How to Use Eddy Current Technology to Test Ferrous and Non-Ferrous Wire.

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Eddy Current inspection is a technique used for detecting surface seams, cracks, pits, slivers and internal discontinuities in ferrous and non-ferrous wire. Different test sensor configurations including encircling coil and rotary probes can be used. When using encircling coil eddy current testing, the wire passes through the coil excited by an alternating current with one or more Drive signals. Rotary probe inspection can reliably detect surface seams and cracks using eddy currents which are induced by one or more probes traversing the surface of the material under test. Wire sizes can range from ultra-fine below .002” (.051mm), fine wire .002”(.051mm) to .005”(.127mm), standard wire .006”(.152mm) to .725”(18.42mm). Encircling coil testing can be used for the whole range whereas Rotary probe inspection can only be used above .200” (5.08mm).

The composition of the material under test influences the selection of the test frequency as does the size of material. Usually, materials that have very low conductivity and small dimensions require a higher-test frequency from 1MHZ to 5MHZ and will be tested with smaller wire-tester type coils. Rotary inspection is used on larger type material for detecting longitudinal type defects. Depending on the length and depth of the defect, speed of rotary and line the proper probe element can be determined. This paper will discuss the advantages obtained by using different eddy current methods, testing wire products.

Introduction

Before selecting an eddy current test coil and mode it is important to know what type of defects need to be detected and the characteristics, such as type of product and dimensions that are being inspected.

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. This includes the use of multiple coil windings electrically connected in different configurations, as well as their width and spacing. 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. Flaw testing is restricted to detecting short variations that can lie on the surface or sub surface of the material under test. In order to ensure 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 (a shaped coil can be manufactured).

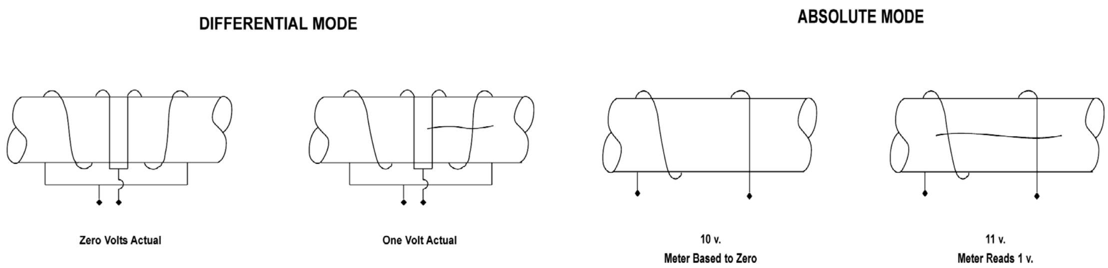
Absolute or Differential Test Modes Used for Testing Wire

In actual testing, a single coil system (absolute mode) or a system of two or more coil windings 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 below.

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 applications.

Another coil option, called a Dual Coil configuration, uses two coils, one for flaw detection, and a second for detecting ferrous inclusions in non-ferrous materials, both supplying test results to the instrument through a single cable connection.



Using Probes for testing wire material greater than .200” (5.08mm)

Principles of Operation

Surface seams and cracks in metallic materials can be reliably detected using 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.

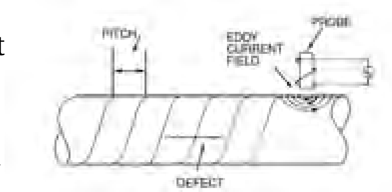


Fig 1

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 how a surface defect which is longer in length than the helical pitch can be consistently detected, whereas a shorter defect can be missed. 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 in wire products, 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. Frequency selection, filter speed and types and controlling line speed are some adjustments to increase S/N (signal to noise).

Types of coils used for testing different sized wires.

Eddy current testers can successfully inspect small diameter wire from .002" (.051mm) to .725" (18.42mm) using different types of coils depending on their application. Specialized alloys including nickel-titanium, tungsten-rhenium, Nitinol, L605, Inconels and Hastelloy's used in medical and other applications can be tested using high frequency wire tester coils up to 5 Megahertz. Other types of alloys like copper and steels can be tested at lower frequencies below 600 Kilohertz.

When testing special alloys, it is important to select the correct bushings and bobbins in order to prevent damage to the material being tested. It could be as simple as using delrin bushings, or for more sensitive materials, ceramic bobbins and bushings. Most standard steels can use off the shelf drill bushings.

