

Technical Cleanliness Analysis by Eddy-Current Method

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ABSTRACT

Technical Cleanliness (TC) encompass a wider range of application fields with electronics production as one of them. Focusing on this application area, the parameter of conductivity can be considered a crucial property of particulate contaminants deposited on Jomesa filter.

In this short communication paper, the applicability of eddy-current testing method is described in form of initial Proof of Concept study. Obtaining information about conductivity properties of investigated particles can significantly amend current investigations by established methods stipulated in VDA 19 and ISO 16232 standards.

Keywords · Technical Cleanliness · Contamination analysis · Particulate identification · Eddy-current testing · VDA 19 · ISO 16232

Introduction

Technical Cleanliness has grown into significance in several areas of economic activities. For industry of electronics production this study represents analysis of particulate contaminants or simply particles of unknown origin and character. In order to characterise these, several methods are described in VDA 19 and ISO 16 232 standards. The eddy-current testing can serve as another piece or analytical method to further enhance description of properties of investigated particles.

Eddy-current testing is one of the core methods of the so-called non-destructive testing (NDT) methods. This technique is based on creation of induced currents in a sample of conductive material. This is achieved by the magnetic field of a probe, the coil, with alternating current running through it. When the coil approaches the sample, current is induced in it having the shape of eddies, hence the eddy-current measurement. The induced current is of opposite polarity (direction) to the current running through the coil and the same is valid for magnetic fields of the coil and the sample. The induced magnetic field in the sample affects, diminishes the strength of coil's magnetic field which can be detected and measured by the apparatus.

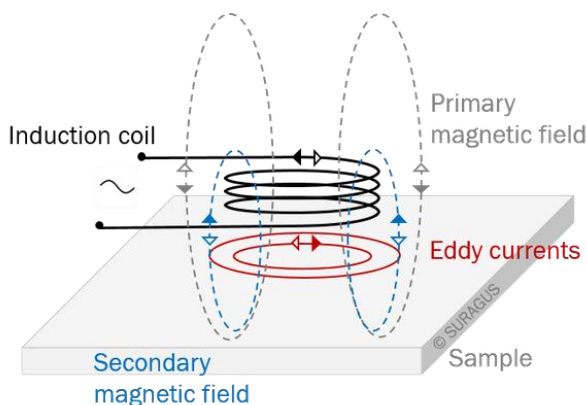


Figure 1. Schematic depiction of eddy-current creation in a conductive sample [1]

1. Materials and methods

1.1 Samples

Samples of 99%+ purity Tin and Aluminium were used as sources of paramagnetic materials, while Copper (C1100) was used for material of diamagnetic properties. Particles of these materials were placed on clean/fresh Jomesa filter and identified by an optical microscope. The dimensions are displayed in Figures 6-11:



Figure 2. Positioning of particles of Tin (topmost), Copper (bottom right) and Aluminium (bottom left)



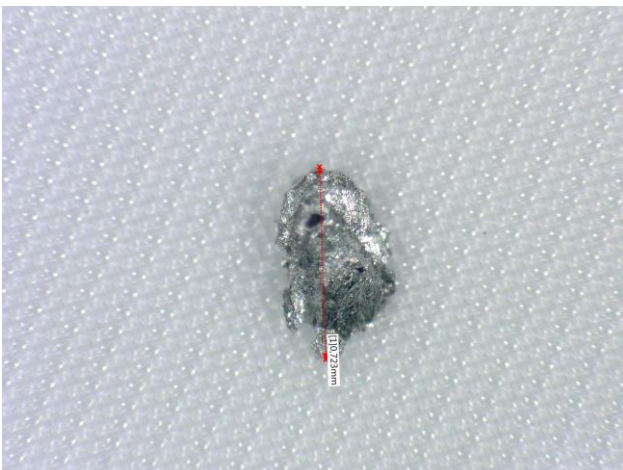
Figures 3-5. From left- Tin, Copper and Aluminium samples



Figures 6-7. Tin particles, from left- bigger, size 1.266 mm; smaller, size 0.729 mm



Figures 8-9. Copper particles, from left- bigger, size 0.952 mm; smaller, size 0.410 mm



Figures 10-11. Aluminium particles, from left- bigger, size 0.723 mm; smaller, size 0.443 mm

1.2 Apparatus and measurement conditions

The measurement was performed using Evident NORTEC 600 eddy-current apparatus with absolute type of coil. The operating frequency was set at 5MHz. Additionally, a differential type of coil operating at 2.8 MHz frequency was also used.

