FLAW DETECTION USING FLUX LEAKAGE TECHNIQUES

PRINCIPLES OF OPERATION

Magnetic Flux Leakage (MFL) inspection techniques are electromagnetic test methods primarily used to detect flaws or defects in high-permeability ferromagnetic metals such as carbon steel tubing, plate, wire rope and tubular parts.

MFL inspection can be applied with an active or a residual magnetization technique, using a DC magnetizing source. In the case of active magnetization, enough flux density is created in the material to bring it to near-saturation. In residual magnetization a temporary saturation is created. In both cases, detection of defects depends on a flux sensor probe detecting changes in the "leakage flux" that extend beyond the test piece. (Figure 1)

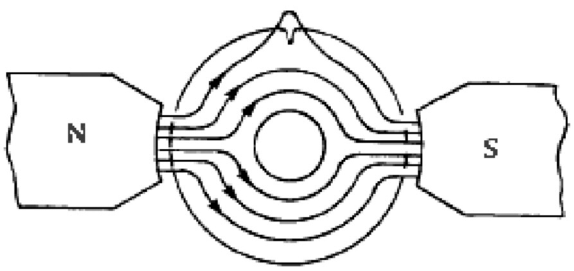


FIGURE 1
Outside diameter crack causes flux lines to "leak" beyond the tube.

ACTIVE MFL MAGNETIZATION

In Active MFL magnetization, the DC magnetizing field creates an intense magnetic flux in the material, some of which will extend or leak beyond it when interrupted by either a surface or internal defect. This "leakage flux" will generate a signal voltage in an external flux sensing probe as it is moved relative to the fixed material, or as the material is moved relative to a fixed flux sensor probe.

RESIDUAL MFL MAGNETIZATION

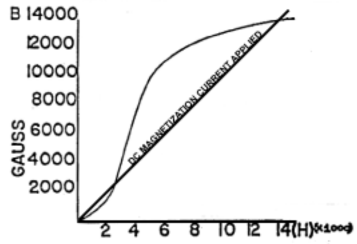
Where residual MFL magnetization is used, after saturation of the material has been achieved and the DC magnetizing field is de-energized, its remaining or residual magnetization will create constant yet very weak leakage flux patterns for surface and near-surface defects only. As a result, residual MFL techniques are most often used with dry magnetic particles for standard visual tests, or magnetic particles with-dye penetrant for "black-light" visual inspections. Effectiveness is limited to surface and near surface defects, but systems can be automated.

PRINCIPLES OF SATURATION

An important aspect of flux leakage technology is understanding the relationship between flux density and the applied magnetizing force. As shown in Figure 2 the flux density (B) in iron typically exhibits an initial rapid rise with a subsequent leveling off as the magnetic force (H) is increased. Optimum results in flux leakage testing are usually obtained when a flux density level defined as "near saturation" (a point just before the curve begins to flatten out) is reached.

Figure 3 on page 2 illustrates the relationship between Permeability (μ) and the

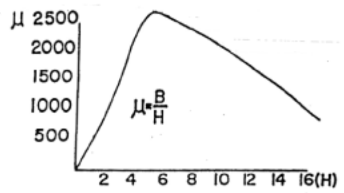
TYPICAL MAGNETIZATION CURVE FOR IRON



B = Flux density (gauss)
H = Magnetic force (oersted)

FIGURE 2

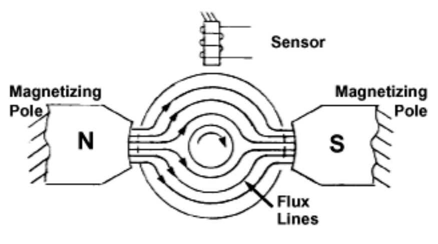
CURVE SHOWING RELATION OF PERMEABILITY TO MAGNETIZING FIELD



μ = Permeability
H = Magnetizing Field (oersteds)
B = Flux Density (gauss)

FIGURE 3

Magnetizing Force (H). Material that is highly permeable, such as iron becomes magnetized very easily and, in fact, augments the magnetic field created by a magnetizing force. Figure 2 shows that when material is fully saturated, its flux density can not be increased further. Figure 3 shows that its high relative permeability declines to a value of nearly 1.