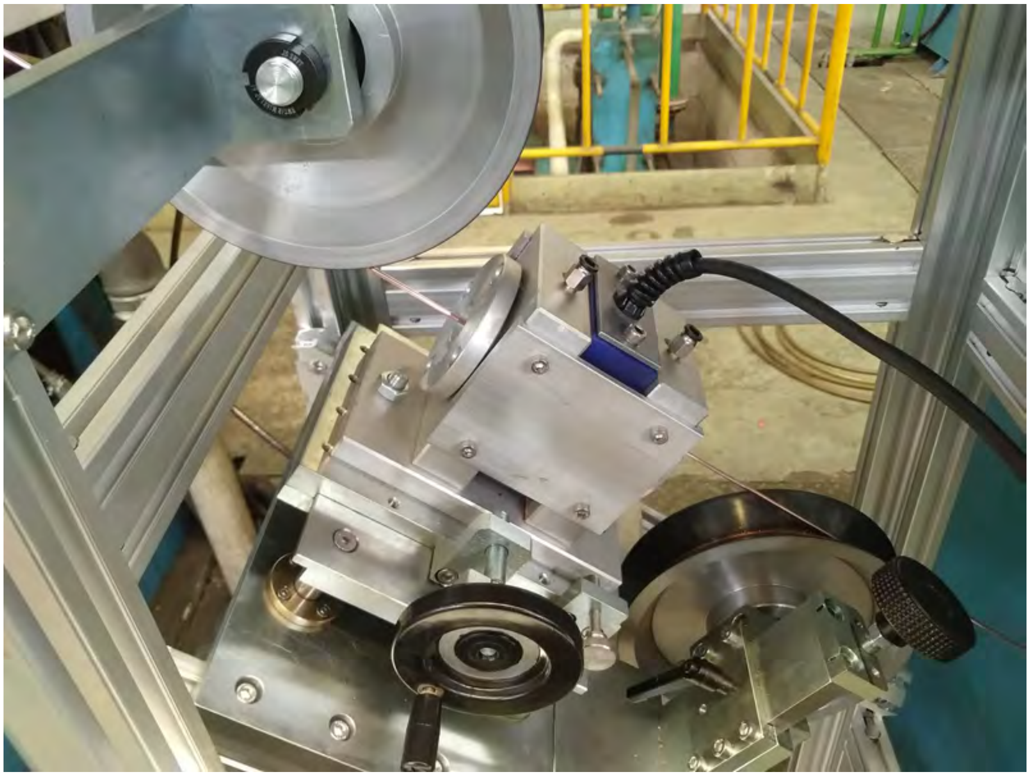
Grading Coil Software

A grading software option provides a convenient way of automatically categorizing the quality of individual segments and entire coils of wire. This knowledge is financially beneficial when determining the selling price of the wire coils or determining how to further process them. The customer can customize the defect types, each based on a specific threshold gate, specify the maximum number of defects for each grade level and configure reports. Surface defects as well as inclusions are detected and categorized.

The importance of knowing the quality of the coil cannot be minimized. Further processing a coil through a multi-drawing process, that would have been classified as scrap by their own standards, wastes both time and money.

