INTERNATIONAL

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Standard Practice for Electromagnetic (Eddy-Current) Sorting of Nonferrous Metals[1]

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1. Scope

1.1 This practice describes a procedure for sorting nonferrous metals using the electromagnetic (eddy-current) method. The procedure is intended for use with instruments using absolute or comparator-type coils for distinguishing variations in mass, shape, conductivity, and other variables such as alloy, heat treatment, or hardness that may be closely correlated with the electrical properties of the material. Selection of samples to evaluate sorting feasibility and to establish calibration standards is also described.

1.2 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

E 105 Practice for Probability Sampling of Materials[2]

E 122 Practice for Choice of Sample Size to Estimate a Measure of Quality for a Lot or Process[2]

E 1316 Terminology for Nondestructive Examinations[3]

3. Terminology Definitions

3.1 Definitions of terms relating to electromagnetic testing are given in Terminology E 1316.

4. Summary of Practice

4.1 The techniques that are primarily used in electromagnetic sorting employ the absolute (single-) and comparative (two-) coil methods using either encircling or probe coils. The decision of whether to use single-coil or two-coil operation is usually based on empirical data. In the absolute-coil method (encircling or probe), the equipment is calibrated by placing standards of known properties in the test coil. The value of the tested electrical parameter, which may be correlated with alloy, heat treatment temper, or hardness, is read on the display of an indicator. In the comparative coil method (encircling or probe coils), the test specimen in one coil is compared with a reference piece in a second coil to determine whether the test specimen is within or outside of the required limits.

4.1.1 *Absolute Coil Method*:

4.1.1.1 *Encircling Coil*—Samples of known classification (standards) are inserted consecutively in the test coil, and the controls of the instrument are adjusted to obtain appropriate response. Typically, three samples would be used representing the upper, lower, and mid-range for which calibration is required. The test is then conducted by inserting the specimens to be sorted into the test coil, and observing the instrument response.

4.1.1.2 *Probe Coil*—The probe coil is placed consecutively on the standards of known properties and the controls of the instrument are adjusted for appropriate response (see 4.1.1.1). The test is then conducted by placing the probe on the specimens to be sorted and observing the instrument response.

4.1.2 *Comparative Coil Method*:

4.1.2.1 *Encircling Coil*—Known reference pieces (standards) representing the minimum or maximum limits, or both, of acceptance or sorting category are inserted in the reference and test coil. The instrument controls are adjusted for appropriate responses. The test is then conducted by inserting specimens to be sorted in the test coil, leaving the known reference in the reference coil and observing the instrument response.

4.1.2.2 *Probe Coil*—Both probe coils are placed on the reference pieces (standard) representing the minimum or maximum limits, or both, of acceptance or sorting category. The instrument controls are adjusted for appropriate responses. The test is then conducted by placing the test probe on the specimens to be sorted (the other probe is left on the reference standard) and observing the instrument response.

4.2 The range of instrument response must be so adjusted in the initial step that the anticipated deviations will be within the range of readout.

4.3 Both absolute and comparative methods using encircling coil(s) require comparing the specimens to be tested with the reference piece(s). Two or more samples representing the limits of acceptance may be required. In the absolute method,

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[2] *Annual Book of ASTM Standards*, Vol 14.02.

[3] *Annual Book of ASTM Standards*, Vol 03.03.

the electrical reference signal from the instrument is adjusted with the standard in the coil. In the comparative method, any electromagnetic condition, that is not common to the test specimen and the standard will produce an imbalance in the system. The comparative method is usually more stable since it suppresses most of the interferences.

4.4 The testing process may consist of manual insertion of one specimen after another into the test coil or an automated feeding and classifying mechanism may be employed. In automated setups, it is sometimes necessary to establish empirically the time required for the test specimen to remain in the test coil while the reading is being taken, especially if low frequencies are employed.

5. Significance and Use

5.1 Absolute and comparative methods provide a measure for sorting large quantities of nonferrous parts or stock with regard to composition or condition, or both.

