Weld repaired area detection on cast piece by using Eddy Current NDT method

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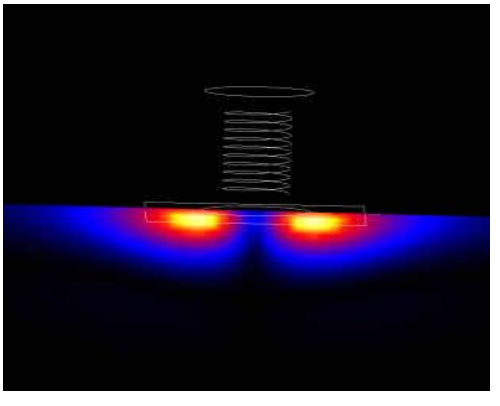
SCOPE:
This study covers detection of weld repaired areas on 90% spheroid casting (Ferromagnetic) pieces over paint.: Eddy Current Techniques has been used as a non destructive testing method

Basic Principles of Eddy Current Inspection:

Eddy current inspection is one of several NDT methods that use the principal of "electromagnetism" as the basis for conducting examinations. Several other methods such as Remote Field Testing (RFT), Flux Leakage and Barkhausen Noise also use this principle.

Eddy currents are created through a process called electromagnetic induction. When alternating current is applied to the conductor, such as copper wire, a magnetic field develops in and around the conductor. This magnetic field expands as the alternating current rises to maximum and collapses as the current is reduced to zero. If another electrical conductor is brought into the close proximity to this changing magnetic field, current will be induced in this second conductor. Eddy currents are induced electrical currents that flow in a circular path. They get their name from "eddies" that are formed when a liquid or gas flows in a circular path around obstacles when conditions are right.



One of the major advantages of eddy current as an NDT tool is the variety of inspections and measurements that can be performed.

In the proper circumstances, eddy currents can be

- Crack Detection
- Material Thickness Measurements
- Coating Thickness Measurements
- Conductivity Measurements For:
    - Material Identification
    - Heat Damage Detection
    - Case Depth Determination
    - Heat Treatment Monitoring

Some of he advantages of eddy current inspection

- Sensitive to small cracks and other defects
- Detects surface and near surface defects
- Inspection gives immediate results
- Equipment is very portable
- Method can be used for much more than flaw detection
- Minimum part preparation is required
- Test probe does not need to contact the part
- Inspects complex shapes and sizes of conductive materials

Some of the limitation of eddy current inspection include:

- Only conductive materials can be inspected
- Surface must be accessible to the probe
- Skill and training required is more extensive than other techniques
- Surface finish and and roughness may interfere
- Reference standards needed for setup
- Depth of penetration is limited
- Flaws such as delaminations that lie parallel to the probe coil winding and probe scan direction are undetectable

Depth of Penetration & Current Density

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 flow is limited to the area of the inducing magnetic field. Eddy currents concentrate near the surface adjacent to an excitation coil and their strength decreases with distance from the coil as shown in the image. Eddy current density decreases exponentially with depth. This phenomenon is known as the skin effect.

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 net magnetic flux and causing a decrease in current flow as 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.

The depth that eddy currents penetrate into a material is affected by the frequency of the excitation current and the electrical conductivity and magnetic permeability of the specimen. The depth of penetrant decreases with increasing frequency and increasing conductivity and magnetic permeability. The depth at which eddy current density has decreased to 1/e, or about 37% of the surface density, is called the standard depth of penetration (δ). The word 'standard' denotes plane wave electromagnetic field excitation within the test sample (conditions which are rarely achieved in practice). Although eddy currents penetrate deeper than one standard depth of penetration they decrease rapidly with depth. At two standard depths of penetration (2δ), eddy current density has decreased to 1/e squared or 13.5% of the surface density. At three depths (3δ) the eddy current density is down to only 5% of the surface density.

Eddy Current Instruments

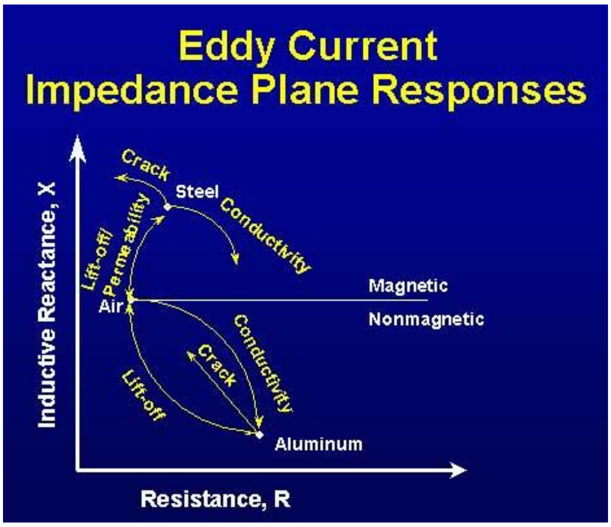
The most basic eddy current testing instrument consists of an alternating current source, a coil of wire connected to this source, and a voltmeter to measure the voltage change across the coil. An ammeter could also be used to measure the current change in the circuit instead of using the voltmeter. Please see picture 1. Test system used in this study.