Tube Rotates Past Fixed Sensor & Magnetizing Poles

FIGURE 4

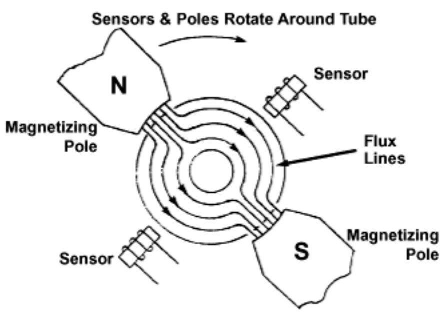


FIGURE 5

TRANSVERSE MAGNETIZATION TO DETECT LONGITUDINAL DEFECTS

Figure 4 illustrates transverse magnetization using north and south poles of a magnet applied on opposite sides of a tube to create a strong, transverse magnetic field, adjusted to reach near saturation.

The poles and flux sensors rotate about the tube resulting in rotating transverse flux lines within the tube walls that are consistently perpendicular to all radii of the tube. Note that an identical transverse magnetization occurs when rotating the tube past fixed poles and sensors, as shown in Figure 5. It is the relative rotation between the tube and the poles and sensors that causes leakage flux which, in turn, creates a voltage in the flux sensors.

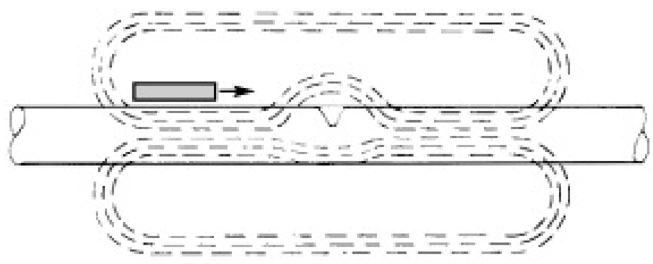


FIGURE 6
LONGITUDINAL MAGNETIZATION

LONGITUDINAL MAGNETIZATION TO DETECT TRANSVERSE DISCONTINUITIES

To detect transverse discontinuities, a longitudinal magnetic field, parallel to the axis of the tube, is applied and nearly saturates the region of the tube directly under the flux sensors. (Figure 6). North and south poles of a magnet are positioned longitudinally over a given sector of a tube, or a direct current is passed through encircling DC electromagnetic coils, centrally positioned about the full circumference of the tube under test.

Passing the tube through the magnetizing system results in magnetization of the tube wall that is longitudinal to the axis of the tube under test. Forward motion of the flux leakage field, as it passes the sensors, produces a flux signal.

ID AND OD DISCONTINUITIES

The signal level created in a flux sensor by leakage flux from a defect varies with respect to the severity of the discontinuity, and its location in a given wall thickness, when other conditions, such as speed, are constant. An increase in the relative speed between the leakage field and the sensors will increase the amplitude of the signal. Generally, the thicker the wall, the broader the flux pattern on the outside diameter caused by a defect located on the inside diameter surface. Likewise, the flux pattern caused by a defect located on the outside diameter will be narrower than that of a similar ID defect. See Figure 7.

