4th International DAAAM Conference
"INDUSTRIAL ENGINEERING-INNOVATION AS COMPETITIVE EDGE FOR SME"
29-30th April 2004, Tallinn, Estonia

CALIBRATION OF COATING THICKNESS GAUGES

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Abstract:

In the field of coating thickness gauges till now the calibration method has been used, where with the coating thickness gauge the coating thickness, reproduced by the coating thickness standard has been measured. The difference between the coating thickness value reproduced by the coating thickness standard and the reading of the calibrated coating thickness gauge would give us in this case the correction in the mentioned calibration point. In the presentation a new calibration method of the coating thickness gauges will be described. A special measuring object with the changeable coating thickness has been measured simultaneously with the standard measuring instrument and the calibrated thickness gauge. The calibration device worked out for the applying of the proposed measuring method will be analysed and examined. Accuracy characteristics of the mentioned device will be given and measurement uncertainty of the calibration results will be analysed. The researching results show us that using the new method we can substantially increase the calibration accuracy of coating thickness gauges.

Keywords: Coating thickness, measurement of coating thickness, coating thickness gauge, calibration of the coating thickness gauges.

1. INTRODUCTION

A modern product has no detail or element without the coating. Coatings are widely used to cover and decorate the pieces and products composed from the pieces. The product life period and qualities (parameters) are directly depending on the coating thickness. Without the accurate measuring of the coating thickness it would not be possible to produce most of the products, especially electronic products.
As the coating in general cannot be separated from its base material for measurement, its measurement by a direct method is not possible. By non-destructive methods the coating thickness can only be determined from one side (from the free side of the coating). Thus, only indirect methods are available for the determination of the coating thickness.
The need to measure the thickness of several kinds of coatings has lead to the design and use of a series of gauges, applying the measuring principle, where the dimension (coating characteristic) for example the magnetic or electrical resistant dependent on the coating thickness is measured non-destructively. The received result is transformed to the coating thickness value.
However, in connection with these measuring instruments another problem has arisen: to assure the traceability of the coating thickness measuring results. It means that to make a right decisions the coating thickness measuring results must be reliable. To achieve this, the coating thickness measuring result must be related with the appropriate base value. In general it is a state or international standard [1]. Hence, the scientific goal is to establish uniformity and traceability in the measurement of coating thickness through the calibration of relevant measuring instruments. The calibration of the coating thickness measuring instruments gives us the relation between the reading of the gauge and the coating thickness value, presented for measurement. To achieve the abovementioned goal, it is necessary to work out modern and scientifically well founded calibration methods as well as measurement standards for their implementation.
In this work we have observed a calibration method worked out in Tallinn Technical University, Chair of Metrology and Measuring Instruments. Also, we describe the standard instrument and researching results applied to carry out the mentioned calibration method.

2. THE NATURE OF THE CALIBRATION METHOD OF THE COATING THICKNESS GAUGES

In Tallinn Technical University, Chair of Metrology and Measuring Instruments a calibration method of coating thickness gauges has been worked out, where the special coating, created for the calibration procedure and to be kept stable during a certain period has been measured at the same time by the standard gauge and the calibrated gauge.
The scheme of the calibration of the coating thickness gauge is given in Figure 1.

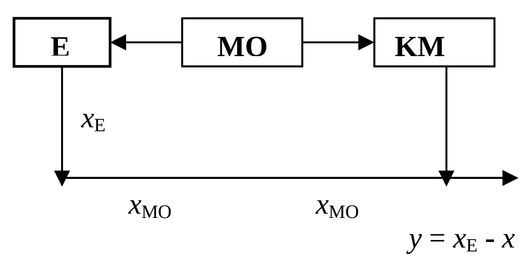

Fig. 1. The measuring of the coating thickness by the standard instrument and the calibrated gauge at the same time: E – standard instrument; MO – special coating (measuring object); KM – calibrated coating thickness gauge

By the mentioned calibration scheme the calibration model of the coating thickness gauge is given by:

$$y = x_E - x + \sum_{i=1}^{N-2} \delta x_i \qquad (1)$$

where y – the estimate of the correction to the coating thickness gauge indication,

x_E – the coating thickness value realized by the measurement standard,

x – the indication of the calibrated coating thickness gauge,

$\sum_{i=1}^{N-2} \delta x_i$ – the amount of the corrections considered in the calibration procedures.

To carry into effect the abovementioned calibration method of coating thickness gauges, a standard measuring instrument has been worked out, which scheme of principle is given in Figure 2 and 3.

