Magnetic Analysis Corporation

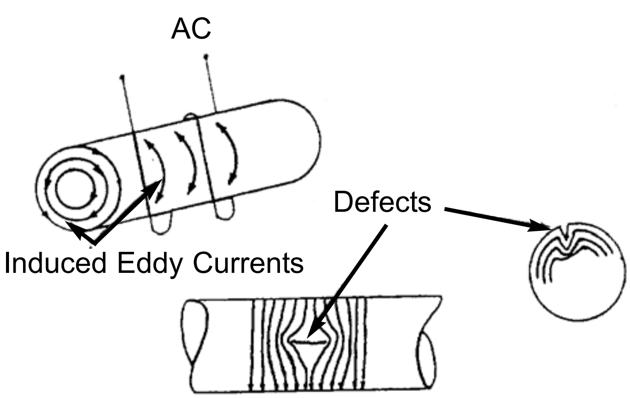
DATA SHEET NO GI-2

FLAW DETECTION USING ENCIRCLING COIL EDDY CURRENT SYSTEMS

PRINCIPLES OF OPERATION

The detection of flaws such as seams, cracks, pits, slivers, weld-line defects and internal discontinuities in metallic materials can be done conveniently by using an encircling coil eddy current system. This type of inspection system is most frequently used to locate surface defects in bar stock or wire products, and to detect both ID and OD defects in tubing. The test is usually conducted at production speed.

The basic principles of operation in encircling or through coil systems are simple. The test coil is excited by an alternating current of a given frequency which induces a flow of eddy currents around the material that is passing through the coil. When a flaw in the material passes through the coil, it causes a change in the flow of eddy currents. It is this change that is detected by the electronics.



Probable Flow of Eddy Currents Around a Defect

TESTING MAGNETIC MATERIALS

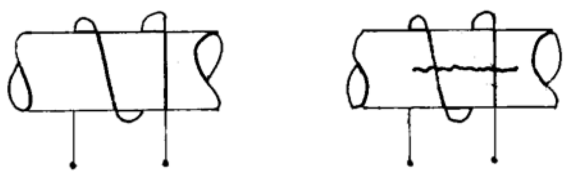
When testing materials such as carbon steel, austenitic stainless, alloy steels having a permeability higher than 1, it is often necessary to saturate the material with a magnetic field. The effect of this magnetic saturation is to even out the permeability variations in the material, thereby making the material appear to the test coil system as though it were non-magnetic. The material can be saturated by using a permanent magnet or a saturating coil in which D.C. current is flowing. In either case, the eddy current test coil is placed within the saturating field and performs the test.

ABSOLUTE OR DIFFERENTIAL TEST MODES

In actual testing, a single coil system (absolute mode) or a system of two or more coils that electrically subtract from each other (differential or null mode) may be used to detect defects.

When the absolute mode is used, the output of the coil containing acceptable material is fed into the electronics, and variations from this norm are detected. When the coils are connected in the differential mode, they continually test and compare adjacent segments of the material as it passes through the coils. If there is “good” material in both coils, the resulting difference is zero. In electronic terms, when the absolute mode is used, the change seen by the electronics is the difference between the biasing voltage output for good material and the change in this voltage caused by a defect passing through the coil. For example, if a defect causes a change of 1 volt in the output of the coil, and the normal output of the coil is 10 volts, then the electronics senses a 10% change. When using the differential mode, the same defect would theoretically produce an infinite change as the difference, and the electronics would register 1 volt as compared to zero. The two modes are illustrated in the diagram below.

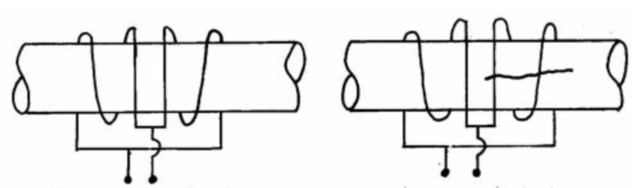
ABSOLUTE MODE



10 v.
Meter Biased to Zero

11 v.
Meter Reads 1 v

DIFFERENTIAL MODE



Zero Volts Actual

One Volt Actual

Generally, a differential mode system is more sensitive to intermittent defects because one section of material is being compared to the next. However, with long, uniform discontinuities such as seams, a differential mode system may indicate only the beginning and the end of the seam, and nothing in between. Conversely, the absolute mode would signal for the complete length of the defect. However, the ability of the differential mode to detect smaller changes and to produce a better flaw signal-to-noise ratio makes it more suitable for general applications.

