Non-Destructive Measurement of Coating Thicknesses

Measuring the thickness of coatings is an essential part of surface technology. This article describes the most commonly used non-destructive measurement processes and provides helpful information on calibrating measuring devices.

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Materials and components can be coated with a layer of another material for a wide range of reasons. The coating may consist of paint, electroplating or a multi-layer structure. The reasons for applying it include functional requirements, such as corrosion protection, and also decoration, as in the case of vehicle paints and decorative chrome finishes. During the application process, the thickness of the coating layers is an important consideration. The key factors in this respect include making efficient use of resources, providing adequate protection, keeping weight to a minimum and guaranteeing the dimensional accuracy of the component.

Non-destructive measurement

Two different non-destructive processes are generally used for coating thickness measurement: the magnetic method in accordance with ISO 2178 and the eddy current procedure in accordance with ISO 2360.

The magnetic or magnetic induction procedure is used to make non-destructive measurements of the thickness of non-magnetic coatings on magnetic substrates (ferromagnetic materials, in other words, iron and steel). The coatings being measured must not be magnetic. These can include varnishes, paints, enamel, plastics, rubber, glass, aluminium, lead, chrome, copper, brass, zinc and tin.

The eddy current (electrical) process makes non-destructive measurements of the thickness of non-conductive coatings on non-magnetic metallic substrates, for example aluminium, aluminium alloys, copper, brass, zinc and die-cast zinc. The coatings being measured must be electrically insulating, such as varnishes, paints, plastics, rubber, glass, ceramics and also enamel and anodised coatings.

Magnetic induction procedure

In the magnetic induction process, a low frequency alternating current is passed through a field coil wound around an iron core (probe). This creates an alternating magnetic field in the space around the tips of the iron core *(Figure 1)*.

When the tip is moved close to an iron component, the magnetic field strengthens and the voltage generated in a second coil (the measuring coil) increases. This voltage has a non-linear dependency on the distance between the probe tip and the iron surface. When a measurement sensor is placed on the coating, the tip of the probe is a specified distance from the iron. As a result, a predefined voltage is generated in the coil. This is electronically evaluated and the coating thickness is shown on a digital display.

Eddy current procedure

The eddy current process uses only one coil and a high frequency alternating current is passed through it *(Figure 2)*. The resulting alternating electromagnetic field generates an alternating current when the coil is moved close to a metal part. This is referred to as the eddy current and it flows in a circular movement around the metal object. The eddy current and the alternating magnetic field that it produces weaken the original field. The effect of this on the coil is to change its inductivity, which is a characteristic property of any coil.

When a measurement sensor is placed on the coating, the coil is a specified distance from the non-ferrous metal substrate and, therefore, a predefined coil inductivity is generated. This is evaluated electronically and the coating thickness is shown on a digital display.

In some devices, the two coil systems are arranged in such a way in the measurement sensor that the alternating field of both coils – the low frequency and the high frequency alternating field – is influenced by placing the sensor on the object that is being measured. The measurement signals of both coils are evaluated automatically by a microprocessor in such a way that the appropriate measurement procedure for the substrate is chosen and the correct coating thickness is displayed. This means that there is no need to select a substrate or a measurement procedure in advance.

Measurement without calibration and zeroing

Both measurement processes require the magnetic flux lines to be undisturbed *(Figure 3a)*. However, this will not be the case if the probe is placed on a curved surface *(Figure 3b)* or an edge *(Figure 3c)* for example.

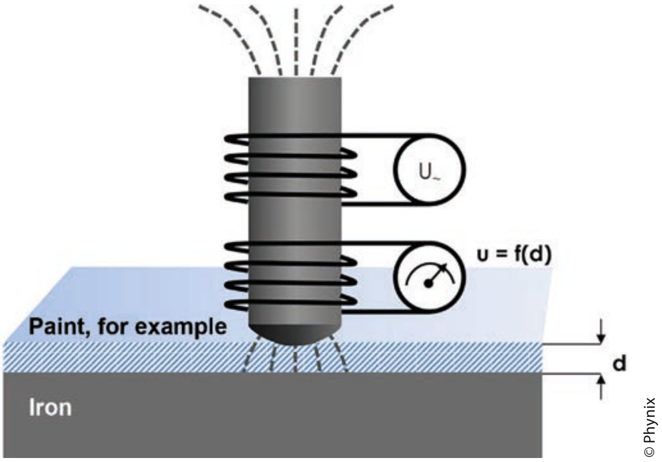

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Figure 1 > Magnetic induction measurement probe.

