Non-Contact Coating Thickness Measurement Ensures Protection Against Corrosion

Systems based on the principle of advanced thermal optics are now being used for the fully automated measurement of the thickness of coatings, including zinc flake systems, on the production line. This technology is now available in the form of a hand-held device which can also measure wet coatings and therefore makes it possible to identify and correct problems in the process before the coatings are cured.

Andor Bariska, Tobias Kleyer

The main function of corrosion protection coatings is to minimise the damage caused to components by the effects of corrosion. As it will never be possible to achieve complete corrosion resistance, the challenge lies in guaranteeing sufficient protection for the component during its specified service life.

Zinc flake systems provide effective cathodic corrosion protection

A key quality indicator of the coatings and metallic films that are used to provide corrosion protection is their thickness. This also has an impact on the functional properties and the fit of components.

One coating of this kind is a zinc flake system from Dörken MKS. This is a metallic coating consisting of many small flakes which is designed to protect a variety of different components against corrosion. Zinc flake films usually contain a combination of zinc and aluminium flakes (in accordance with ISO 10683 or EN 13858), which are embedded in an inorganic matrix.

Zinc flake systems are made up of a base coat and a top coat. The base coat has the anti-corrosion properties and, because of its zinc content, provides effective cathodic corrosion protection for the components. This means that the zinc corrodes, because it is the less noble metal, and protects the steel from rusting. If the coating is damaged, the zinc in the base coat is sacrificed to safeguard the nobler steel substrate when it comes into contact with water and oxygen.

A top coat is usually applied over the zinc flake base coat. This increases the corrosion protection and gives the coating additional multifunctional properties, such as increased resistance to chemicals or mechanical damage, a coloured finish or a specific friction coefficient for threaded parts. The special feature of the system is that it can prevent substrate corrosion (red rust) for more than 1000 hours in the salt spray test in accordance with ISO 9227 (NSS), even when it is applied in extremely thin layers. This coating system is usually between 8 and 20 µm thick.

Duration of the salt spray test (without red rust)	Reference coating thickness*
> 600 h	6 µm
> 720 h	8 µm
> 960 h	10 µm

* The reference coating thickness includes both the base coat and the top coat, depending on the type of coating system.

Source: ISO 10683 Fasteners – Non-electrolytically applied zinc flake coating systems

Table 1 > Corrosion protection depending on the coating thickness (duration of the salt spray test without red rust).

Corrosion protection is heavily dependent on the coating thickness

The coating thickness is chosen on the basis of the type of coating system and the required protection. The ISO 10683 standard "Fasteners — Non-electrolytically applied zinc flake coating systems" includes a table which indicates the extent to which

the level of corrosion protection depends on the thickness of the coating (by means of the duration of the salt spray test without red rust). Test panels with coatings of different thicknesses (Figures 1 and 2) demonstrate the correlation.
A variety of different application processes can be used with coatings of this kind. First of all, the material is generally thinned to a suitable viscosity in a similar way to paint. It is then applied at the required thickness by means of a spraying or dip-spinning procedure, for example. After this, the wet coating is dried or cured for a specific period to produce the finished result.
To ensure that the specified level of protection is provided, the thickness of the coating is measured during the application process. Ideally, the measurement procedure should be reliable, reproducible, simple, fast and non-destructive. It must also be possible to measure the coating thickness on highly curved surfaces, for example on bolts, and on edges and in corners.
In the past, a contact measurement process such as magnetic induction was generally used to determine coating thickness. This involved manually positioning a probe on the surface of the coating. The coating thickness could be calculated on the basis of changes in the electromagnetic field, depending on the distance. Only dry coatings can be measured using this method and the roughness of the surface leads to a wide variation in the measurements. This process is not suitable for some types of components, such as springs and screw threads, because the probe cannot be positioned on them.

Figure 1 > Test panels with a coating thickness of 9 µm: without exposure (left) and after 1200 hours of the salt spray test in accordance with ISO 9227 (NSS) (right).

Figure 2 > Test panels with a coating thickness of 11 µm: without exposure (left) and after 2500 hours of the salt spray test in accordance with ISO 9227 (NSS) (right).