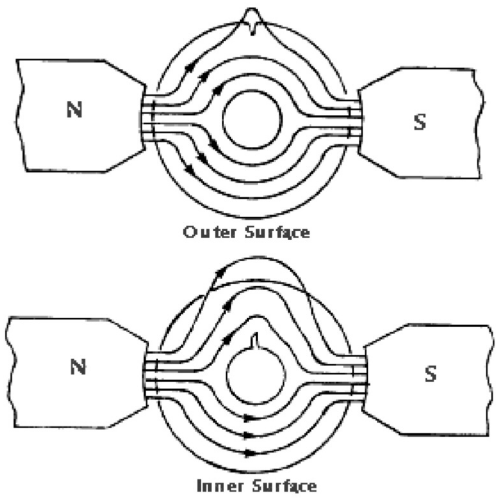


FIGURE 7
FLUX LINES FROM OUTSIDE
AND INSIDE DIAMETER DEFECTS

As a result, the broader or more slowly occurring ID defect's leakage pattern will create a lower frequency signal in the flux sensor than the frequency of the signal created by the OD defect's narrower leakage pattern. These differences in signal frequency can be analyzed with selective circuits in the test instrumentation to determine whether detected defects are located on the inside or outside surfaces or in the tube walls .

APPLICATIONS

The leakage flux test method is used for the detection of outer surface, inner surface, and subsurface discontinuities in magnetic steel tubular products of uniform cross section such as seamless and welded tubing.

Properly applied, this method can detect the presence and location of significant longitudinally or transversely oriented discontinuities such as pits, scabs, slivers, gouges, roll-ins, laps, seams, cracks, holes, and improper welds. The amplitude and frequency of the voltage generated by the flux sensor in response to a discontinuity is generally indicative of the severity and location of that discontinuity.

NATURAL & ARTIFICIAL DEFECTS

Significant differences can exist between the signals created by natural and artificial defects such as drilled holes or notches. Substantial work should be done, therefore, with actual samples containing the types of natural defects that need to be detected. Figure 8 shows several typical discontinuities and how their corresponding signals may appear on a test screen monitor.

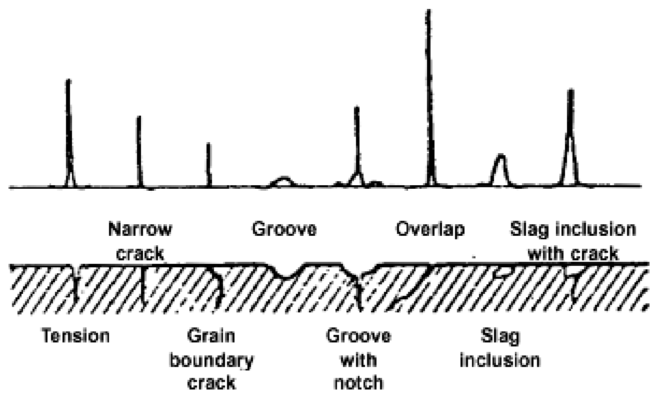
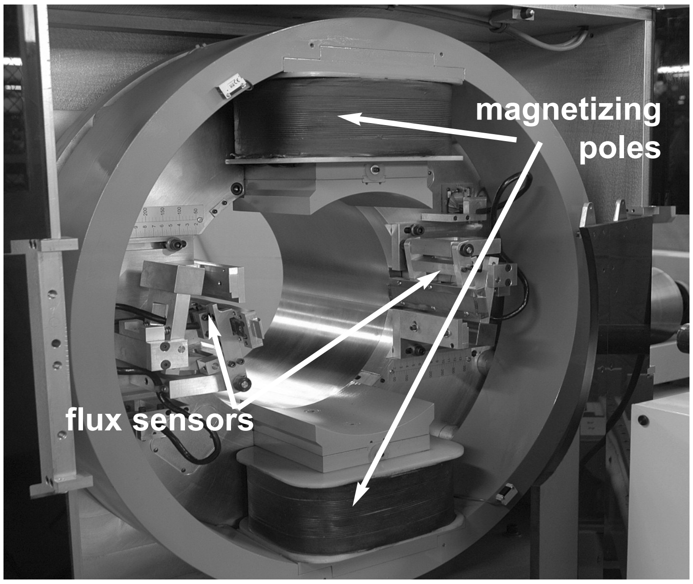


