

Discrimination of Metal Differences Using Electromagnetic Comparators

A frequent problem in industry is how to separate different parts that have been intentionally or accidentally mixed. Electromagnetic comparators can be used to economically and quickly solve this problem. Typically, the kinds of mixes that comparators will separate are variations in alloy, heat treatment, hardness, structure, dimensions, (including length) and certain kinds of cracks.

PRINCIPLES OF THE TEST

When a metal part is placed inside or near a coil which is excited by an alternating current, the voltage output from the coil will be affected. This is the basic principle employed by all electromagnetic comparators. The effect that the part has on the output of the coil is directly related to the permeability, conductivity, and physical dimensions of the part.

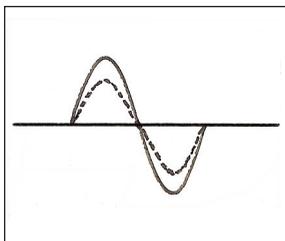
The voltage output of the coil may be affected in three different ways:

1. amplitude (a change in the magnitude of the voltage output)
2. phase (a change in the time relation of the output voltage)
3. harmonic distortion (occurs when high power is used on ferrous material to nearly saturate the part.)

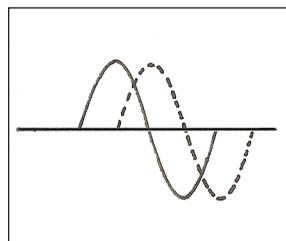
On a linear oscilloscope or monitor presentation, the type of wave forms that you would see for these various types of changes are shown below.

LINEAR PRESENTATION

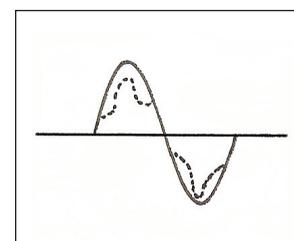
AMPLITUDE



PHASE



**HARMONIC
DISTORTION**

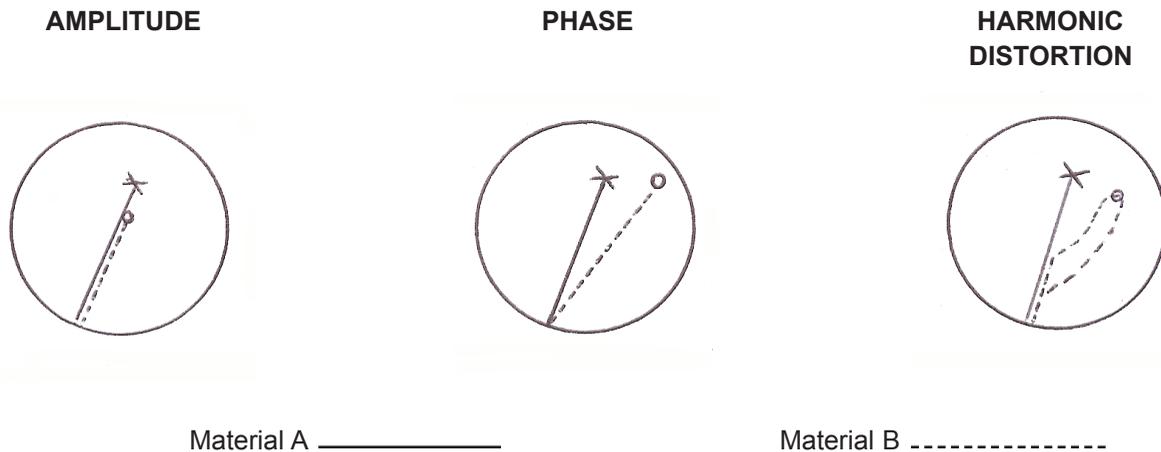


Material A _____

Material B

VECTOR PRESENTATION

On an instrument using a vector presentation, the changes would appear as shown below.



The amount of change produced will be affected by the excitation frequency of the coil, the conductivity or permeability of the material, and the sensitivity of the instrument. Non magnetic (non ferrous) parts have differences in electrical conductivity. Magnetic (ferrous) materials, however, have differences in both electrical conductivity and magnetic permeability, although the permeability differences generally have a greater effect.