Applications

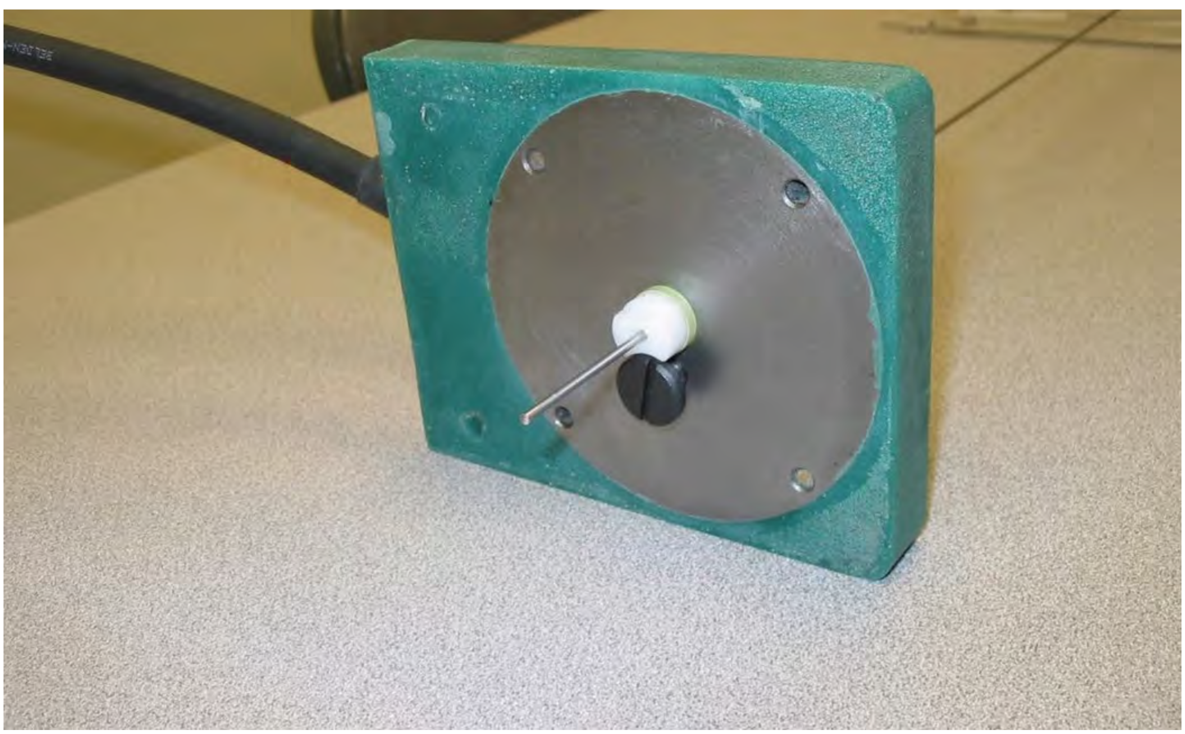
These are High Frequency Wire Tester Coils already in use. Other applications are to show the versatility of the equipment.



A typical setup for testing wire on a reel-to-reel system.

Coils of wire to be tested on a reel to reel system.

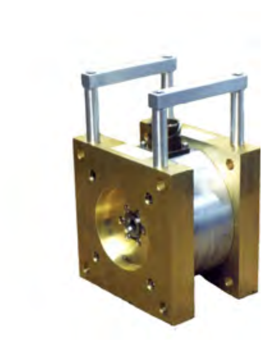
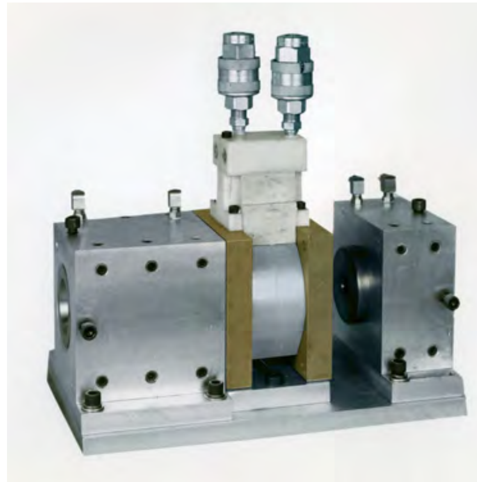
XWNE3 XSB (extra small body) High Frequency (3MHZ) test coil screen showing a defect in a Nitinol **standard wire.**



XWNE3 (3MHZ) High Frequency Test Coil with .071” (1.83MM) 300 Series Stainless Steel material shown.

Offline test of a spool of wire displayed in a chart showing test results at 1,079 ft.
Setups are done offline so no markers are turned on (gates are shown).
A spool of wire is run to select optimum settings for test.

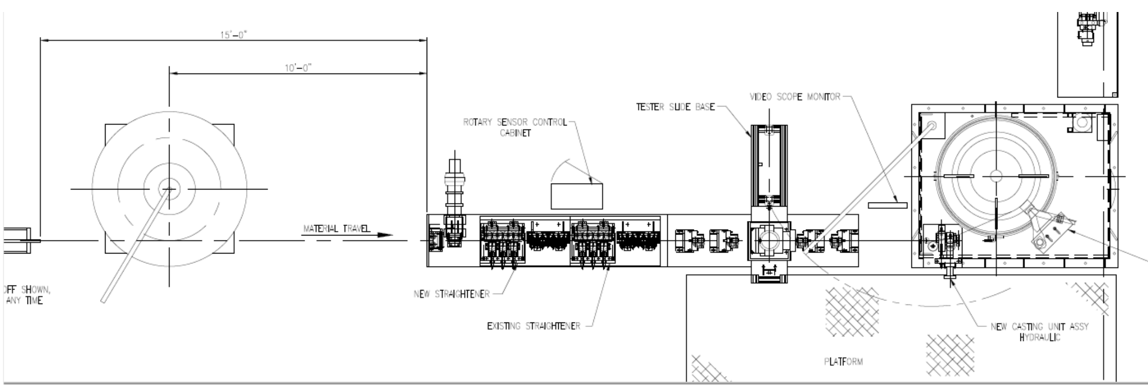
Water cooled hot coil testing wire after furnace heat treatment.