1.3 Absolute and differential type of EC measurement

Eddy-current measurement can assume two main setup configurations- the absolute and differential.

The absolute configuration uses a single active probe/coil for generating electromagnetic (EM) field with the same coil or another coil(inactive) to receive the signal back from induced eddy-currents in the sample. The signal is detected as total impedance of the coil, Z , due to opposite polarity of EC's electromagnetic field. In the impedance plane display (Figures 13, 16-19 and 21), where $Z = R + jX_L$, the horizontal axis represents Resistance (R) and the vertical axis represents Inductive Reactance (X_L). Result of measurement is displayed as a vector having a unique, characteristic angle and length(magnitude). Both parameters change with the change of conductivity; - angle rotates clockwise and vector's length increases with higher conductivity. Therefore, the vector can be used for identification of material the investigated sample is made of, provided the sample is not an alloy of several metals.

Conversely, the differential configuration uses two active coils for generating and receiving EM fields, with detected signal being the net impedance imbalance between them, ΔZ . The signal has characteristic loop-type shape resembling number 8 or infinity ∞ . This type of probe is not suitable for identification of material, but it can still be used for detecting conductive particles on Jomesa filter.

1.4 Magnetic and non-magnetic materials

From the perspective of magnetisms, the conductive materials can be divided into magnetic materials, like Iron or Cobalt, both ferromagnetic, and to non-magnetic materials, like Copper (diamagnetic) or Aluminium and Tin, which are paramagnetic. As eddy-current measurement is based on electromagnetic interaction between the coil and the sample, the diamagnetic samples are slightly repelled to the external magnetic field of the coil, while paramagnetic samples being slightly attracted and ferromagnetic samples being strongly attracted to the coil. This is especially true in case of smaller thus lighter particles.

Therefore, to prevent damaging the coil or the sample, a 6-um [2] thick Mylar film was used as physical barrier for this purpose.

Alternatively, the Jomesa filter can be also used as a physical barrier if turned around and opened from the back side, keeping the particles immobilised against the front lid.

2. Results and discussion

2.1 EC measurement from the back side of the filter

Usually, particles on the Jomesa filter are analysed directly from above, having no obstacle between them and measurement apparatus. Due to possibility of electromagnetic interaction between particles and the coil, the Jomesa filter can be used as physical barrier preventing attachment of particles to the probe. Figure 14 displays such setting with Figures 16 and 17 displaying results of measurement for larger and smaller particles, respectively. Naturally, larger particles provided smooth vectors with ideal shape, which can be used for identification of sample's material. Vectors of smaller particles are more rough and not sufficiently distinct; - measured signal can be used for confirmation of presence of a conductive particle, but it cannot be used for identification of material with sufficient credibility.

2.2 EC measurement from the front side of the filter

Alternatively, a Mylar film can be used for immobilisation of particles on Jomesa filter. This setting is displayed in Figure 15, with results displayed in Figures 18 and 19. Once more, larger particles provided better result in terms of the shape of the vectors. Worth noting is also better result for smaller particles in comparison to previous setting, which is contemplated to be caused by thickness of the Mylar film being only 6 um.

2.3 Differential type of EC measurement

Differential type of probe cannot identify material of the sample. Thus, only presence of conductive particle(s) can be confirmed by this setting displayed in Figure 20, where Mylar film was used for immobilisation of particles. The measurement result is displayed in Figure 21 with vectors following the theory by having characteristic loop-type shapes. Both the angles and the lengths have changed in comparison to absolute measurement result. For this type of probe only the larger particles were responsive enough to produce a reasonable result.