5.2 The comparative or two-coil method is used when high-sensitivity testing is required. The advantage of this method is that it almost completely suppresses interferences.

5.3 The ability to accomplish these types of separations satisfactorily is dependent upon the relation of the electric characteristics of the nonferrous parts to their physical condition.

5.4 These methods may be used for high-speed sorting in a fully automated setup where the speed of testing may approach many specimens per second depending on their size and shape.

5.5 Successful sorting of nonferrous material depends mainly on the variables present in the sample and the proper selection of frequency and fill factor.

5.6 The accuracy of a sort will be affected greatly by the coupling between the test coil field and the tested part during the measuring period.

6. Interferences

6.1 The influence of the following variables must be considered for proper interpretation of the results:

6.1.1 The correlation shall be established so that electrical properties of various groups do not overlap and are well defined in the calibration procedure used.

6.1.2 The test frequency must be selected to provide a well-defined separation of variables.

6.1.3 The temperature of the standard and test specimen shall be controlled within limits that will permit a well-defined range of conductivity or permeability, or both, for which the correlation of the group or groups is valid. Cooling of the test standard when high field strengths are used or allowing test specimens to cool or heat to an established ambient range, or both, may be required.

6.1.4 The geometry, mass, and thickness of the standard and test specimen shall be controlled within limits that will permit sorting.

6.1.5 Magnetic permeability variations can interfere when sorting paramagnetic materials.

6.1.6 Signal response can result from a change in relative motion between the test specimen and the test coil, such as the length of time the specimen is in a test coil (see 4.4).

6.1.7 Conductivity has an unambiguous relationship to hardness for certain alloys. However, when alloys are mixed, identical conductivity does not necessarily indicate the same hardness.

6.1.8 Care must also be exercised in using conductivity to sort overheated parts quenched at a high temperature as the conductivity reading for acceptable parts may repeat at a large increase in temperature.

6.1.9 Lift-off can result in a change in the test system output with probe coils. This effect is a change in the magnetic coupling between the test specimen and probe coil. Care must be exercised to prevent this effect from interfering with test results; either mechanical or electronic compensation must be used.

6.1.10 For certain heat-treatable (aluminum) alloys, conductivity values can also repeat themselves during the aging cycle at a constant temperature. Thus, for such alloys, conductivity is not unique as a monitor of temper, etc.

7. Apparatus

7.1 *Electronic Apparatus*—The electronic apparatus shall be capable of energizing the test coils with alternating currents of suitable frequencies and power levels and shall be capable of sensing changes in the electromagnetic response of the coils. Equipment may include any suitable signal-processing devices (phase discriminator, filter circuits, etc.) and the output may be displayed by meter, oscilloscope, recorder, signaling devices, or any suitable combination required for the particular application.

7.2 Test coils may be of the encircling or probe-coil type and shall be capable of inducing an electromagnetic field in the test specimen and standard, and sensing changes in the electric or magnetic characteristics of the test specimen.

7.2.1 When selecting the test coil, the objective should be to obtain a coil fill factor as large as possible. This means that the inside of the test coil should be filled by the test specimen as much as possible. This is of primary importance for tests requiring high sensitivity.

7.2.2 For complicated test specimen shapes, a corresponding insert shall be provided to ensure that each test specimen can be placed in the same position within the test coil. These inserts, as well as any other accessories, should consist of nonferromagnetic, electrically nonconductive material.

7.3 *Mechanical Handling Apparatus*— A mechanical device for feeding and sorting the test specimens may be used to automate a particular application.

8. Sampling

8.1 Sampling (see Practices E 105 and E 122) is a method to obtain assurance that materials are of satisfactory quality. Instead of 100 % inspection, a portion of the material is examined to show evidence of the quality of the whole. There are two important needs for this approach: first, in the final inspection or tests made to assure that products delivered are in conformance with specification requirements; second, to control parts and assemblies while they are being processed. Statistical acceptance sampling tables and statistical process-control sampling tables have been developed to meet these needs.