International Symposium on NDT in Aerospace, 22 to 24 November 2010, Hamburg/Germany.

Paint thickness measurement on CFRP and similar substrates

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Abstract: Carbon fiber reinforced plastics (CFRP) are more and more used in aerospace applications because of their potential to considerably reduce the weight. Using CFRP, however, the problem occurs that at painted parts the paint thickness has to be measured non-destructively. Traditional procedures using eddy current or ultrasound come to their limits because the substrate is only medium conducting and furthermore anisotropic. These substrate properties reduce the reliability of traditional non-destructive paint thickness measurements considerably.

In 2007 we have presented a new procedure to measure paint thickness on CFRP in a laboratory environment. This procedure was based on microwave technology.

The present paper describes the development of an instrument which allows the paint thickness measurement also mobile in an industrial environment. Basically it makes use of the above mentioned microwave procedure. The instrument that was presented in 2007 already showed the measurement results to be not depending on the paint type. The new instrument furthermore allows measurements not depending on the substrate material that means not depending on the type of CFPR, on its anisotropy and on the lightning protection, if present. The instrument can also be used to measure paint thickness on metal substrates. Furthermore it is possible to measure the electrical conductivity of the substrate and thereby classify it.

1. Introduction

For thickness measurement of paint on metallic substrates traditionally eddy current or ultrasonic methods are used. These methods are nondestructive. Paint layers on carbon fiber reinforced plastic (CFRP), however, can only hardly be measured nondestructively because CFRP

- is of only medium electrical conductivity
- can have quite different electrical conductivity, especially in situations with and without metallic lightning protection
- is of very inhomogeneous conductivity if the lightning protection is of grid-type
- furthermore is anisotropic in its conductivity.

Beside of eddy current and ultrasound based paint thickness measurements on CFRP also a capacitive method is considered. However, using this method the measured result depends on the dielectric constant of the used paints and paint layers. This needs an extremely high calibration effort.

2. Problem Solution

Here, for the thickness measurement of paint on CFRP a special microwave procedure is proposed. In [1] already a procedure on microwave basis was presented which could determine the paint thickness under laboratory conditions. Here a measurement system to be used in practice is introduced. A microwave resonator makes up the probe. The painted surface of the device under test is simultaneously one wall of the resonator. The complex input reflexion coefficient of the resonator is measured for its real part and its imaginary part. The data evaluation then yields the paint thickness and a hint on the substrate conductivity.

The procedure is designed such that it can also be used on anisotropic substrate material and also on differently conducting types of substrate material. The raw data can even be evaluated regarding the substrate conductivity.

The displayed paint thickness value is furthermore independent from the dielectric constant of the paint. Therefore a calibration of the instrument is possible with arbitrarily isolating foils, for example PMMA foils.

3. Measurement instrument

Figure 1 shows the measurement system consisting of a handheld measuring module and a laptop for the display of the measured thickness. The latter will shortly be replaced by a handheld display module. Both modules are interconnected without cable by Bluetooth.

Figure 1: Paint thickness measurement system, consisting of measurement module and display module (here laptop)

Figure 2: Measuring module

The measuring module is to be positioned with low pressure on the painted surface of the object. In figure 1 the object is a partially painted CFRP coupon. Then the push button switch at the measuring module, see figure 2, is pressed and then the measured paint thickness in micrometers occurs on the display module.
Figure 2 shows the measuring module more detailed. The microwave resonator is inserted into the bottom.

The calibration of the system with foils of known thickness has to be done only seldom. An adjustment of the system using one defined sample without paint should be done approximately each half an hour; this is as simple as a normal thickness measurement.

4. Example Measurements

Quite a couple of tests have been performed. Here we will describe one test series. Test coupons were at our disposal with various thicknesses of paint. They were painted according to procedures used in aerospace industry. Therefore the paint generally consisted of several different paint layers. A fragment of each coupon had been investigated for the individual paint layer thicknesses by micrograph method. The total thickness is plotted in figure 3 for comparison with the microwave based measurements. Three coupons of these series were made from pure CFRP substrate. Four of these coupons were CFRP with expanded copper foil for lightning protection (mesh).