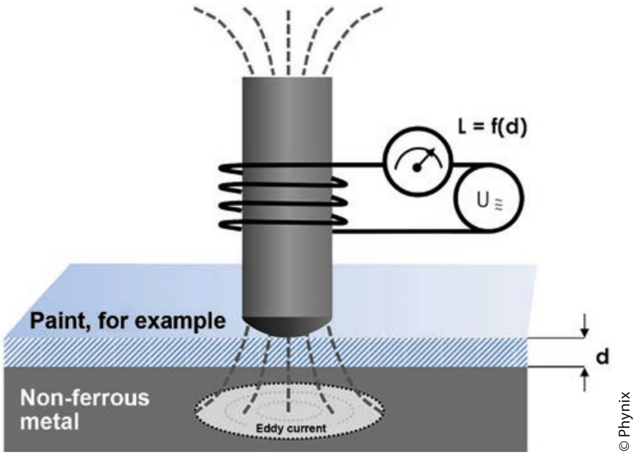

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Figure 2 > Eddy current measurement probe.

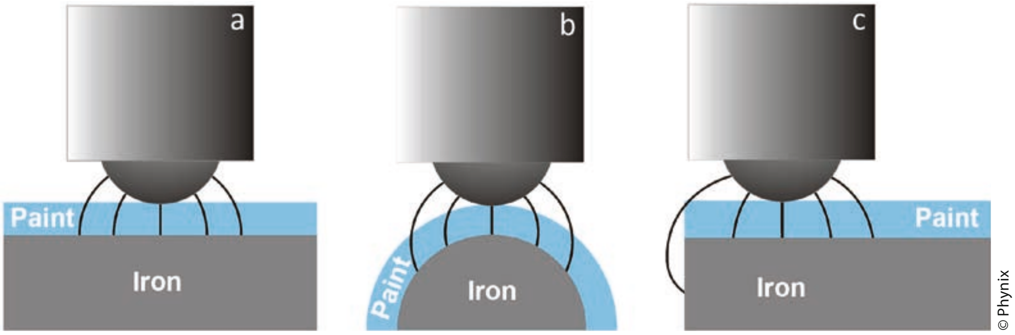

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Figure 3 > Flux lines on a level surface (a), on a cylinder (b) and on an edge (c).

Geometric limits are generally specified for the measurement probes. If the surface falls below these limits, compensation is needed. These limits relate to the surface being measured, for example, and include the radiuses of convex or concave curves, the distance to edges and the thickness of the measurement object.

In both the examples shown *(Figures 3b and 3c)* the magnetic field in the measurement coil is not as powerful as on the level surface *(Figure 3a)*, despite the coating thickness being the same. This can be seen in the diagram at the end of the flux lines. As a result, the coating thickness measurement displayed will be too large. In these and in similar cases (measurements in grooves, measurements on very thin metal sheets), the measuring device can be adjusted to these special geometric measuring conditions. In this procedure, known as zeroing or one point calibration, the probe is placed in the same position on an uncoated object several times. This allows the device to compensate for the change in the flux lines, which is the equivalent of zeroing. The important factor here is to ensure that the zeroing process is carried out on a measurement object with no coating in the same position and in a similar way as the subsequent measurement on a coated object.

The zero test plates included with most measuring devices are not suitable for zeroing, because they do not show the change in the flux lines, but instead show the ideal case of a measurement on a level surface. These zero test plates are only useful for checking the measurement uncertainty in ideal conditions.

Complex measurement surfaces rarely occur in practice, which means that the preset factory calibration can generally be used. However, in some industries a wide variety of different parts, very small components or workpieces with complex curves have to be measured regularly, for example when electroplating or coating screws. In these cases, it would not be practical to zero the measuring device using an uncoated sample before measuring every different type of screw.

These industries in particular will benefit from using coating thickness devices which allow several different calibrations to be stored in files named by the user (for example, the product name or article number can be used). With these devices, the zeroing process is carried out once for each different product type and the results are stored. The different calibrations can then be accessed immediately for the different product types without the device needing to be zeroed using an uncoated sample on every occasion. //

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