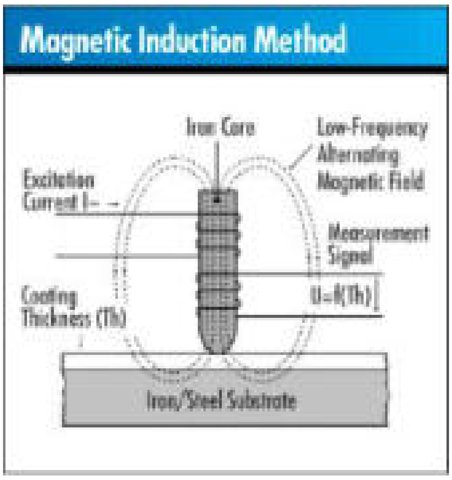
Understanding Coating Thickness Measurement – Helmut Fischer

Many of the materials used in today's products have some sort of coating, whether it's the shiny new paint job on your Lexus, the anodized protection on some of its parts or the gold plating on the contacts in its electrical system. For reasons of economy or functionality, the thickness of these coatings must be accurately measured to ensure parts perform as required or that material (e.g., gold) isn't being used unnecessarily, driving up product costs.

Over the years, a variety of equipment has been developed to help manufacturers monitor and control the thickness of coatings. Most of these tests are non-destructive and cover a wide range of coating thickness and material.

What follows is a brief explanation of the various coating thickness technologies and their likely applications. Specific applications require specific instruments. For example, liquid or powder coating on an automotive part, anodize over aluminium, gold on a printed circuit board, or paint thickness on an outdoor structure such as a bridge or water tank all require instruments that use certain test measurement methods. A basic understanding of these methods is essential in selecting the appropriate unit.

Helmut Fischer - Magnetic Induction method



This technology measures nonmagnetic coatings over ferrous substrates and magnetic coatings over nonmagnetic substrates. When the probe is positioned on the sample, the linear distance between the probe tip that contacts the surface and the base substrate is measured.

Inside the measurement probe is a coil that generates a changing magnetic field. When the probe is placed on the sample, the magnetic flux density of this field is altered by the thickness of a magnetic coating or the presence of a magnetic substrate. The change in magnetic inductance is measured by a secondary coil on the probe. The output of the secondary coil is transferred to a microprocessor, where it's viewed as a coating thickness measurement on a digital display.

This method is quick and can be used with either a bench top or hand-held coating thickness gage. Common applications include liquid or powder coatings, as well as plating's such as chrome, zinc, cadmium or phosphate over steel or iron substrates.

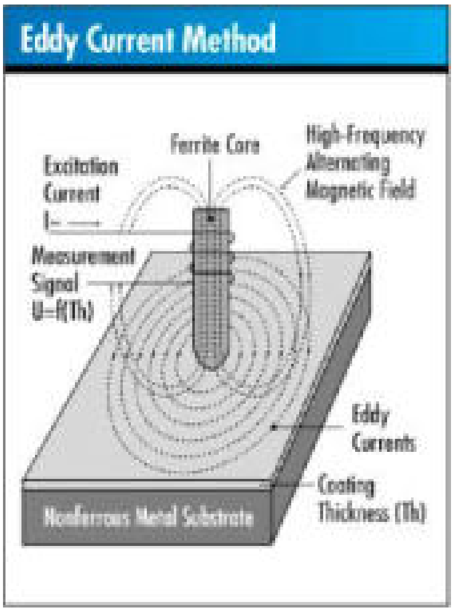
Factors such as the part's geometry and the coating's thickness determine whether the magnetic inductive method is the proper approach. Typically, coatings such as paint or powder greater than 0.1 ml can be measured using this method.

With the magnetic induction method, users should keep in mind that an erroneous reading could occur when measuring a coating such as nickel over steel. Because nickel is partially magnetic, a magnetic inductive probe won't read this coating correctly. To do so, a phase-sensitive eddy current method is used instead.

A top coat with a zinc galvanize over steel is another typical application. Users should be aware that with a magnetic inductive probe, the thickness reading will equal the total thickness over both the top coat and the zinc galvanize. Different equipment is used to measure each coating separately.

With this method, as with most measurement methods, it's often necessary to calibrate the instrument on a bare, uncoated substrate. However, some newer instruments have the capability to detect the substrate material through the coating and calibrate themselves accordingly. This is useful when measuring a sample for which the substrate is unknown and a bare substrate is unavailable.

