Testing Critical Medical Tubing Using High Frequency Eddy Current Coils

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Abstract:

Encircling coil eddy current testing of thin walled, small diameter tube is conducted as it travels through a coil excited with one or more high frequency signals. The composition of the material under test influences the selection of the test frequency. Usually these materials have very low conductivity and small dimensions that require a high test frequency. In the past, these materials were tested at a maximum of 1 MHZ due to coil design and limitations to the input stages of electronics. With new electronics which are linear, and coil designs which are low impedance, it is possible to test these materials with greater S/N (signal to noise) and use the phase response to reject mechanical, permeability and dielectric noise. This paper will discuss the advantages obtained by testing these types of materials at higher frequencies using new coils designs. Permeability is the ability of a material to concentrate magnetic flux. Soft iron is a material that is easily magnetized.

Keywords: eddy current, high frequency, small diameter tubing, low impedance coil, low permeability, titanium

Introduction

Coil Selection

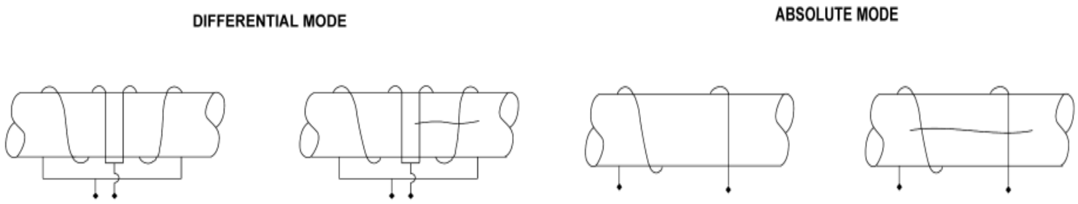
The coils can be either absolute or differential mode. Some equipments permit use of both methods simultaneously. Coils can be wound with different physical characteristics such as the spacing between the differential coils, the actual width of the coils and the use of multiple coils electrically connected in different configurations. The purpose of these different coil systems is to improve the detection of specific types of defects. Absolute testing is useful for mean wall thickness, mean diameter and conductivity measurements, from which eccentricity can be deduced. Flaw testing is restricted to detecting short variation that can lie on the OD, ID, or somewhere midwall. In order to insure equal test results on a product that does not have a round cross section, coils may be manufactured to conform to the cross section of the product.

Absolute or Differential Test Modes

In actual testing, a single coil system (absolute mode) or a system of two or more coils which electrically subtract from each other (differential 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 sees 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 above.

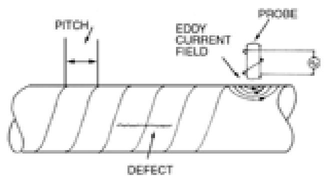
Generally, a differential mode system is more sensitive to intermittent defects because one section of material is being compared to the next. However, with long, uniform discontinuities, a differential mode system may indicate only the beginning and the end, and nothing in between. Conversely, the absolute 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 application.



Using Probes for testing material

Principles of Operation
Surface seams and cracks in metallic materials can be reliably detected by the use of eddy currents which are induced by one or more probes traversing 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 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 of this type of system. Although the probe can be hand held as the piece under test is examined, this method is usually too slow and unreliable. Generally, it is much more economical and reliable to rotate the part past a fixed probe, or rotate the probe around the part as it is fed through. In either of these cases, the examined area is a helix with a pitch determined by the speed of rotation and the linear throughput speed.

Figure 1 illustrates that a surface defect which 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.

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.

High Frequency ERIC VI Tester for Small Diameter Medical Wire & Tube

The high performance High Frequency Model ERIC VI 6 channel eddy current tester successfully inspects small diameter wire .0035" (.089 mm) and tubing with wall thickness of .004" (.10 mm). Specialized alloys including nickel-titanium, tungsten-rhenium, uranium, trans uranium alloys, L605, Inconels and Hastealloys used in medical applications such as guide wires and stents can be tested. ERIC VI's test frequencies ranging up to 20 MHz, high speed circuitry and graphics, allow accurate defect detection at test speeds up to several thousand fpm.

Applications

These are High Frequency Coils already in use. Other applications are to show the versatility of the equipment.