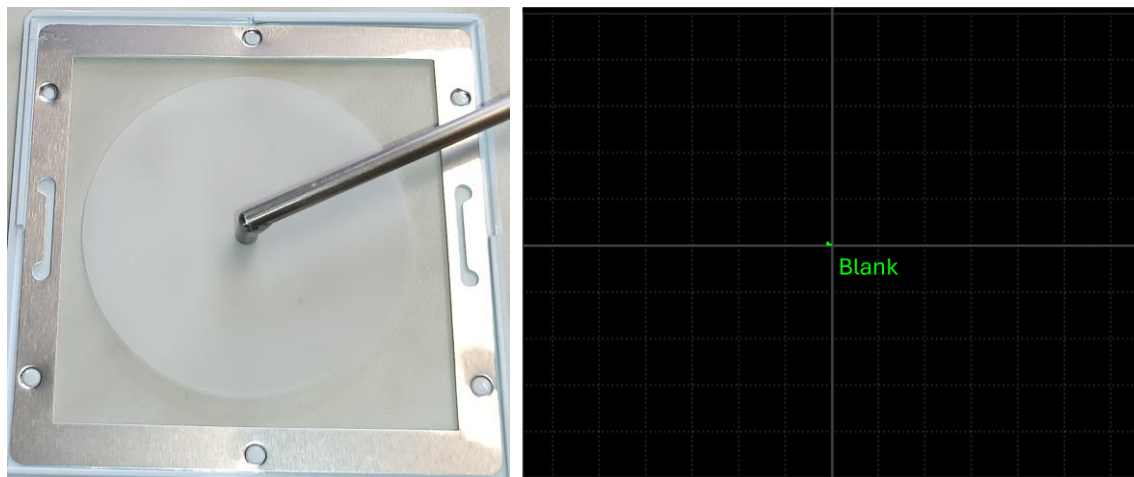


Figure 12-13. Blank measurement and corresponding response of the apparatus

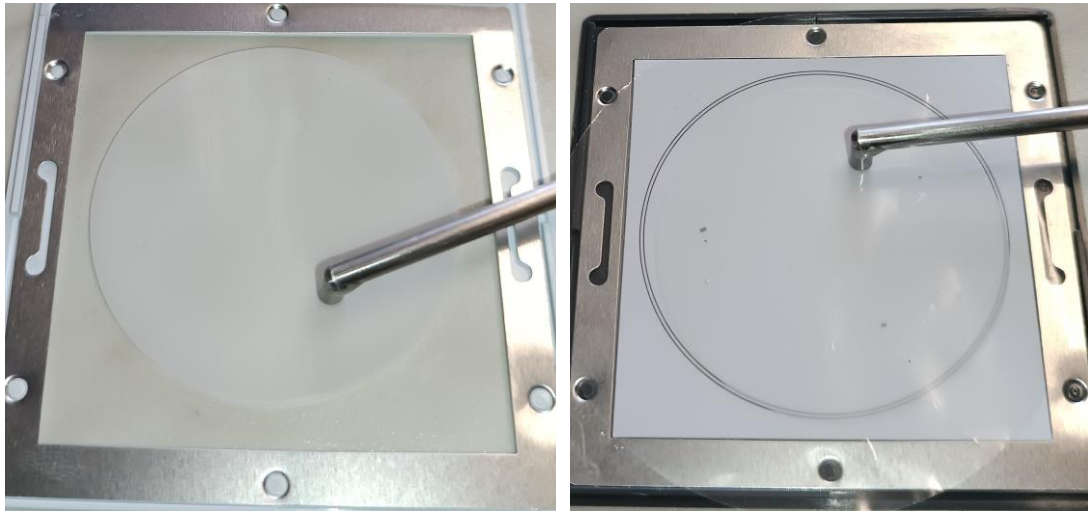


Figure 14-15. From left, EC measurement from the back side and the front side with Mylar film visible