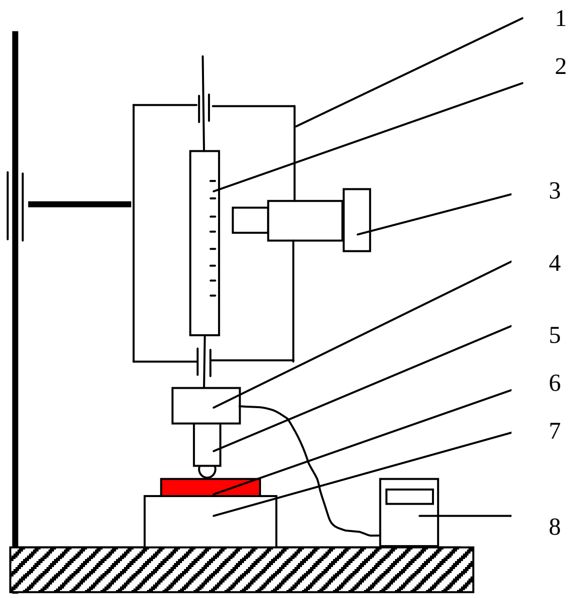

Fig. 2. Standard measuring instrument with the coating thickness gauge to be calibrated: 1 – Abbe linear gauge, 2 – linear gauge stock, 3 – reading device, 4 – fixture, 5 – probe of the coating thickness gauge, 6 – film, 7 – base material,
8 – indication device of the coating thickness gauge.

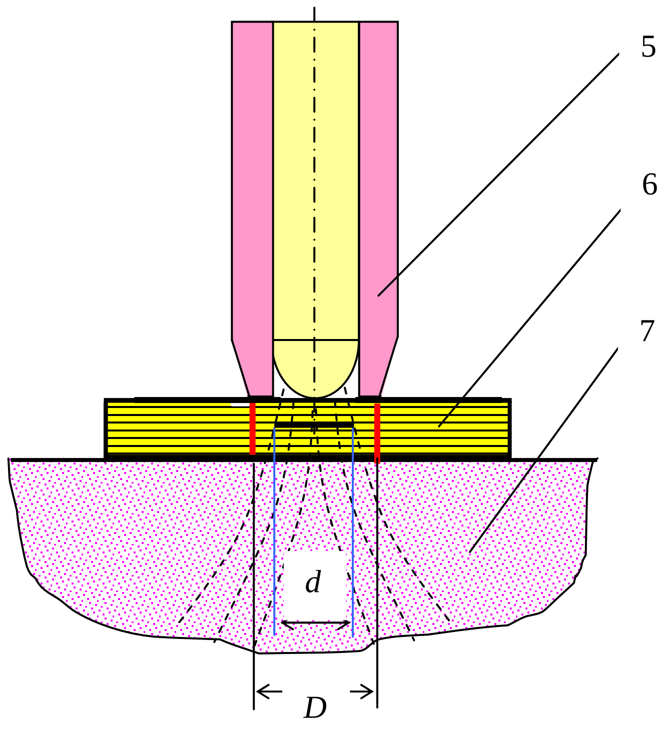

Fig. 3. Measuring principle: 5 – probe of the coating thickness gauge, 6 – film, 7 – base material, *d* – the surface measured by the calibrated coating thickness gauge, *D* – the diameter of the contact circle

Coating thickness measuring instruments with the indication previously adjusted and fixed will be calibrated by the following procedure:
The standard measuring device and the coating thickness gauge to be calibrated are simultaneously measuring the thickness of the same coating. The probe of the calibrated coating thickness gauge measures the thickness in the diameter *d*. The standard measuring device measures the thickness in the diameter *D*. The developed standard measuring instrument is shown in Figures 2 and 4. The coatings with different coating thickness were measured.

3. RESEARCH RESULTS

The developed standard measuring instrument and the calibrated coating thickness gauge are shown in Figure 4.
During the research the universal coating thickness gauge “eXacto FN” by ELEKTRO-PHYSIK was calibrated and two different modes were used. Mode “ferrous” is used to measure the non-magnetic coatings on steel and on other ferrous metals. The measuring principle is called “Magnetic induction principle” and it can be described as follows: The measurement works on the transformer principle. The inductive coupling between the primary (induction) coil and the secondary (measuring) coil is influenced by the thickness of the non-magnetic coating on the magnetic (ferrous) substrate. With increasing of the coating thickness the strength of the measuring signal diminishes. Mode “nonferrous” is used to measure all insulating coatings on non-ferrous metals (aluminium, copper, brass, zinc etc.). The principle called “Eddy current principle”. A high-frequency, electro-magnetic field is induced into the non-ferrous metal. Thus, an eddy current is produced which size serves to measure the

thickness of the insulating coating. The feedback of the eddy current on the probe results in a thickness value.