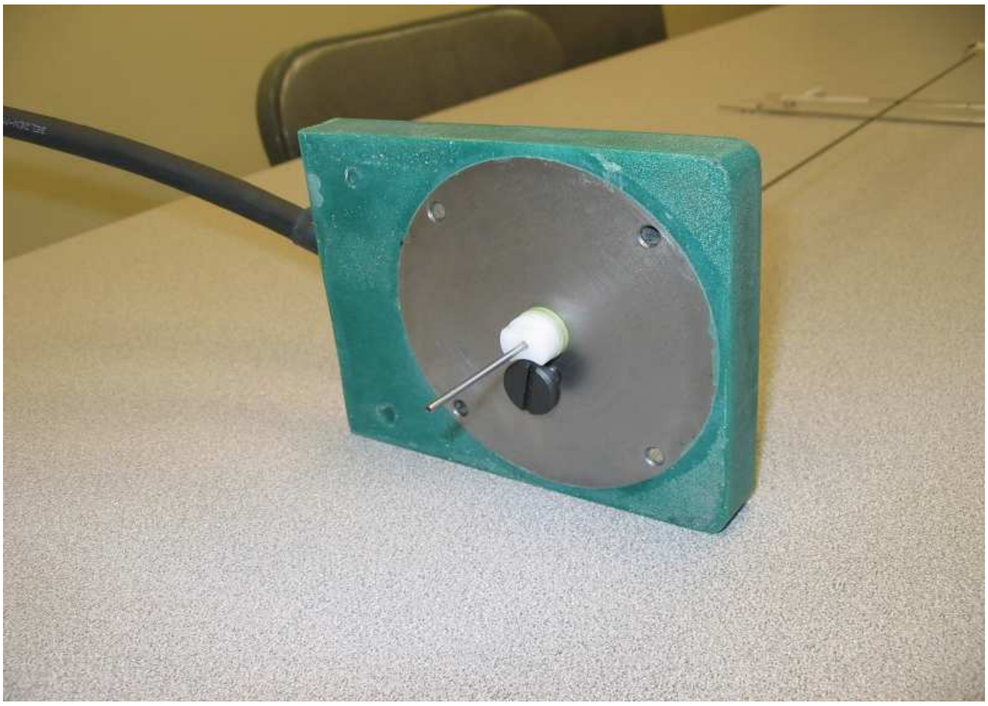


FIG 1

Fig 1- XWNE High Frequency Test Coil with .071” L605 material shown.

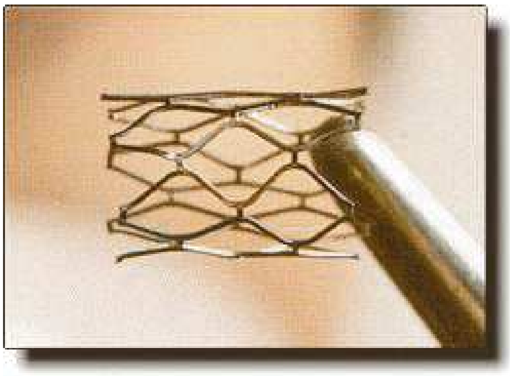


FIG 2

FIG 2- Material after processing (STENT).

