COBEM-2017-1710
ELECTROMECHANICAL IMPEDANCE METHOD APPLIED IN A SILICONE RUBBER MODEL

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Abstract. *Structural systems are inevitably subject to environmental factors and loads that can cause damage, which in turn can compromise safety and operational efficiency. Structural health monitoring (SHM) techniques have been of particular interest in increasing the reliability of highly responsible structural systems, while reducing maintenance costs. Most structural engineering systems are composed of mainly ferrous metals and aluminum alloys whose failure modes are reasonably well characterized. The experimental procedure uses a piezoelectric transducer as sensor and actuator, PZT, attached to the surface of the monitored structure. Due to the electromechanical coupling between the sensors and the structure, the presence of the damage in the structure changes the impedance signal. Damage metrics are then used to identify and quantify the damages. In the present work, SHM technique was applied in a silicone rubber model to detect the presence of inclusions made of polylactic acid (PLA). The detection and evaluation of the damage intensity were made based on the comparison between the impedance functions measured before and after the damage, using damage metrics.*

Keywords: *Structural health monitoring, Electromechanical impedance technique, Piezoelectric transducers, Silicone rubber, PLA inclusion.*

1. INTRODUCTION

According to Farrar, Lieven and Bement. (2005), damage, in the context of mechanical and structural systems, is defined as intentional or unintentional modifications of the physical and / or geometric properties of the system, including changes in the boundary conditions and connectivity, which can cause system failure. With regard to the types of structural and material systems to which structural integrity monitoring techniques can be applied, various types of structural engineering systems involving high risks and maintenance costs have been applied, such as: building structures (bridges, buildings, telecommunications towers), aircraft structures, off-shore structures, oil pipelines of the petrochemical industry and entertainment vehicles, roller coasters, for example. The structures most commonly analyzed with the SHM technique are fabricated from metallic materials and more recently from composite materials (Tsuruta, 2008).

The present work proposes the use of the structural health monitoring based on electromechanical impedance for the identification of damages in hyperelastic materials, especially silicone rubber. This technique are performed for the purpose of inspecting, qualifying and evaluating the integrity of a structure without destroying, damaging or generating significant changes in structural systems. In mechanical and structural systems, damage is defined as the intentional or unintentional modifications of the physical and/or geometrical properties of the system (Farrar, Lieven and Bement, 2005).

In this work, a model of silicone rubber was used and the damage was simulated by inclusions made of PLA. The electromechanical impedance technique was then used to evaluate the presence of the damage in the structure. The detection and evaluation of the damage intensity were made based on the comparison between the impedance functions measured before and after the damage, using damage metrics.

2. MATERIALS AND METHODS

Figure 1(a) shows the silicon rubber model used for the tests. Two equal parts mounted one on the top of the other composes this. Each part has length with 200 mm, width with 150 mm and thickness with 5 mm. Inside this sample, three ball-shaped holes were fabricated to fit the balls made with the same material (Fig. 1(b)). Holes have different diameters: 30 mm, 20 mm and 10 mm. Furthermore, seven piezoelectric patches (diameter with 10 mm and thickness with 1mm) were coupled on the top of the specimen.

The measures were made at the frequency range of 80 kHz to 300 kHz and the number of averages was 512. To simulate damage the silicon rubber ball with 30 mm were replaced by a ball made of PLA (Fig. 2). For the tests, the specimen was replaced in the thermal chamber (Fig. 3(a)) at a temperature of 25°C. Ten measures were taken before and after replacing the PLA ball. An electromechanical impedance meter was used to measure the impedance signatures (Fig. 3 (b)).
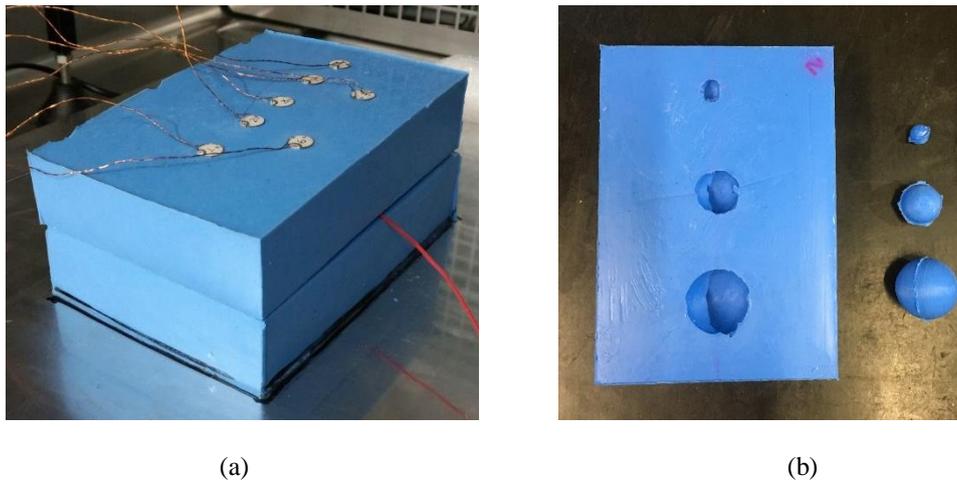

(a)

(b)

Figure 1. Model of silicone rubber: (a) Perspective view, (b) Longitudinal section with the silicon rubber balls.