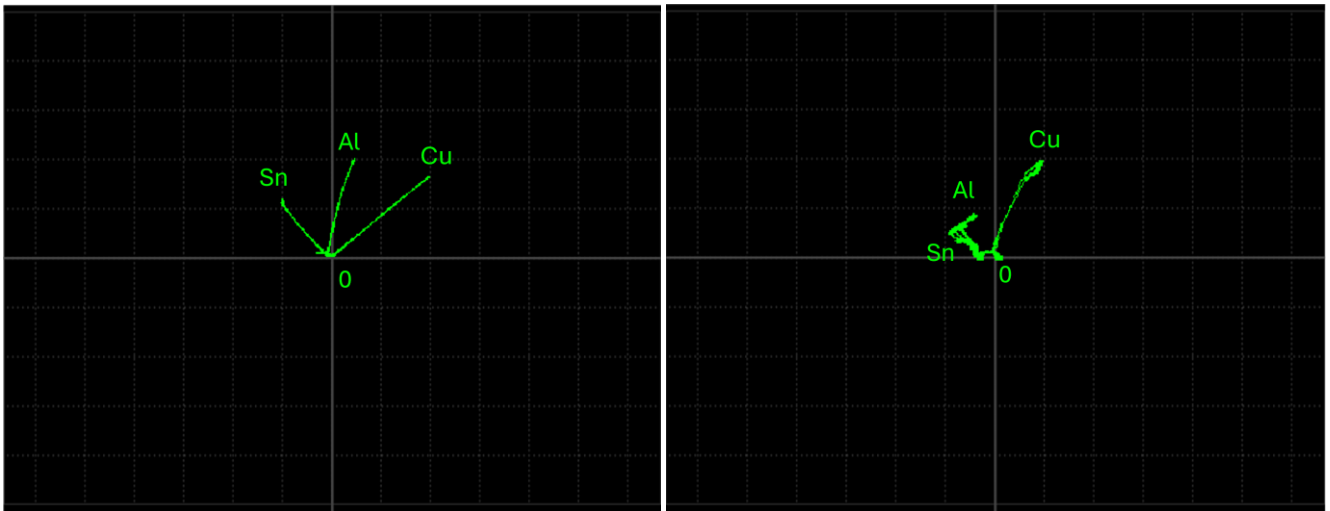


Figure 16-17. Measurements from the back side of the filter, with bigger particles result on the left and smaller particles result on the right

