

Defect depth effect on the reflection coefficient of an open-ended coaxial sensor

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Abstract. In this paper we present a realization of an open-ended coaxial sensor of internal diameter (2a) and the outer diameter (2b) for the detection of defects in a plate of aluminum, those defects are with different depth and created by using electro-erosion technique. Wire with a pressure of the order of μm , the measurements of the reflection coefficients (S11) are carried out using a VNP vector network analyzer. The network analyzer has been calibrated in a frequency band from 200MHz to 20GHz. The AC voltage created between the two conductors generates an electromagnetic field across the internal dielectric. This field extends outside the cylinder to a distance comparable to its diameter 2b, which represents the thickness of the sensor-sensing material in contact with the plate. The waves are subsequently reflected to the inside of a sensor carrying information on the electromagnetic properties of the medium in contact with the sensor opening. Therefore, the sensor provides measurements in reflection mode only, giving the reflection coefficient as a function of the frequency of the waves guided and reflected at the sensor opening. The experimental results were valid in comparison comparing with the found in the literature.

1. Introduction

The most common microwave techniques, on the other hand, have always required the cutting and machining of samples in appropriate test patterns (waveguide or cavity); They are therefore destructive and do not provide a response in real time. [1]

New non-destructive methods become particularly interesting by the growing availability of inexpensive, robust and easy-to-use solid state sources; they provide interesting ways to solve simple rather difficult problems. [2]

The coaxial probe method is a method of microwave measurement that allows the reflection coefficient at the probe terminal to be measured deep down the probe terminal to the measured materials in order to capture the complex microwave permittivity of the materials. This technique not only has the advantages of being non-descriptive and non-invasive materials, but also the ability to measure bandwidth and ease of sampling. As a result, this method has been widely applied to measure the permittivity of microwave complexes of dielectric materials and composites. [3]

There are several applications of open ended coaxial cable sensors that can be applied in Non Destructive Testing (NDT), Characterization of dielectric and composite materials, fluids. Other applications such as the medical field and quality control of agri-food products. [4, 5]

In this paper, we described the sensor realization, we measured the reflection coefficients (S11) using the open-ended coaxial cable technique with the network analyzer, actually varies the depths of defects to have the effect of depth of defect on the reflection coefficient, for both types of defects



(circular or line). The calculation of the reflection coefficient by network analyzer makes It possible to detect the behavior of the equipment.

The objective of this realization of these sensors is the detection of surface defects for conductive materials and deep defects for dielectrics. They can be used for the characterization of different materials. The proposed sensors are based on resonant and non-resonant near-field methods.

2. Sensor configuration

The aluminum anion 1000 is used for manufacturing the sensor. Copper with resin make the capacitor. Hence, the configuration of the sensor is made of two conductors (aluminum and copper) separated with the resin as isolation. [6, 7]

2.1 Sensor with resonant cavity

The sensor with resonant cavity has the following characteristics:

- Weight :6.48 G
- Dimensions:
Diameter $D = 15.85\text{mm}$
Height $H = 25.70\text{mm}$
- Frequency without load:

$$Fr = 23.97 \text{ GHz}$$

The following figure represents the diagram of sensor.

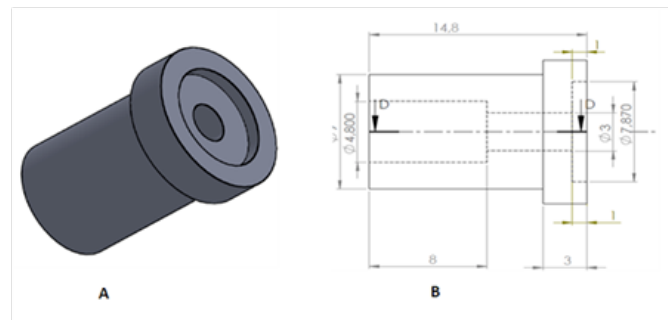


Figure 1. Sensor with resonant cavity performed with solid Works software.