Helmut Fischer - Eddy Current method



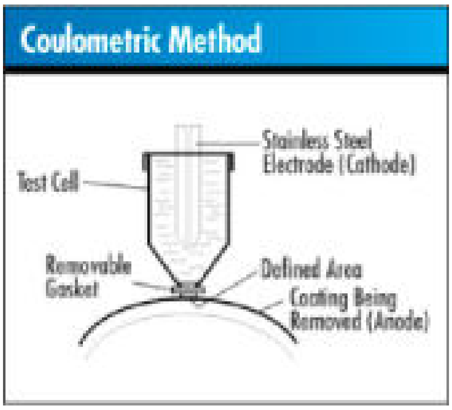
This method measures nonconductive coatings on nonferrous conductive substrates, nonferrous conductive coatings on nonconductive substrates and some nonferrous metal coatings on nonferrous metals. Eddy current measuring is similar to the magnetic inductive method previously mentioned. It even uses many of the same probe designs.

As with a magnetic induction probe, the eddy current method also contains a coil. In this case the coil has the dual function of excitation and measurement. This probe coil is driven by a high-frequency oscillator to generate an alternating high-frequency field. When near a metallic conductor, eddy currents are generated in the conductive material. This causes an impedance change in the probe coil. The distance between the probe coil and the conductive substrate material determines the amount of impedance change, which can be measured, correlated to a coating thickness and displayed in the form of a digital reading. Common applications include liquid or powder coating over aluminium and nonmagnetic stainless steel, and anodize over aluminium.

As with the magnetic inductive method, the eddy current method's reliability depends on the part's geometry as well as the coating's thickness. Users should know the base substrate prior to taking a reading. An eddy current probe shouldn't be used for measuring a nonmagnetic coating over a magnetic substrate such as steel. Neither is this method reliable for measurements of nickel over aluminium.

In cases where users must measure coatings over magnetic or nonferrous conductive substrates--such as in a job shop--they'd be best served with a dual magnetic induction/eddy current gage that automatically recognizes the substrate.

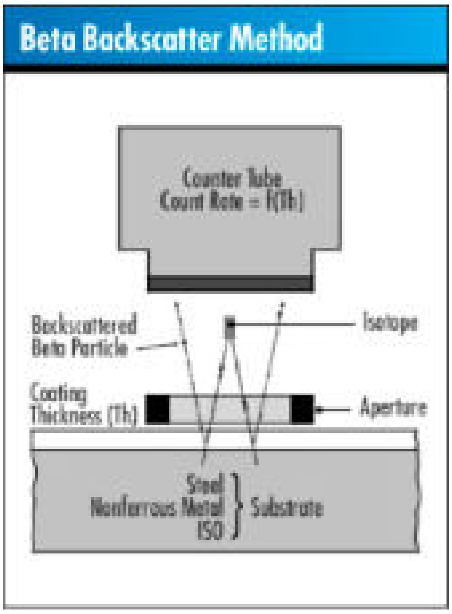
Helmut Fischer - Coulometric method



This measurement technology is a destructive testing methodology that has many important functions. Measuring the duplex nickel coatings in the automotive segment is one of its more significant applications. With the coulometric method, the weight of an area of known size on a metallic coating is determined through localized anodic stripping of the coating. The mass-per-unit area of the coating thickness is then calculated. The coating's measurement is made using an electrolysis cell, which is filled with an electrolyte specifically selected to strip the particular coating. A constant current runs through the test cell, and because the coating material serves as the anode, it gets de plated. The current density and the surface area are constant, and thus the coating thickness is proportional to the time it takes to strip the coating. This method is particularly useful for measuring electrically conductive coatings on a conductive substrate.

The method can also be used for determining the coating thickness of more than one layer on a sample. For example, the thickness of nickel and copper can be measured on a part with a top coating of nickel and an intermediate copper coating on a steel substrate. Another example of a multilayer coating is chrome over nickel over copper on top of a plastic substrate. Coulometric testing is commonly used in electroplating plants with a small number of random samples.

Helmut Fischer - Beta Backscatter method



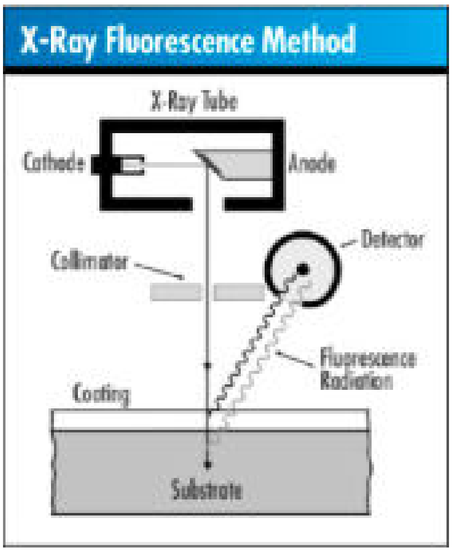
This method begins when a test sample is exposed to beta particles from a beta-emitting isotope. A beam of beta particles is directed through an aperture onto the coated component, and a proportion of these particles are “backscattered” from the coating through the aperture to penetrate the very thin window of a Geiger Muller tube. The gas of the GM tube ionizes, causing a momentary discharge across the GM tube electrodes. The discharge--in the form of a pulse--is counted and then translated into coating thickness.

