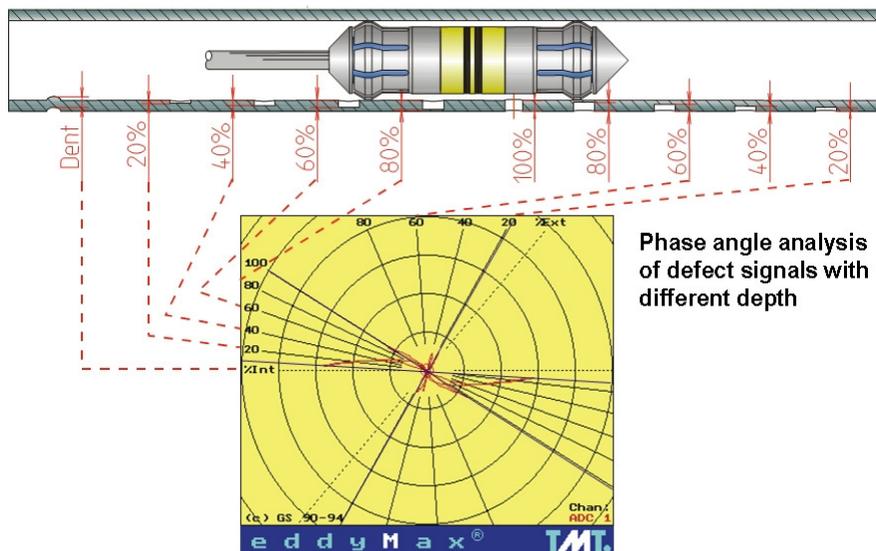


Diagram 4: Phase angle analysis



Eddy Current based inspection of Ferro and Non-Ferromagnetic materials

The Eddy Current field line penetration into the tube wall is essential for the possible detection of defects on either side of the wall by means of field line changes due to inhomogeneities like defects.

The standard depth of penetration is described as the following function:

$$\delta = \frac{1}{\sqrt{\sigma \mu_0 \mu_r f}}$$

- δ = Standard Depth of penetration [mm]
- σ = Material electric conductivity [Ω/mm^2]
- μ_0 = Absolute permeability
- μ_r = Relative permeability
- f = Frequency

Non ferromagnetic materials have relative and absolute permeability value of 1. The standard depth penetration of the Eddy Current field lines depends on the material electric conductivity and the selected frequency. Therefore, non ferromagnetic materials can be well inspected with the modes and channels as described in the Multiple Frequency Eddy Current Technique.

Ferromagnetic materials, on the other hand, have relative and absolute permeability values far larger than 1. Consequently, the Eddy Current field line depth of penetration is very limited. This is sufficient for surface defect detection such as surface braking crack detection in carbon steel materials.

This formula shows that the conventional Eddy Current technique is not capable of inspecting and detecting on either side of the ferromagnetic tube walls. Therefore, other extended Eddy Current techniques like the Magnetic Biased Eddy Current Technique and Remote Field Eddy Current Technique are used to overcome the described limitation.