2.2 Sensor without resonant cavity

The sensor without resonant cavity has the following characteristics:

- Weight :7.01 G
- Dimensions
Diameter $D = 15.85\text{mm}$
Height $H = 25.70\text{mm}$
- Frequency without load

$$Fr = 23.32 \text{ GHz}$$

The following figure represents the diagram of sensor.

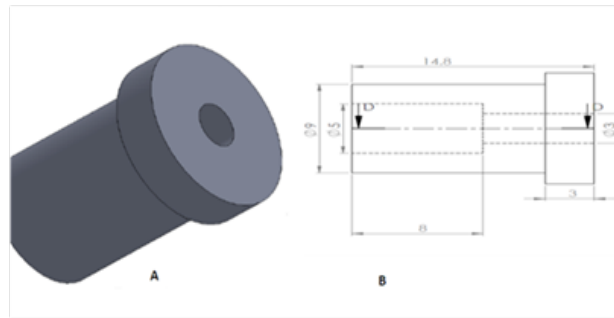


Figure 2. sensor without resonant cavity performed with solid Works software.

2.3 Defects types and samples

The defects were create in two stainless steel aluminum plates of series 304L with 4 mm thickness, two types of defects were create in these two plates: [8]

2.3.1 Défauts circulaire

Circular Defects with different depths (from 1mm to 2.5mm) and section $S=3\text{mm}^2$ are inserted in a the aluminum plate of dimensions $150 \times 120 \times 4\text{mm}^3$.

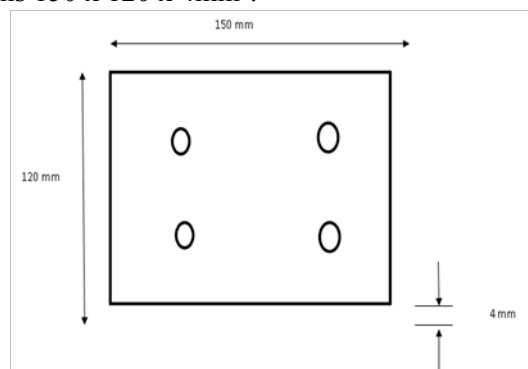


Figure 3. Circular Defect with different depths.

2.3.2 LinearDefects

Linear Defects with different depths (from 1mm to 2.5mm) and width of 5 mm are inserted in a the aluminum plate of dimensions $150 \times 120 \times 4\text{mm}^3$.

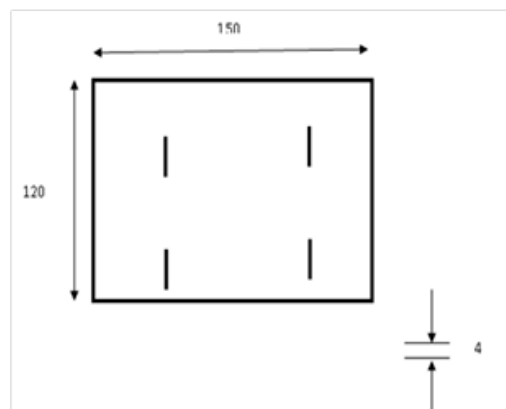


Figure 4. Linear Defect with different depths.

2.4 Experimental step

The following figure depicts the experimental setup for detection of the surface defects.

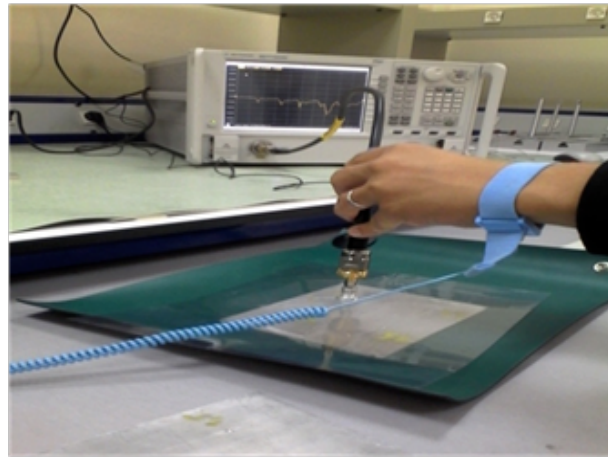


Figure 5. Experimental measurements. [9]