Non-contact measurement of wet and dry coatings

In order to overcome these disadvantages, the Swiss company coatmaster AG has developed a measurement method based on advanced thermal optics. This involves using a computer-controlled light source to heat the surface for a short time. The subsequent dynamic temperature changes are recorded by high-speed infrared sensors, which do not come into contact with the coating, and the resulting data is converted into the coating thickness by specially developed algorithms. The non-contact measurement method allows the coating to be measured directly after application while it is still wet and provides the necessary accuracy and repeatability for controlling the process.
coatmaster measuring systems are used for fully automated measurement of coatings, including zinc flake systems, on the production line. Now the company has also developed a hand-held device, the Flex, on the basis of this tried-and-tested technology (*Figure 3*).
The hand-held system has all the advantages of the coatmaster technology, in other words, accurate, non-contact measurement of both wet and dry coatings, regardless of the angle and distance.

Measuring coating thickness in one second

If the measurement procedure is integrated into the coating application process, both the base coat and the top coat can be monitored. The device is calibrated once for each coating material by adjusting its measurement signals with the aid of a microscopic section of the coating layer. The product-specific application is stored and this allows a reliable measurement of the thickness of the coating on a component to be completed in around one second. If the device is calibrated when the coating is wet, it shows the coating thickness that can be expected after curing.
A series of tests carried out at the Dörken MKS technical centre in the German town of Herdecke demonstrated the accuracy and reproducibility of the measurements made with the hand-held device. A microscopic section was used for the one-off calibration process (example in *Figure 4*).

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Figure 3 > Hand-held device for non-contact measurement of the thickness of wet and dry coatings.

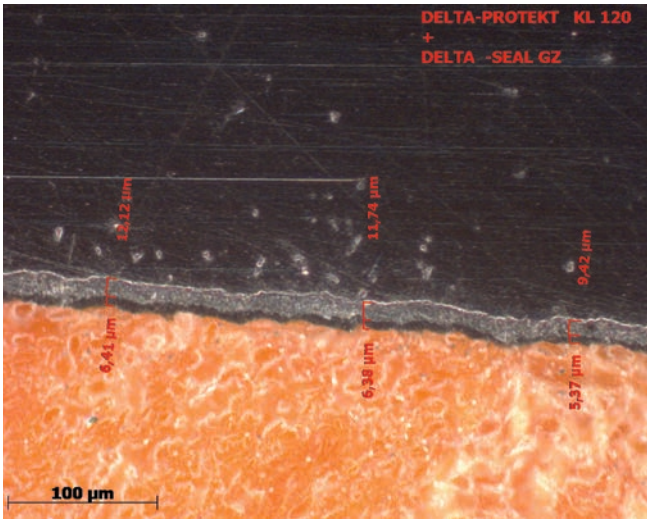

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Figure 4 > Measurement of the thickness of a zinc flake coating consisting of a base coat and a top coat using a light microscope.

Close correspondence with the light microscope

A comparison between the coatmaster Flex and the light microscope shows that the measurements made with the hand-held device are very close to those made with the microscope on both wet and dry coatings (*Figure 5*).

Another test highlighted the fact that measurements of wet coatings made with the coatmaster Flex are dependent on the flash-off time (*Figure 6*). For example, the device can be calibrated on the basis of a measurement made 45 seconds after the wet coating is applied. If this calibration is subsequently used in the process, provided that the environmental conditions remain consistent there should be no differences in the measurements taken after 45 seconds. However, when a measurement is made 0 seconds or 90 seconds after the application, evaporation could lead to a maximum discrepancy of 10%. If the typical times of the coating process are known, the calibration measurement should be carried out at the time when the actual measurements will be made to ensure that the procedure is as accurate as possible.

The normal distribution of the Flex measurements if they are repeated is less than 0.3 µm.

The coatmaster Flex hand-held device gives coaters the option of measuring the coating thickness on wet components, which means that problems with the process can be identified and corrected quickly before the parts are cured. In addition, the accurate, reproducible measurements of dry coatings ensure the reliability of the quality assurance process, even on parts with complex shapes or those made from stainless steel.