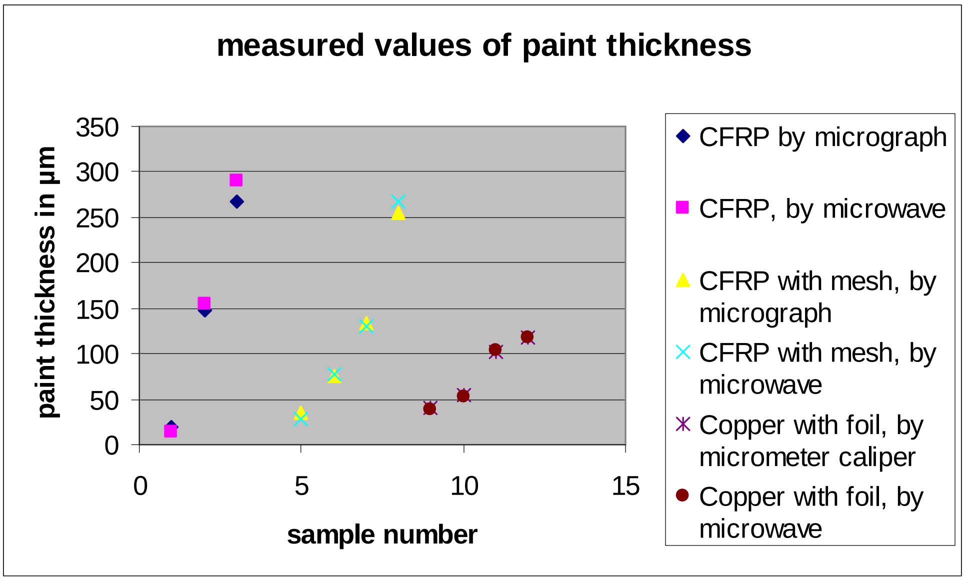

Figure 3: Reference values and measured values of paint thickness

Figure 3 also shows the results of the microwave based measurements. The values are averages of each three single measurements on four positions of the coupon.

Generally, the coincidence of the results obtained by the destructive micrograph method and the nondestructive microwave method is very good. Sample 3 shows the largest difference between both types of measurements. This difference is caused by unusually many small hillocks distributed over the surface of the coupon. This led to an increase in the distance between the microwave resonator and the conducting substrate.

Table 1: sample no. 7: repeatability of measurements

position no.	measured thicknesses in µm		
1	127	127	125
2	130	128	128
3	131	124	128
4	144	144	138

The measurement results on sample no.7 which are shown in table 1, give an idea of the repeatability of the measurements. These measurements were performed in the sequence first measurement at the position 1, 2, 3, 4, then second measurement at the positions 1, 2, 3, 4, then third measurement at the positions 1, 2, 3, 4. The spread of the results of repeated measurements on the same position tend to be smaller than the paint thickness variation of the lengths of the coupon which is in the order of about 7 cm.

In order to show the ability of the system to measure thicknesses of isoating layers on metal substrates a plane copper plate was covered with various transparent foils as used in office applications. The thickness of these foils was carefully measured by a micrometer caliper. These foils have dielectric constants up to 2.9 while the foils used for calibration were from PMMA with its dielectric constant of 2.1. On the right hand side of the diagram in figure 3 the brown points show the identity of the measuring results by micrometer caliper and microwave.

5. Conclusions

An instrument has been described that allows the simple and quick measurement of paint thickness on CFRP and other substrates. This instrument is ready to be used in industrial practice. The substrate may be isotropic or anisotropic. It also may have medium or high electric conductivity. The thickness measurement is independent from the dielectric constant of the paint.

The authors would like to thank Carsten Brandt from Airbus Operations GmbH in Bremen/Germany who placed the coupons at our disposal together with the results of micrograph measurements.

References

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