Materials with low atomic numbers backscatter the beta particles at a significantly lower rate than materials with high atomic numbers. For a sample with copper as a substrate and a gold coating of 40 µm, beta particles are scattered by both the substrate and the coating material. If the gold coating thickness increases, so does the backscatter rate. The change in the rate of particles scattered is therefore a measure of the coating thickness. Reliable applications for the beta backscatter method are measurements where the atomic number of the coating and substrate differ by 20 percent. These include gold, silver or tin on electronic components as well as coatings on machine tools, decorative plating on plumbing fixtures, and vapour-deposited coatings on electronic components, ceramics and glass. Other applications could include organic coatings such as oil or lubricant over metals.

The beta backscatter method is useful for thicker coatings and for coating/substrate combinations where magnetic induction or eddy current methods won’t work. It’s also less costly than the X-ray fluorescence method.

Changes in alloys affect the beta backscatter method, and different isotopes and multiple calibrations might be required to compensate. An example would be tin/lead over copper, or tin over phosphorous/bronze. Both applications are typical in printed circuit boards or contact pins, and in these cases the changes in alloys would be better measured with the X-ray fluorescence method.

Helmut Fischer - X-ray Fluorescence method



X-ray fluorescence is a versatile, noncontact method that allows the measurement of very thin multilayer alloy coatings on small parts and complex shapes.

Measurement is performed by exposing the part to X-radiation. A collimator focuses the X-rays onto an exactly defined area of the test specimen. This X-radiation causes characteristic X-ray emission (i.e., fluorescence) from both the coating and the substrate materials of the test specimen. This characteristic X-ray emission is detected with an energy dispersive detector. Using the appropriate electronics, it's possible to register only the X-ray emission from the coating material or substrate. It's also possible to selectively detect a specific coating when intermediate layers are present. Common applications include printed circuit boards, electronic components, jewellery and optical components.

X-ray fluorescence isn't used to measure organic coatings. It's also somewhat limited by the coating's thickness, usually not exceeding 0.5-0.8 mils. However, unlike the beta backscatter method, X-ray fluorescence can measure coatings with similar atomic numbers, such as nickel over copper. Different geometrical parts can also be measured with this method.

As previously mentioned, different alloys affect an instrument's calibration. Analysing base material as well as the coating's thickness is critical to ensure precision readings. A state-of-the-art X-ray system and software program will reduce the need for multiple calibrations, save time and improve quality.

Helmut Fischer - Hand-held Coating Thickness gages

These gages typically operate using the magnetic induction method, the eddy current method or a combination of both. In today's economy, many manufacturing companies have multiple applications; therefore, selecting the right gage to meet multiple tasks is critical. Hand-held gages come with either built-in integrated probes or units with probes on a cable. These units are ideal for one-hand operation and are most often used on a larger measurement surface such as an automobile part or appliance. Units that have detachable probes offer more flexibility, and they also allow users to exchange probes in the future if the application should change.

Many hand-held units also have complete statistical capabilities--including instant averaging, high/low and standard deviation--that can be downloaded to a computer for detailed process control. Some units will even take readings and immediately send the measured values to a computer via a wireless radio transmitter. In those cases, operators don't have to wait until the end of a shift or lot to download the stored readings. Access to the data is immediate.

Influences in coating thickness measurement can affect the accuracy of the reading, and users should be aware of these when taking measurements. Some of these influences include distance to the edge of the part, surface curvature, thickness and magnetic properties of the substrate, heat treatment, magnetic particles in the coating material, external magnetic fields and residual magnetism, surface roughness and contact force (i.e., probe pressure).

A corrective calibration can be established by taking readings of certified foils on the actual substrate that will be in use. This calibration can then be stored so that users don't have to recalibrate for every part. If a gage offers this capability, users can press a button to select the application that represents the specific calibration. Some gages can calibrate through the coating.

Comparisons have been made between probes that require calibration for curvature and new curvature-compensated probes. Special probe designs virtually eliminate curvature dependence and improve the accuracy of the readings. This in turn makes it possible to measure the coatings on differently shaped surfaces without having to constantly recalibrate to specific part geometry.

There are several different types of measurement methods and a wide variety of gages, both hand-held and bench top, from which to choose. Knowing some of the benefits and limitations of each method is important when deciding which unit will be most suitable.