Picture 1: Test system

The impedance plane diagram is a very useful way of displaying eddy current data. As shown in the figure below, the strength of the eddy currents and the magnetic permeability of the test material cause the eddy current signal on the impedance plane to react in a variety of different ways.

If the eddy current circuit is balanced in air and then placed on a piece of aluminum, the resistance component will increase (eddy currents are being generated in the aluminum and this takes energy away from the coil and this energy loss shows up as resistance) and the inductive reactance of the coil decreases (the magnetic field created by the eddy currents opposes the coil's magnetic field and the net effect is a weaker magnetic field to produce inductance). If a crack is present in the material, fewer eddy currents will be able to form and the resistance will go back down and the inductive reactance will go back up. Changes in conductivity will cause the eddy current signal to change in a different way.

When a probe is placed on a magnetic material such as steel, something different happens. Just like with aluminum (conductive but not magnetic) eddy currents form which takes energy away from the coil and this shows up as an increase in the coils resistance. And, just like with the aluminum, the eddy currents generate their own magnetic field that opposes the coils magnetic field. However, you will note for the diagram that the reactance increase. This is because the magnetic permeability of the steel concentrates the coil's magnetic field this increase in the magnetic field strength completely overshadows the magnetic field of the eddy currents. The presence of a crack or a change in the conductive will produce a change in the eddy current signal similar to that seen with aluminum.



Conductivity Measurements

One of the uses of eddy current instruments is for the measurement of electrical conductivity. The value of the electrical conductivity of a metal depends on several factors, such as its chemical composition and the stress state of its crystalline structure. Therefore, electrical conductivity information can be used for sorting metals, checking for proper heat treatment, and inspecting for heat damage.

The technique usually involves nulling an absolute probe in the air and placing the probe in contact with the sample surface. For nonmagnetic materials, the change in impedance of the coil can be correlated directly to the conductivity of the material. The technique can be used to easily sort magnetic materials from nonmagnetic materials but it is difficult to separate the conductivity effects from magnetic permeability effects, so conductivity measurements are limited to nonmagnetic materials. It is important to control factors that can affect the results such as the inspection temperature and the part geometry. Conductivity changes with temperature so measurements should be made at a constant temperature and adjustments made for temperature variations when necessary. The thickness of the specimen should generally be greater than three standard depths of penetration. This is so the eddy currents at the back surface of the sample are sufficiently weaker than variations in specimen thickness that are not seen in the measurements.

Generally large pancake type, surface probes are used to get a value for a relatively large sample area. The instrument is usually setup such that a ferromagnetic material produces a response that is nearly vertical. Then, all conductive but nonmagnetic materials will produce a trace that moves down and to the right as the probe is moved toward the surface. Think back to the discussion on the impedance plane and these type of responses make sense. Remember that inductive reactance changes are plotted along the y-axis and resistance changes are plotted in the x-axis. Since ferromagnetic materials will concentrate the magnetic field produced by a coil, the inductive reactance of the coil will increase. The effects on the signal from the magnetic permeability overshadow the effects from conductivity since they are so much stronger.

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There are 3 major parameter in eddy Current testing:

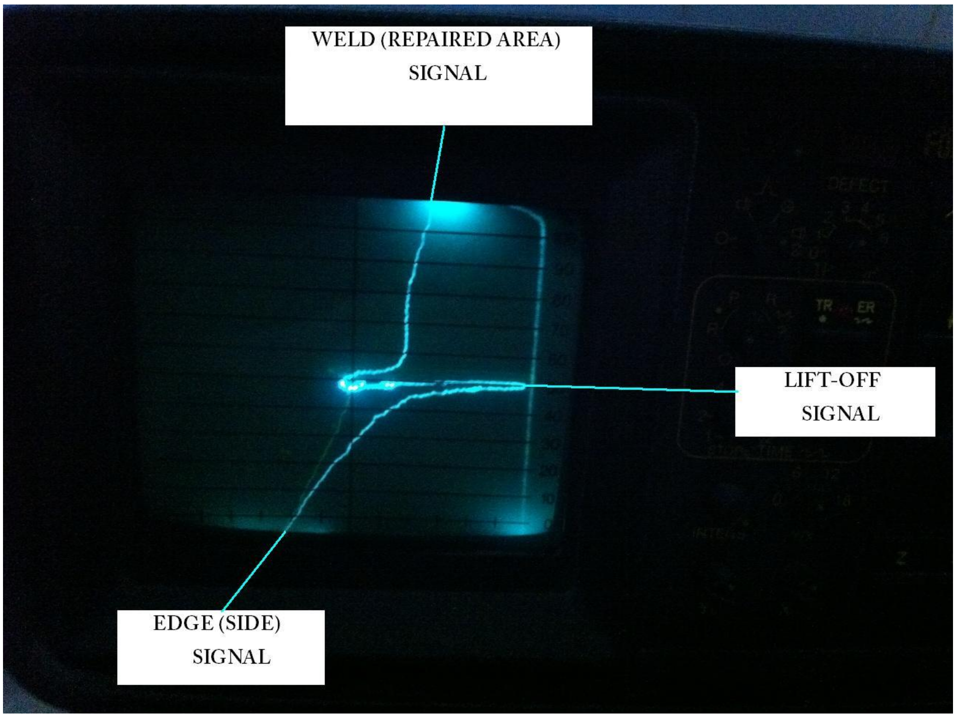
1. Conductivity of material
2. Magnetic Permability of material
3. Geometry of part

For any eddy current inspection purpose only one parameter shall be variable. Other 2 parameter shall be constant to find out changes in the parameter that aimed to be find out.

In our case 3 major parameter are variable: the material is 90 % sphero therefore ferromagnetic and permeability is variable, geometry is not constant , thickness and shape is diffrenet, and conductivity of cast part and the welded section is also variable. The only useful variably for our purpose is conductivity difference between cast and welded section. For this reason detection of repaired area on cast piece conductivity measurement principle has been used.

Theoretically conductivity difference between cast part and the welded part should show us the repaired area. As it explained above it was difficult to separate the conductivity effects from magnetic permeability effects, and edge effect. All calibration parameters such as probe type, frequency, phases, dB value etc. areso adjusted to obtain different signals with different phase (angle on screen).

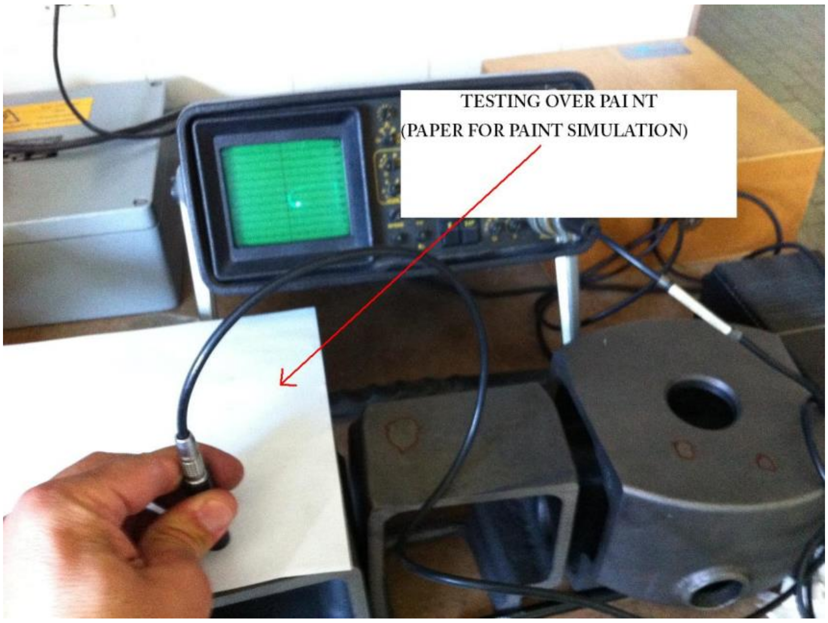
As a result of the as it shown in the below picture 3 different signals with three different phase are obtained.



Picture 2: Eddy current signals

As it seen above picture phase angles of 3 signals are aprox.90 degrees. This allow to find out repaired section on the casting.

To simulate paint on the casting, sheet of paper is placed on the casting surface and the inspection is conducted with the same parameter. The result was the same; to find out repaired section over the paint is possible with this technique.



CONCLUSION:

1. Eddy Current method is suitable method for detection of conductivity difference.
2. With the proper parameter selection it is possible to detect conductivity difference between cast and welded section.
3. The technique describe above is one of the most sensitive method for the purpose
4. With the technique it is also possible to detect welded section over paint
5. The system is portable therefore the cast part can be tested on the vehicle if there is accessibility to surface of the part.

Annex1: Weldoncast-IspectionVideo

To watch video please go below link

http://www.dailymotion.com/video/xjkqon_weldoncast-et