3. Results and Discussion

3.1. Sensor with resonant cavity

- **Case 1: circular defect**

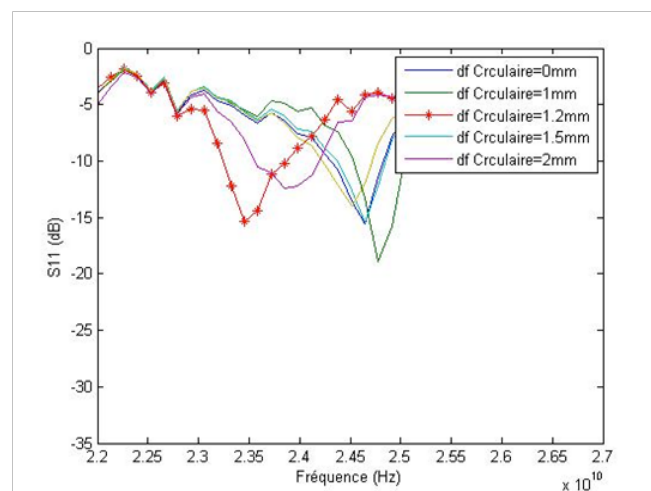


Figure 6. S11 Variation dependant on circular defects.

In this figure one notices that each time in fact the depth of defects varies the reflexion coefficient S11 varies as well in frequency and in amplitude. These variations are related to the presence of the defect.

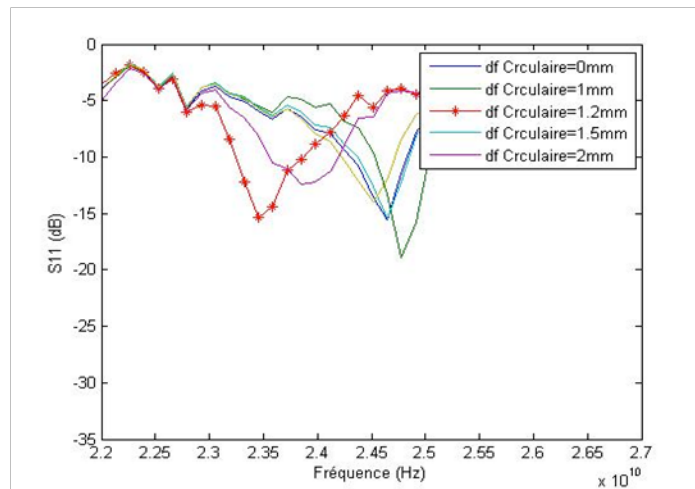


Figure 7. S11 Variation dependant on circular defects.

- **Case 2: linear defect**

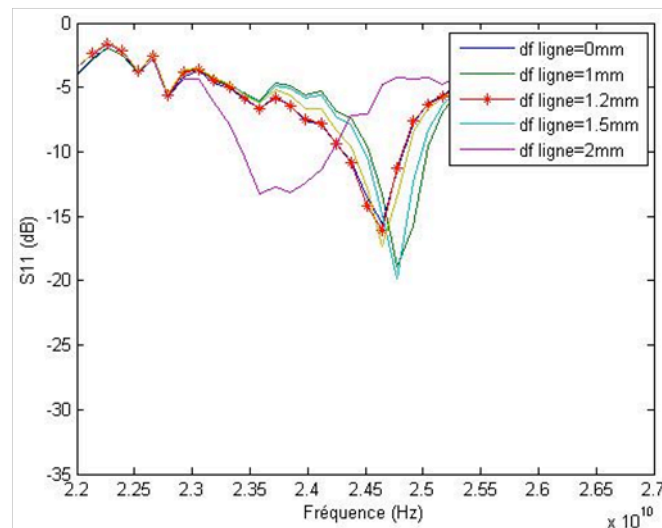


Figure 8. S11 Variation dependant on linear defects.