Test results for L605 Material

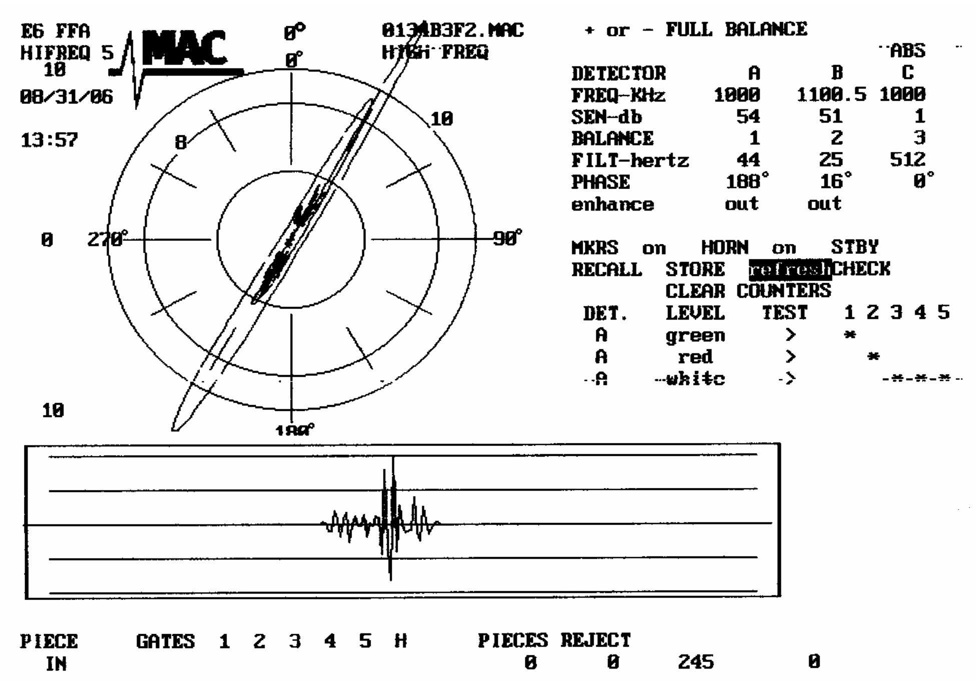


FIG 2- .071 dia. L605 tubing. Test results at 1MHZ . Notice Material noise is in phase with flaw signal. This is because the electromagnetic skin depth is much greater than the wall thickness of the tube so there is no discrimination between the response of the tubes lateral movement (or diameter change) of the tube in the coil and the flaw which penetrates the surface. The testing of tubing that has been hydro tested to failure can be very noisy unless phase separation from higher frequency testing is used to separate the flaw signal from the diameter changes caused by plastic yielding.

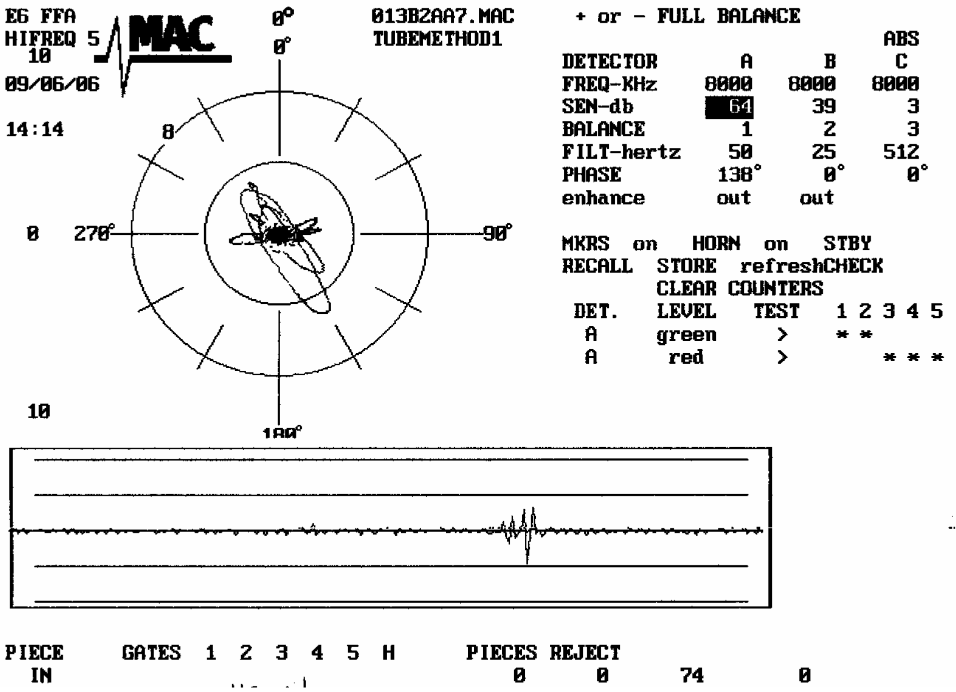


FIG 3

FIG 3- .071” dia. L605 tubing Test results at 8MHZ . Notice how Material noise is no longer in phase with the flaw signal. The noise here is caused by lateral motion of the tube within the coil, and as the defect has some depth. The tubes motion dependent phase response differs from the phase response of the flaw. This is due to the fact that the electromagnetic skin depth has been reduced at the increased frequency, and this leads to a measurable delay of the signal as it propagates through the wall. This delay is the phase shift of the flaw response.

Other Applications
Using multiple test coils.

FIG 5- A Quad coil platform used on a multi line aluminum extruder. This system uses a single 4 channel Eric 6 High Frequency unit to simultaneously test for defects on the four lines. The difficult test here is for small defects that lie on the middle of the top or bottom surface, because of the low field density in these regions and the presence of the varying finning that is extruded on the bore of this tube. Flaws down to .010” diameter are easily detected on the middle of the large flat surfaces.

FIG 6
Extruded aluminum tubing with internal fining approximately 1” x .125” in cross section.