These benefits have prompted S. Scherdel GmbH & Co. KG, a German contract coating company working with zinc flake systems supplied by Dörken MKS, to buy a hand-held device for measuring coatings

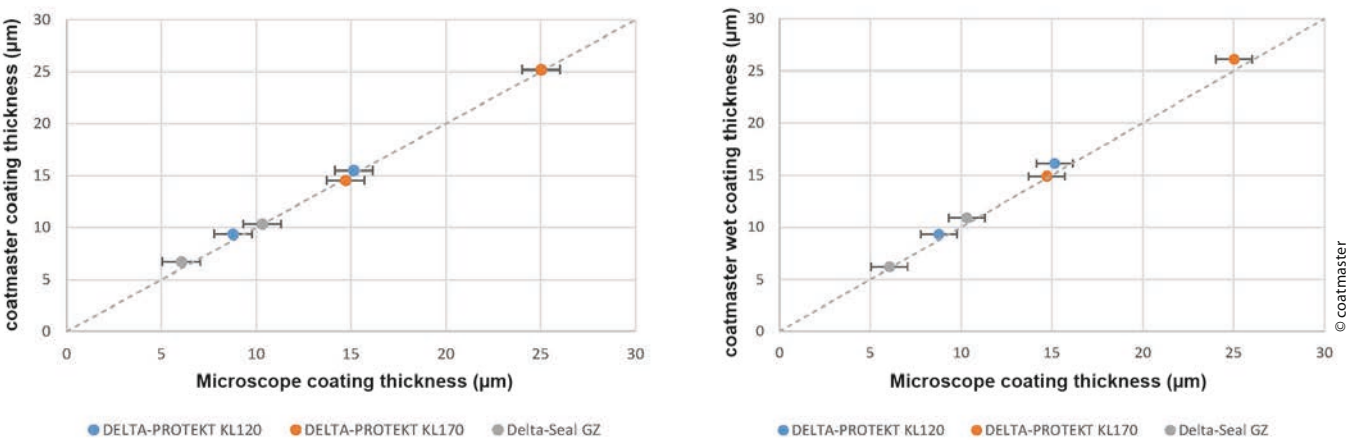

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Figure 5 > Comparison of the thicknesses of dry coatings measured with a microscope and with a coatmaster Flex (left: Flex dry, right: Flex wet). In both cases the measurements correspond closely (R2 = 0.998). The standard error of the microscope measurement is less than 1.5 µm and that of the Flex measurement is less than 0.3 µm.

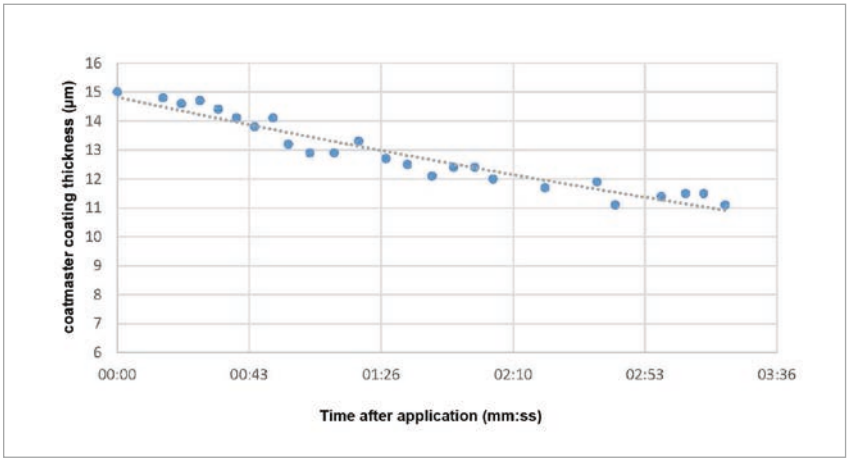

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Figure 6 > The thickness of a wet zinc flake base coat measured with the coatmaster Flex as a function of time. The coat shrinks due to the evaporation of the solvent. An accurate prediction of the dry film thickness with a maximum error of 10% within the first 90 seconds is possible if the device is calibrated after 45 seconds.

during production and for inspecting outgoing goods. The device is currently awaiting approval by the company's end customers in the automotive industry.
Tobias Kleyer from the technology management department at Dörken MKS comments: "The Flex enables our customers to monitor their coating processes quickly and easily. This helps to prevent rejects and ensures that the products are of high quality. The result is that their customers are even more satisfied."

The coatmaster process has been included in the latest version of the ISO 2808 standard "Paints and varnishes – Determination of film thickness" as a standardised process for coating thickness measurement, which will make it even easier to use in practice. //

Autoren

Andor Bariska
Co-founder and global account director
coatmaster AG
Winterthur, Switzerland
info@coatmaster.com
www.coatmaster.com

Tobias Kleyer
Technology management department
Dörken MKS-Systeme GmbH & Co. KG
Herdecke/Ruhr, Germany
mks@doerken.de
www.doerken-mks.de