FIGURE 8
Graphic representation of appearance of indications from different types of natural defects on a monitor

FLUX SENSORS

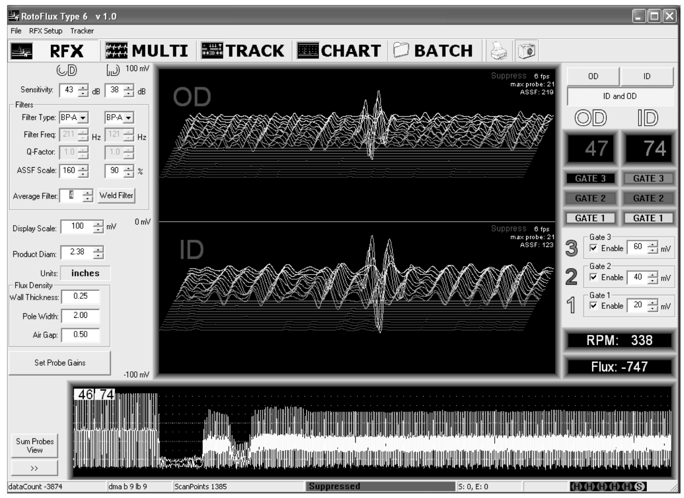


Picture 1
View of a flux leakage rotating headplate with magnetizing poles and flux sensor

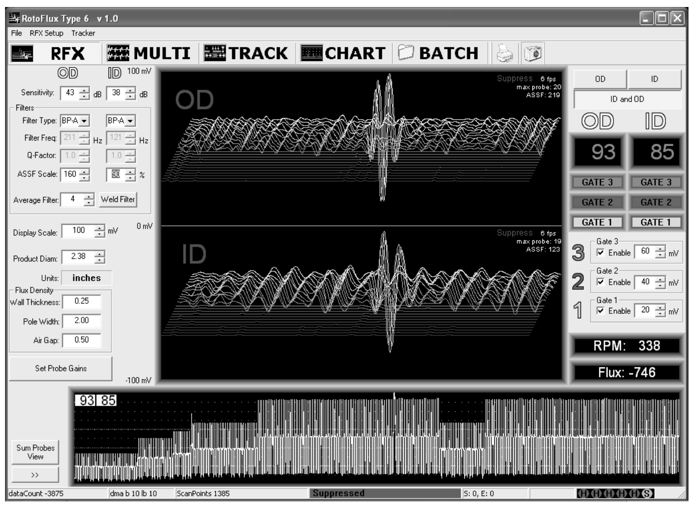
Leakage flux sensors can be several different types, however, electromagnetic coils are the most frequent choice. Because the rotating sensors (or rotating tube) result in a helical pattern of detection, there can be areas that are not covered, depending on the throughput and the relative rotational speed between the sensors and the tube. Therefore, the number and length of the sensors, and the relative rotational speed between the sensors and the tube need to be sufficient to ensure 100% coverage while traversing the surface at the applicable test speed. Multiple probes can be used to increase the speed of test and throughput speed of the test material. Flux sensors should either surface ride, or if air riding, should be held at a uniform distance above the surface of the tube. Picture 1 shows flux sensors and magnetizing poles mounted in a rotary headplate that rotates around the test material.

Picture 2 shows a test screen displaying the signal from a 10% ID notch llocated on the inside diameter of a 2 3/8" OD steel pipe. The signal can be seen on both the ID and OD displays, but the amplitude is substantially greater on the ID lower half of the screen than on the upper OD half.

Picture 3 shows a similar test screen, but with a signal from a 10% OD notch. The amplitude on the OD half of the screen is greater than the ID.



Picture 2
Signal from a 10% ID notch on a 2 3/8" diameter tube



Picture 3
Signal from a 10% OD notch on a 2 3/8" diameter tube

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