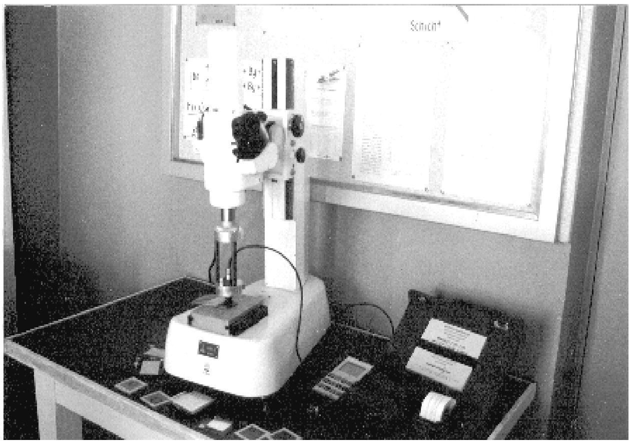

Fig. 4. Coating thickness standard measuring instrument

In this research the coating thickness gauge used at first in ferrous mode. The foils with different coating thickness in steel plate were measured and the single readings of the coating thickness gauge (the measuring instrument to be calibrated) and the length measuring instrument (standard instrument) were fixated. Analogically the coating thickness measuring gauge in nonferrous mode was calibrated.
There have calculated the calibration curve and the curves of expanded uncertainties using the received discreet calibration results. Mentioned calculations have used [2] the solution of the polynomial regression task. This solution uses the method of least squares to fit the higher rank curves with the discreet calibration results got in the calibration process. There has been used the fact, that deviations square sum between the calibration results and calibration curve must be minimal.
The research (calibration) results are given in Figures 5 and 6. To calculate the measuring uncertainty an appropriate program has been worked out.

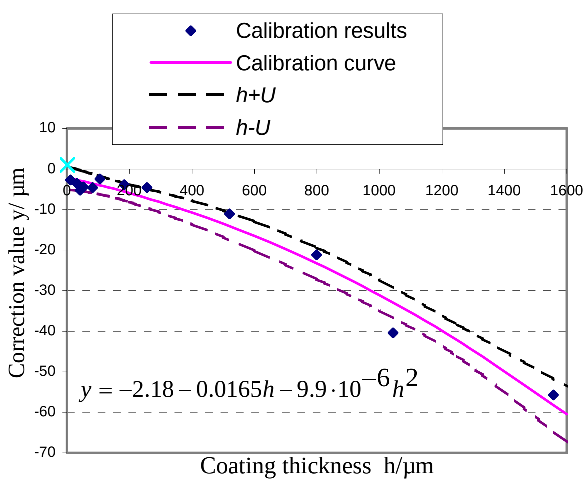

Fig. 5. Calibration curve of the coating thickness gauge. Ferrous mode

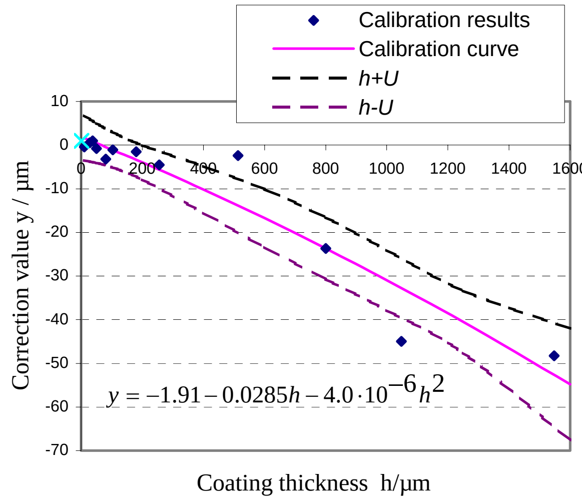

Fig. 6. Calibration curve of the coating thickness gauge. Non-ferrous mode

4. CONCLUSIONS

Research results show us, that the developed coating thickness gauges calibration method and the standard device would enable to calibrate the coating thickness gauges in the arbitrary desired indication points. It let us increase significantly the accuracy of the calibration, as in case of the calibration method held by the Abbe measuring principle.
The pressure of the probe to the surface can also be taken into consideration. This calibration method reproduces quite precisely the coating thickness measuring scheme and procedure, which would significantly increase the reliability of the calibration results.

5. REFERNCES

[1] Kulderknup, E., Laaneots, R., Mathiesen, O., Nanits, M.: Calibration of Measuring Instruments (in Estonian). Tallinn: TTÜ kirjastus, 2000, 107 p

[2] Laaneots, R., Mathiesen, O.: Basis of the Measurement (in Estonian). Tallinn: TTÜ kirjastus, 2002, 206 p

The work is carried out by the support of Estonian Ministry of Education Science Grant No. 142506s03 and Estonian Science Foundation Grant No. 5621