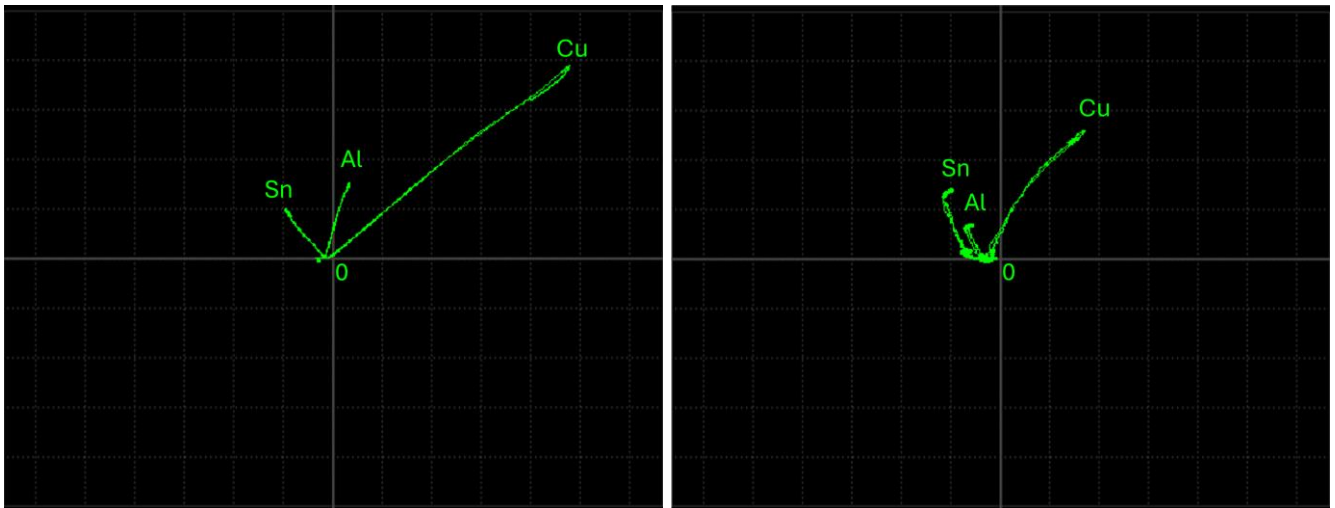


Figure 18-19. Measurements from the front side of the filter using Mylar film, with bigger particles result on the left and smaller particles result on the right

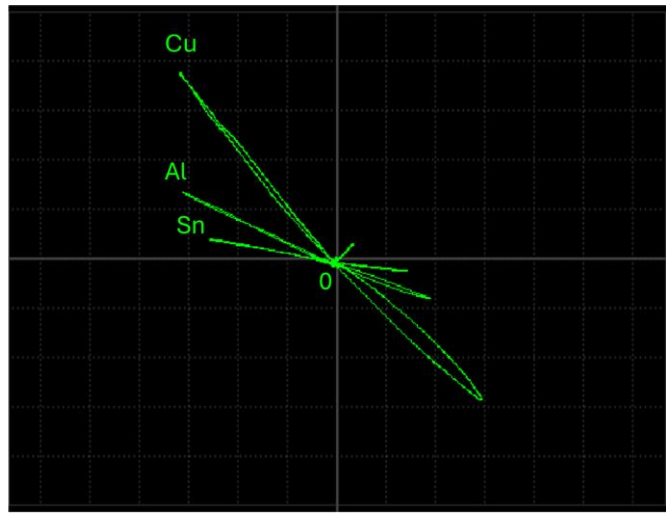
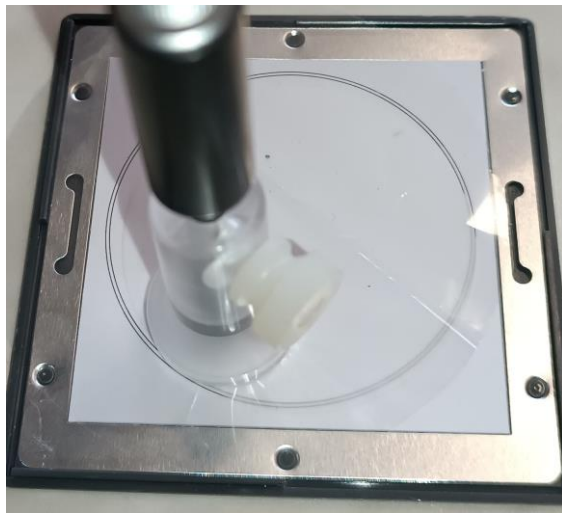


Figure 20-21. Differential type of probe used for EC measurement (from the front side of the filter using Mylar film)- result of bigger particles only

3. Conclusions

This short Proof-of-Concept experiment shows applicability of Eddy-current testing method for investigations of unknown particulate contamination in Technical Cleanliness investigations. This initial report utilises current state of the probes, while further advancements in the probes' design are necessary to improve practical measurement procedure. Nevertheless, information about presence of conductive particles can be achieved and employed in evaluating risks for final products according to VDA 19 and /or ISO 16 232 standards.

References

- [1] https://en.wikipedia.org/wiki/Eddy-current_testing
- [2] <https://store.shimadzu.com/toc-x-ray/x-ray/x-ray-vials/polypropylene-6-0-micrometers-2-5-spectro-membrane-100-per-pack>