FREQUENCY SELECTION

The ability to select between a wide range of frequencies permits an eddy current tester to vary the depth of penetration and to discriminate between signals caused by conditions such as noise, handling marks, and defects. The proper frequency for testing a given material is determined by the conductivity, the type of defects to be detected, the diameter, and in the case of tubing, the wall thickness.

By properly choosing the excitation frequency for a given material, it is often possible to generate a phase shift between the signal for handling marks, and the signal for a defect. When testing tubing, if the excitation frequency is increased, the phase angle between the signal for a defect on the O.D. and the signal for a defect on the I.D. will increase. However, the signal amplitude for the I.D. defect will decrease as compared to the signal amplitude of the O.D. defect when the excitation frequency is increased. Thus, if the excitation frequency is too high, the detection of I.D. defects becomes impossible.

SENSITIVITY SELECTION

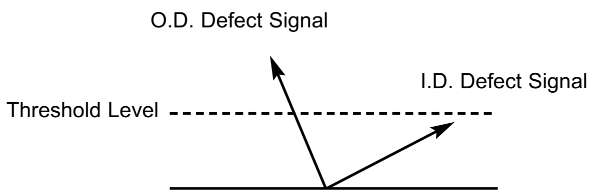
The sensitivity control permits adjustment of the level of defect signal at which the alarm circuits will function.

FILTER SELECTION

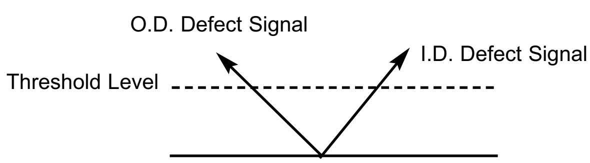
The speed at which a defect passes through the coil produces a change in the flow of eddy currents at a very distinct rate. This rate of change can be equated to a given frequency. Therefore, if circuits are used that only permit the instrument to accept these frequencies, signals generated at other frequencies will be ignored. The circuits that do this are called filters.

PHASE SELECTION

The phase control allows 360º rotation of all signals. This permits the rotation of desired signals to a place where they will exceed the threshold level and activate the alarm circuits. If a signal for an I.D. defect is smaller in amplitude than an equivalent O.D. defect, it is usually possible to adjust the phase control so that both defects activate the alarm circuits equally. This phase rotation is illustrated in the following diagram.



Before Rotating Phase



After Rotating Phase

COIL SELECTION

The coils can be either absolute or differential mode. Some equipments permit use of both methods simultaneously. Coils can be wound with different physical characteristics such as the spacing between the differential coils, the actual width of the coils, and the use of multiple coils electrically connected in different configurations.

For some applications, such as inspecting only the weld portion of a tube or pipe, a tangent or sector coil is used instead of an encircling coil. This provides greater convenience as the material does not need to be threaded through the coil when changing coil sizes etc. Generally, the same principles for encircling coil eddy current testing are applicable also to tangent coils.

The purpose of these different coil systems is to improve the detection of specific types of defects in particular materials. In order to ensure equal test results on a product that does not have a round cross section, coils may also be manufactured to conform to the cross section of the product.

FLAW DETECTION BY USE OF PROBE TYPE EDDY CURRENT SYSTEMS

PRINCIPLES OF OPERATION

Surface seams and cracks in metallic materials can be reliably detected by using eddy current technology. Eddy currents are induced by one or more test probes which traverse the surface of the material under test.

To conduct a test using probe type eddy current instruments, the probes are excited by an alternating current of a given frequency which induces a flow of eddy currents in the metal beneath them. As the test probes pass over a flaw, the flaw causes a change in the flow of eddy currents, and it is this change which is detected by the instrument's electronics. The change in the flow of eddy currents as the probes pass over the defect is generally proportional to the depth of the defect. It is therefore possible to estimate the depth with proper electronic calibration.

Relative motion between the test probe and the material being inspected is a requirement in this type of test. Generally, the material to be tested is rotated past a fixed probe, or the probe is rotated around the part as it is fed through. In either case, the area examined by the probe is a helix with a pitch determined by the speed of rotation and the linear throughput speed.

Figure 1 illustrates that a surface defect that is shorter in length than the helical pitch will not be consistently detected. The helical pitch is a function of the rotational speed of the probes and throughput speed of the material. Increasing the speed of the probes, or using multiple probes decreases the pitch, enabling shorter defects to be detected at the same throughput speed. Decreasing the linear throughput speed also lessens the helical pitch.