FIG 7
Coils for testing the above aluminum extruded tube

Application using High Frequency Probes on special alloys. Rotary probe testing solid round wire of 17-4 PH Steel

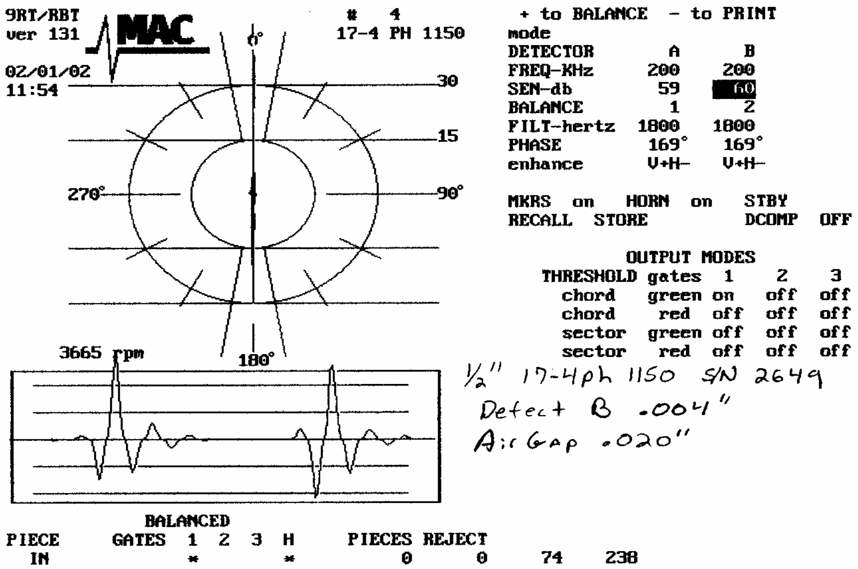


FIG 8

Fig 8- .004" flaw in 17-4 PH. This material was very difficult to test at 200KHZ. The vertical enhance V+H- had to be used to detect the signal. This application of a nonlinear scale response on both the vertical and horizontal signal is good for picking up small and well understood defects from production.

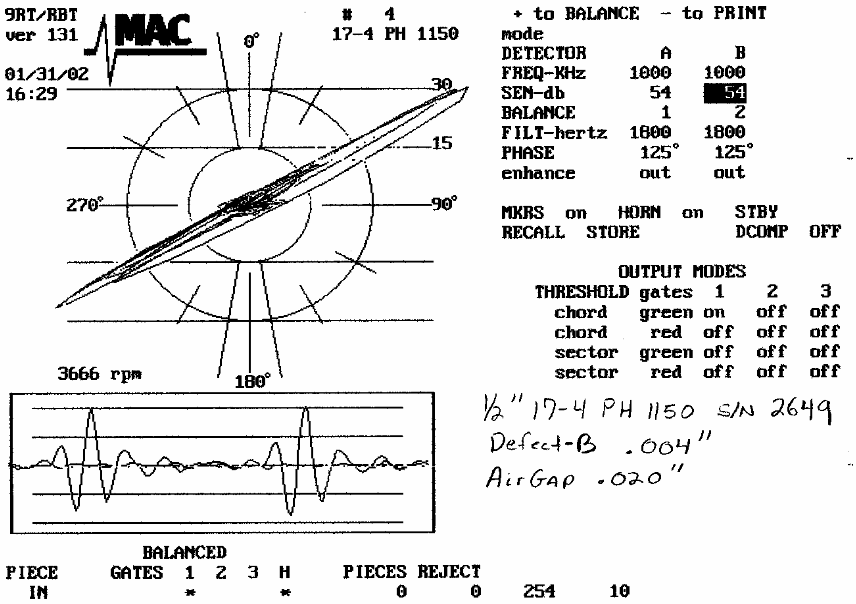


FIG 9 - .004" flaw in 17-4 PH Testing this same material at 1MHZ made a very difficult test simple. The noise signal is in the same plane as the flaw signal response at this frequency.

Other materials like titanium and special alloys are also being tested at 1MHZ using the new high frequencies probes.

Conclusion:

The principal reason for high frequency testing in small diameter tube and wire is to match the electromagnetic penetration to the dimension of the object under test. The low conductivity of the high alloy wires will also force the frequencies to be higher for these small dimensioned objects. Problems arise from testing at high frequencies because of the very high gains required and cabling systems to the sensor. New noise sources both transient and systemic come into play at high frequencies through the dielectric response sensitivity that becomes an issue above 8 MHz.

Materials produced for the medical industry are usually non-ferrous and have a low permeability that is difficult to test. These tubes or wires are also very small (.071" tube with a.005wall, wire down to.004"). Testing these new alloys with smaller dimensions the reflection that is returned to the test coil will also be smaller. Therefore it is important to test this type of material at frequencies up 20 MHz. It allows the eddy currents to be densest on the surface of the material, making them closer to the secondary windings of the test coils. Designing a new coil with a ceramic bobbin or other materials will help to improve the fill factor that is instrumental to this type of testing. With the advancement of electronics and special coils testing frequencies of up to 200 MHZ will be obtainable.

References

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