When sorting for differences in dimension, the entire part must be within the field of the coil, except where the differences are those of inside or outside diameter. Dimensional changes will usually produce a difference in amplitude. In some cases of non magnetic material, they will produce a phase change. Also the phase angle difference between two materials will be greatly affected by the excitation frequency. The harmonic distortion presentation, which occurs when high power is used on ferrous material to nearly saturate the part, is an excellent way to indicate differences in core hardness.

COIL CONFIGURATION

Comparators may operate with either one coil (absolute method) or two coils (differential method). In the absolute method, the part is placed in the coil and the electronic instrumentation is adjusted to read a given value. As the part is changed and a part with different characteristics is inserted, the instrument should read a different value.

In the differential method, the two coils are electronically connected so that their outputs subtract from each other. A part is placed in one coil which is called a reference coil. This part is left in place throughout the entire test. One of the parts to be tested is then placed in the other coil which is called the test coil. The electronic instrument is then

adjusted so that the resultant of the two coils read "0". If a part whose characteristics are different from the first part is placed in the test coil, the electronic instrument should show a difference. Generally, the use of the two coil system provides greater sensitivity.

In addition to utilizing coils that are wound so that a part can be inserted in them, the coils can also be wound so that they can be placed against the part. When coils are wound in this manner, they are referred to as probes. Probes can be made for either absolute or differential mode operation.

SEPARATION AND READOUTS

Variations in the parts being tested are visually indicated by either a meter reading, a change in the test signal pattern on the oscilloscope or monitor, or by the lighting of go and no go lights. Comparators using a meter, oscilloscope or monitor presentation can usually be pre-set to allow a three way separation of parts into those that give a higher than acceptable reading, those that give an acceptable reading, and those below the acceptable range. Comparators equipped for three way separation operate independent relays. This allows the automatic separation of parts.

A frequent misconception is that when a comparator is set up to sort for a particular difference, that difference is all that is sorted. In actuality, the comparator is set up on a particular piece with specific characteristics and *any* deviation from those characteristics will be detected. For example, when the comparator is set up to separate a known alloy mix, it will also separate out any other unknown differences such as parts which may have been improperly heat treated or are the wrong size. For this reason, if you only wish to sort for variations in one property, those differences must be greater than differences which may occur in other properties. The best way to determine whether a comparator will make the particular separation you need is to conduct a trial of the equipment on actual samples of your test material.

SELECTIVE CIRCUITS

FREQUENCY SELECTION

The frequency of the excitation voltage determines what type of differences will be seen between two parts. The excitation frequency determines the extent of the amplitude difference or the phase angle difference between two parts. It is entirely possible that no separation between the parts will exist at a given frequency, while a large difference is seen between the parts at a different frequency. Therefore, a comparator that operates on more than one frequency, or has a variable frequency through a given range, has more selectivity. The penetration into the part under inspection is dependent on the excitation frequency. The lower the frequency, the deeper the penetration.

When testing for case depth, for example, an instrument with a variable frequency will have a greater ability to perform the separation than an instrument with a single frequency.

In the case of separating non-ferrous materials, it is usually necessary to operate at a frequency greater than 1 KHz in order to get a response. This is primarily due to the absence of permeability.

SENSITIVITY SELECTION

The sensitivity control provides the capability of adjusting the level of differences at which the relays will function.

FILTER SELECTION

Filters are generally used in electromagnetic comparators to select a given frequency from the composite excitation frequency. They permit an examination of the specific frequency which is most affected by the material being inspected, while ignoring the effects of the other frequencies of the composite.

In a typical situation, the voltage output of the coils excited by 110 VAC will consist of a fundamental (60 cycle) frequency, the third harmonic (180 cycle), the fifth harmonic (300 cycle), and so forth. Hence, if an equipment has filtering capabilities, you can examine the effect of the differences you are trying to separate on each of these frequencies. These are called pass filters. In addition, an elimination filter can be used which will minimize the effect of a give frequency and examine all others.

PHASE SELECTION

The phase control allows the rotation of all signals 360°. This permits the rotation of desired signals, displayed on an oscilloscope or monitor, to a place where they will exceed the threshold level and activate the specific relay.