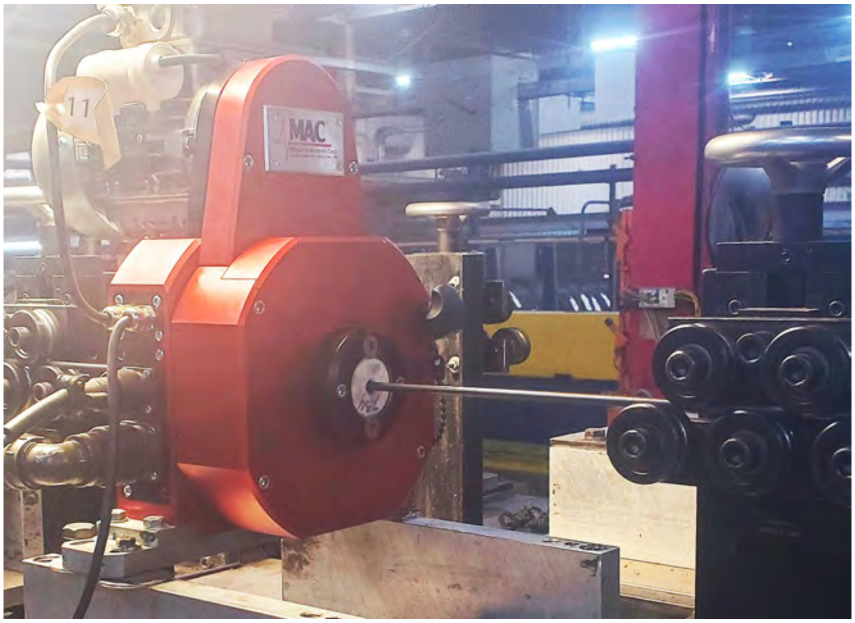
Water-cooled hot coil on the left, and one with bushings and water connections shown at right.

Other Applications

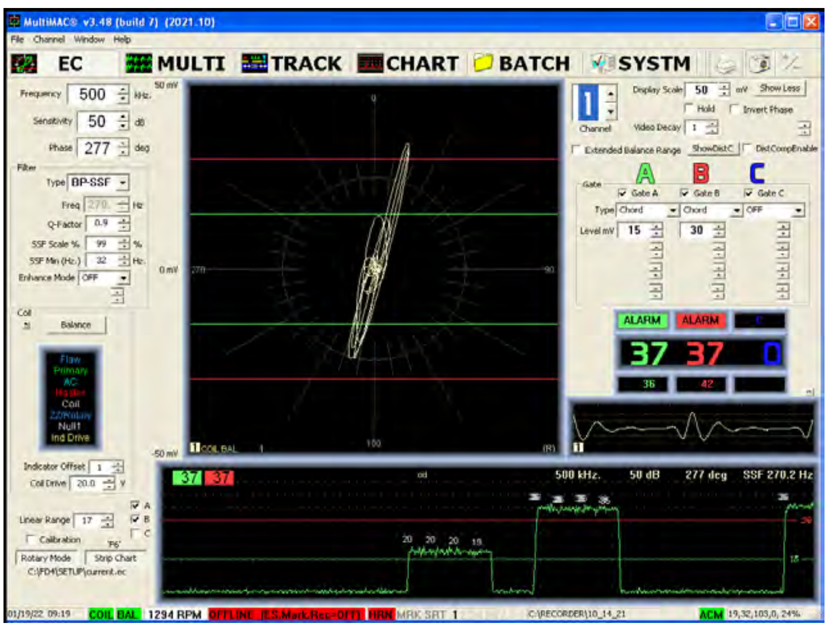
Using EC Rotaries to test wire.