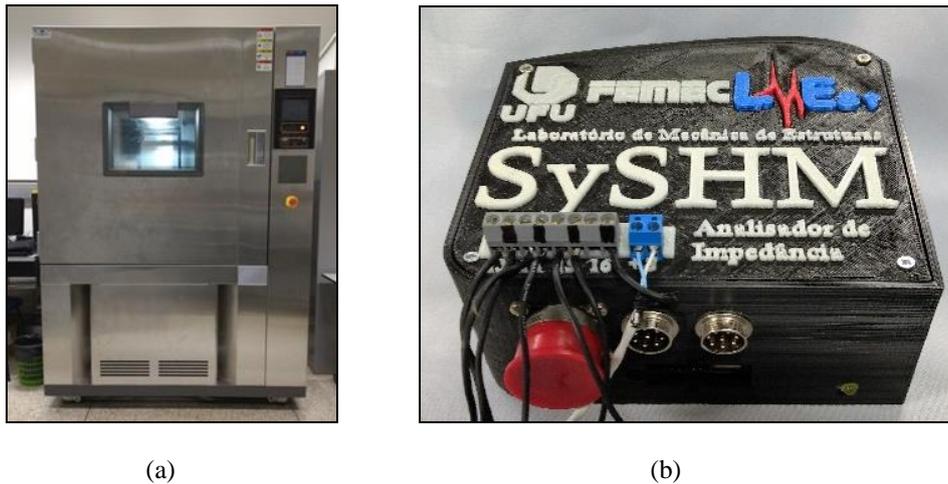Figure 2. Longitudinal view of the phantom sample with damage.

(a)   (b)

Figure 3. (a) Environmental test chamber; (b) Electromechanical impedance meter.

3. RESULTS AND DISCUSSION

Figure 4 (a) shows the impedance signatures before and after replace the PLA ball inside the sample. It is easy to observe the changing in the impedance signatures for the damaged structure. A RMSD damage metric was used to quantify the changes in impedance responses (Fig. 4 (a)). The results show that the value of the damage metric is greater than the baseline indicating that the SHM methodology can detect damage in a silicone rubber material.
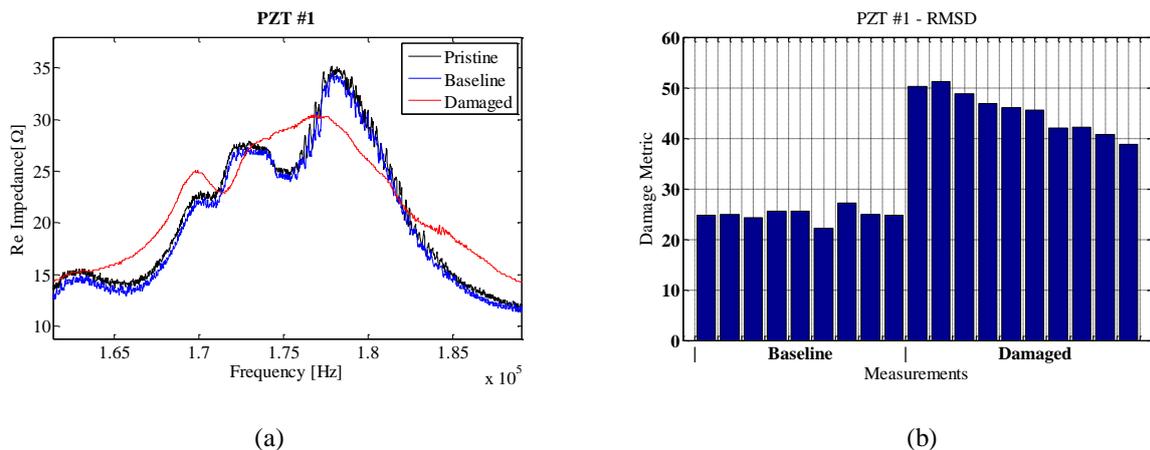

(a)   (b)

Figure 4. (a) Impedance signatures; (b) RMSD damage metric.

4. CONCLUSIONS

The results showed that the SHM method could be used as a technique for detecting damage and consequently identifying presence of inclusion in a model of silicone rubber. However, more analysis should be done to verify the power and sensitivity of this technique. For example, it must be done more tests to establish the minimum size of inclusions that can be identified and the main frequency range of interest.

5. ACKNOWLEDGEMENTS

6. REFERENCES

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7. RESPONSIBILITY NOTICE

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