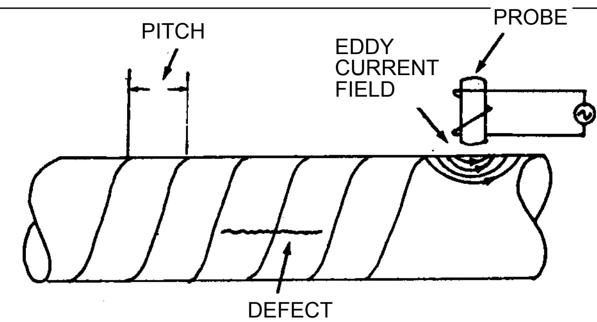


Figure 1

In using eddy current techniques for detecting flaws, other so called "false indications" caused by surface conditions and normal metallurgical variations ("noise"), may be detected. To eliminate these unwanted indications, various selective circuits can be added to the basic instrumentation.

SELECTIVE CIRCUITS

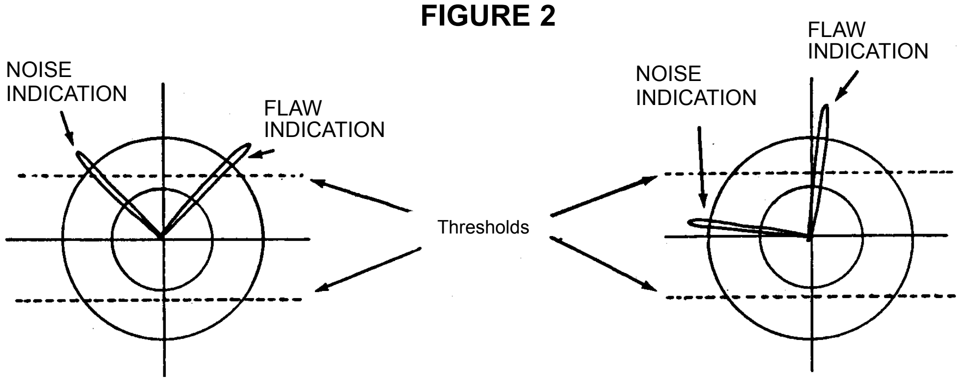
Frequency Selection

The ability to select between several different frequencies permits variation in the depth of penetration on given specimens of the same material. It is also often possible to generate a phase shift between the signal for noise and the signal for a defect by changing the excitation (test) frequency.

Phase Selection

The phase control permits 360 degree rotation of all signals. This allows the tester to discriminate between signals caused by extraneous noise and those for defect signals. If there is a phase difference between the noise and the defect signals, the output to markers,horns etc., can be modified to indicate only those signals in the selected phase.

FIGURE 2



Display before phase modification where both flaw and noise indications pass above the threshold

Display after use of phase selection circuit to rotate the phase so only the flaw indication passes the threshold

Filter Selection

The speed at which the probe passes over the defect causes the change in the flow of eddy currents to occur at a very distinct rate. This rate of change can be equated to a given frequency. Therefore, if circuits are used that only permit these frequencies to enter the instrument, signals generated at other frequencies will tend to be ignored. The circuits that do this are called filters.

Sensitivity Selection

The sensitivity control permits adjustment of the level of defect signal at which the alarm circuits will function.

Probe Selection

The test probes can be connected in either the absolute or differential (null) mode. When the probes are used in the absolute mode, one or more connected in parallel, the equipment is biased on a “good” portion of material and variations in the eddy current flow within the network are detected. When the probes are connected in the differential mode, there must be at least two probes, although they may appear as one. These two probes electrically subtract from each other. In effect, they compare what one senses with what the other senses. The resulting difference is fed into the instrument electronics and evaluated.

Theoretically, probes connected in the differential mode produce a better flaw signal to noise ratio. The probes may also be designed with various configurations and physical characteristics to enhance the testing of different products.

Practical application of this test system requires that the probe and material under test be moved in a controlled manner in relation to each other. For example, cylindrical shaped material can be inspected by rotating a probe around it, or by spinning the material past a stationary probe. A suitable flaw detection system, therefore, consists of an electronic indicator and control unit and (1) a rotary mechanism to spin the probes; or (2) a fixed probe, spin-feed mechanism which moves the test piece. Systems available include:

Systems for Inspecting Rod and Wire:

MultiMac® electronics with a Rotomac® rotary mechanism that spins the test probes. These systems detect surface defects in magnetic or non magnetic grades of rod and wire.

Systems for Inspecting Bar:

MultiMac® electronics and Rotomac® rotary mechanisms are combined with mechanical handling components for moving cut lengths of round bars through the test. Detects surface defects in bar stock, often as an off-line separate test station.

Helitester Systems for Parts:

Incorporates the MultiMac® electronics with a stationary mechanism for holding the test probes constant while the material is rotated past them. This is suitable for inspecting cylindrical parts.

MAC
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