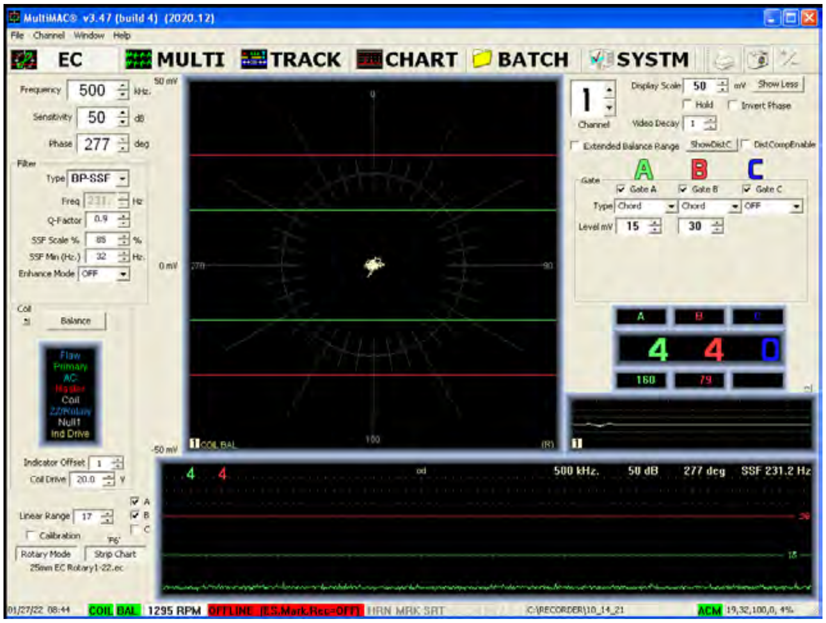
Mechanical drawing showing a full reel to reel test system.



25MM EC rotary testing spring wire at 1,300 RPM.



25MM EC rotary testing a calibration standard (CAL4750 ½" Steel) with .003" (.076MM) and .005" (.127MM) EDM notches.



25MM EC rotary testing a calibration standard (CAL4750 ½” Steel) showing bar noise (no defect).

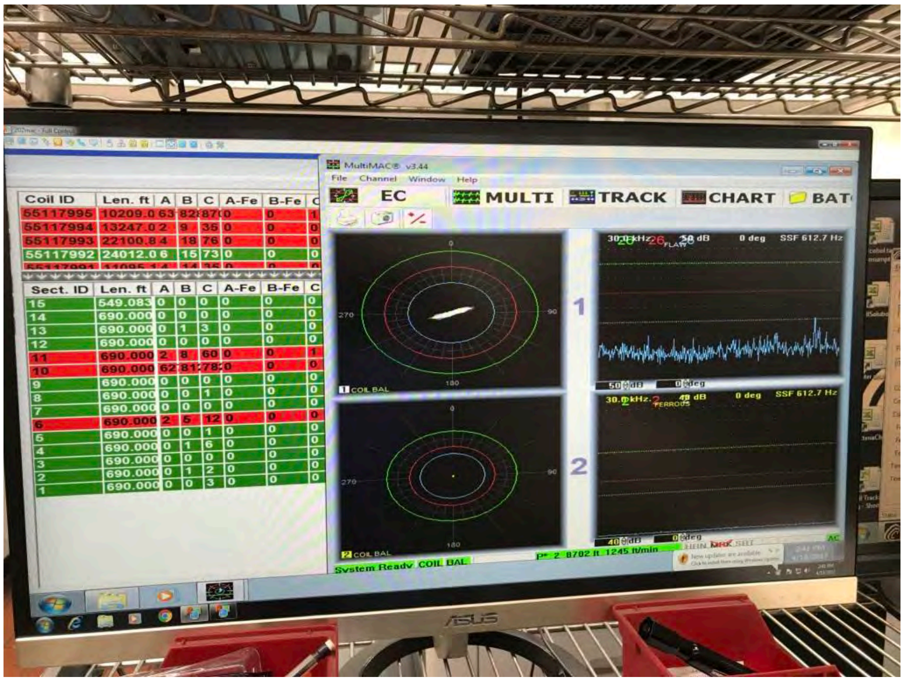
Rotomac® 20MM High speed EC rotary for testing copper wire up to speeds of 18,000 RPM.

20MM High Speed Rotary Test on Ovate Wire Sample .
003” depth at 0 and 90 degrees.