3.2. Sensor without resonant cavity

- **Case 1: circular defect**

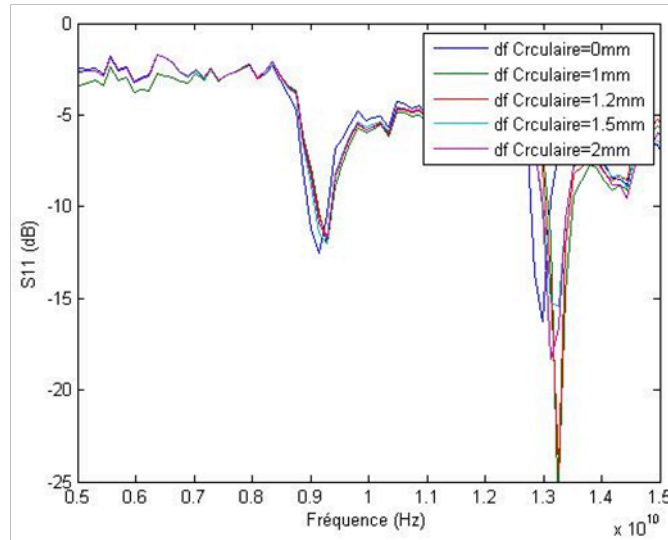


Figure 9. S11 Variation dependant on circular defects.

The variations of the module and the phase of the reflection coefficient are extremely small. Consequently, the resolution and the sensitivity are considerably improved.

- **Case 2: linear defect**

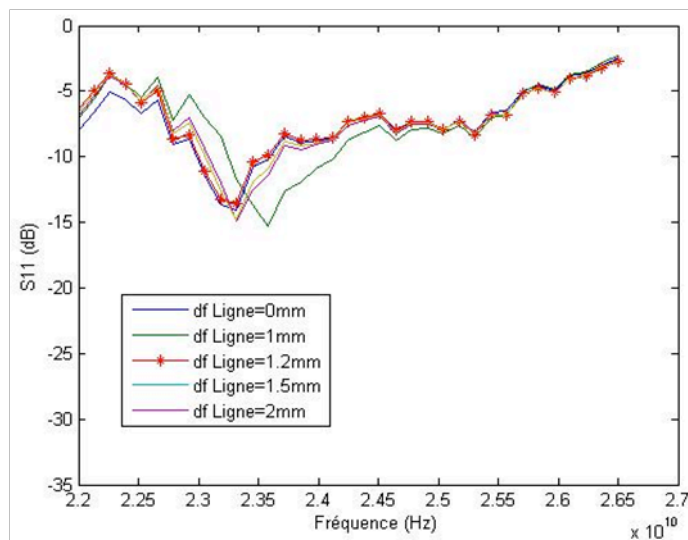


Figure 10. S11 Variation dependant on linear defects.

The variations of the module and the phase of the reflection coefficient are extremely small. Consequently, the resolution and the sensitivity are considerably improved, this variation is the effect of reflection caused by defect this reflection affect the resonant frequency.

In the case of 0 mm defect, we obtain a reflection coefficient of about -15 dB at the frequency 23.5 GHz. Once the defects vary from 1mm to 2 mm, the reflection decreases from -15 dB to -17dB. Also the frequency goes up from 23.5 GHz to 24 GHz.

4. Conclusion

In this work, we demonstrated experimentally the feasibility detection of surface defect using an open-ended coaxial sensor. This sensor is used for the detection of two types of defects (linear and circular) in a plate of aluminium, those defects are with deferent depth and created by using electro-erosion technique. The obtained show that the surface defect affect the sensor characteristics by changing the resonant frequency and band width. So this technique can be used for surface defect detection. Moreover, the technique allows to make defect detection with important incrementing step of the probe, consequently it helps decrease time to characterize a metal surface.

5. Reference

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