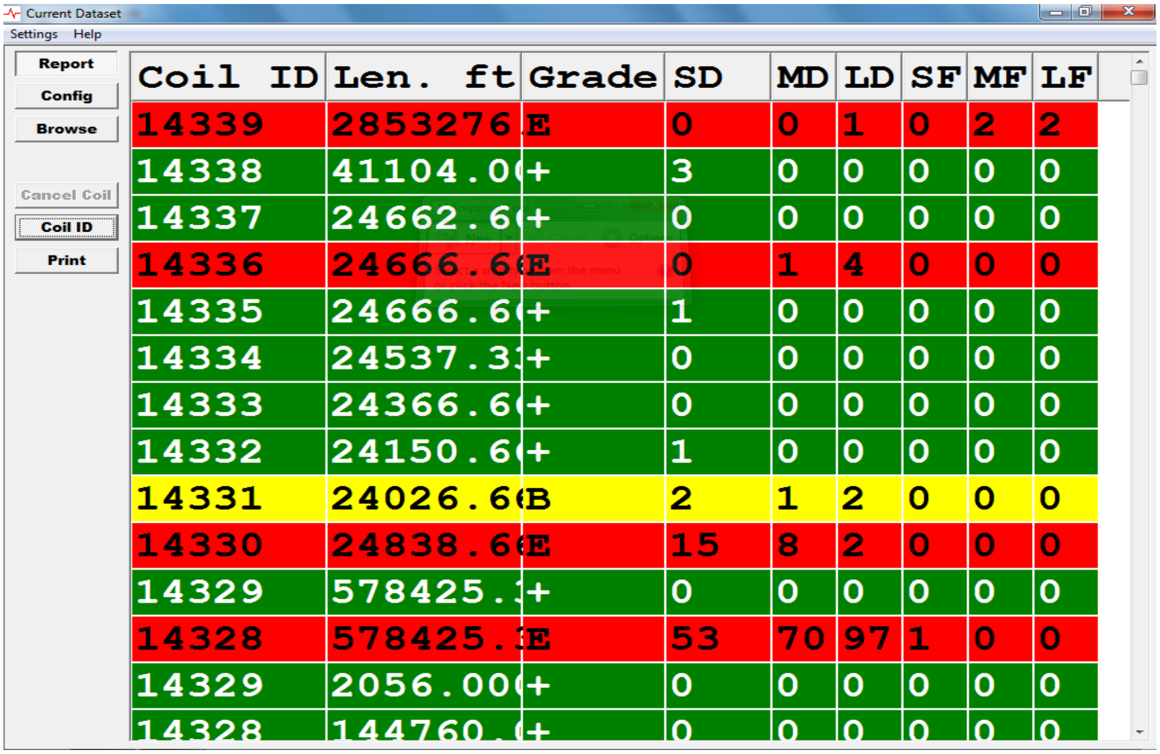
Attached is the strip chart recording of the sample with two long notches. Front section is with distance compensation showing the defects on the major axis 0deg then minor axis 90deg. After that, the distance compensation is turned off and the piece is running backward, showing defects on minor 90deg (barely visible) then major axis 0deg. Channel 1 (probe) is in green and channel 2 (probe) is in red. Speed of rotary 8,974 RPM.

Dual Coil Flaw/MID test.

When testing materials like copper and aluminum, it is advantageous to test for inclusions. When processing these metals, it is possible that broken tooling could be embedded in the material. Inclusions consisting of ferrite steels can be extremely detrimental to the end user, especially when the application is as an electrical conductor. For this reason, a modified absolute winding is used in combination with a DC magnetic field for a Metal Inclusion Detection (MID) test.

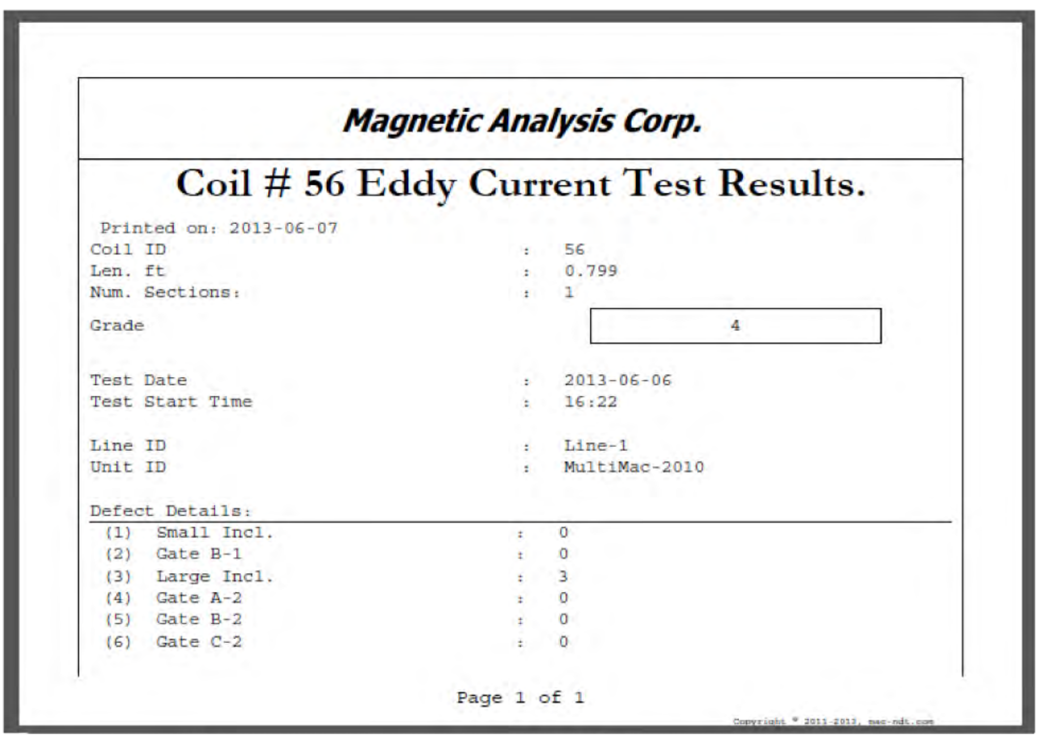


The right hand of the screen shows a typical set up for a Dual Flaw/MID coil. In the background on the left is the grading software showing three gates for flaw type defects (A,B and C) and two for MID (A-Fe and B-Fe) defects.



Coil ID	Len. ft	Grade	SD	MD	LD	SF	MF	LF
14339	2853276	E	0	0	1	0	2	2
14338	41104.0	+	3	0	0	0	0	0
14337	24662.6	+	0	0	0	0	0	0
14336	24666.6	E	0	1	4	0	0	0
14335	24666.6	+	1	0	0	0	0	0
14334	24537.3	+	0	0	0	0	0	0
14333	24366.6	+	0	0	0	0	0	0
14332	24150.6	+	1	0	0	0	0	0
14331	24026.6	B	2	1	2	0	0	0
14330	24838.6	E	15	8	2	0	0	0
14329	578425.	+	0	0	0	0	0	0
14328	578425.	E	53	70	97	1	0	0
14329	2056.00	+	0	0	0	0	0	0
14328	144760.	+	0	0	0	0	0	0

FIG Print-out of report for multiple reels or wire using grading software.



Magnetic Analysis Corp.

Coil # 56 Eddy Current Test Results.

Printed on: 2013-06-07

Coil ID : 56
Len. ft : 0.799
Num. Sections: : 1
Grade 4

Test Date : 2013-06-06
Test Start Time : 16:22

Line ID : Line-1
Unit ID : MultiMac-2010

Defect Details:

(1) Small Incl. : 0
(2) Gate B-1 : 0
(3) Large Incl. : 3
(4) Gate A-2 : 0
(5) Gate B-2 : 0
(6) Gate C-2 : 0

Page 1 of 1

FIG Print-out for coil #56 to be placed on the tested reel of wire, generated from the grading software.

Conclusion:

Eddy current testing has proven to be an invaluable non-destructive testing technique over the past several decades. The ability to detect surface and near-surface defects at a large range of speeds, its non-destructive nature, and the ability to test a wide range of materials, all make this test technology very attractive to the wire producing industry. Additionally, eddy current testing is a quick and reliable method for testing wire, making it a popular choice for quality control in industries such as aerospace, automotive, and telecommunications. In addition to determining the quality of the inspected material it can also be used as a monitoring device for the manufacturing process. Overall, eddy current testing is a valuable tool for ensuring the safety and reliability of wires in a variety of applications at a cost-effective price.

Presented at Interwire Trade Exposition
Atlanta, Georgia
May 9 – 11, 2023