**Integration of Radio Frequency Identification (RFID) Sensors for Process Monitoring of Polymer Composites**

**Adwoa Owusu1, Abdallah Ragab1, Uday Vaidya1,2**

1University Of Tennessee

Tickle College of Engineering

8863 Neyland Drive, Knoxville, TN 37916, USA.

(865)-974-5321

**2**Manufacturing Science Division (MSD)

Oak Ridge National Laboratory (ORNL), Knoxville

2350 Cherahala Blvd, TN 37932, USA

(865)-576-7658.

ABSTRACT

Composite materials have gained popularity over the past few decades as a substitute for traditional materials because of their high strength and stiffness-to-weight ratio properties. They have been widely integrated into aerospace, automobile, and petrochemical sectors as load-bearing components and it is crucial to ensure they meet high quality standards.

The anisotropy and complex failure mechanisms in composites dictate higher reliability and maintainability to ensure safety. The occurrence of defects can stem from the material, the manufacturing process, and the impact of environmental conditions in its in-service phase, and the ability to capture and detect them is essential to preventing material, energy, and time waste.

The laminar architecture of composites presents a unique opportunity to embed wireless sensors into components to monitor conditions and health. Radio Frequency Identification (RFID) technology has been used for decades in inventory and tracking applications. By encompassing integrated circuits and sensors into the technology, RFIDs can sensetheir environment and wirelessly transmit data. This study details the adaptation of (RFID) sensors for monitoring temperature change of a Vacuum Assisted Resin Transfer Molding Process (VARTM) of a glass fiber polymer composite. The observed results show that RFID sensors can successfully be deployed to monitor temperature in polymer composite manufacturing.

**Keywords:** Wireless sensing, Embeddability, RFID, SHM, Integrated Circuits

INTRODUCTION

The integration of composite material into industry continues to diversify from utility to more structural and load-bearing parts and techniques to assess structural integrity must meet the rising demand for quality, safety, and reliability[1]. The robustness and accuracy of these techniques reduce maintenance costs, downtime, and turnaround time while increasing the efficiency and efficacy of operations. The complexity of composite failure complicates its behavior under different loading conditions[2]and therefore, dictates higher standards and techniques that can accurately detect and assess flaws and defects. The lack of standardized tolerances in the manufacturing of composites facilitates the formation of flaws. The accumulation of damage in composite parts is largely attributed to the laminar architecture that impedes the propagation of damage through the material to more visible zones creating a sharp decline in the stiffness and strength of the part[3]. RFID Technology has been in existence for decades[4]. It is a technology that allows the wireless transmission of data using electromagnetic waves. An RFID system consists of a reader(interrogator), a tag(transponder), and an antenna. When the reader emits an EM wave, the tag in the field of that radiation responds by reflecting the radiation with its identification and information to be processed by the microprocessor on the reader. The information is then sent to the data acquisition system for interpretation. RFID applications have mainly centered on identification, tracking, authentication, and transactional purposes[3]. Transponders can be passive or active[5], whereas passive tags do not have batteries and get their power from the electromagnetic wave emitted by the reader, active tags on the other hand are equipped with batteries and are at an advantage when it comes to large data transmission over long distances. They are however accompanied by frequent issues of battery replacements. To reduce the influence of the tag embedment on the mechanical properties of the part, passive tags were used in this research.

A screenshot of a computer

Description automatically generated

**Figure 1: An RFID System**

Experimentation

The RFID reader and passive sensor tag from SensThys were used in this research. The tag measures 90mm x 30mm and 100µm thick. Woven glass fiber was used in this experiment as it is electrically insulative material to prevent the short circuiting of the tag as observed in carbon fiber panels previously .8 and 16 layers of 6”x 6” GF material was laid up and cured with a two-part Prosett-Epoxy Resin. The sensor was embedded in the middle of both layers, the 4th layer for the 8-layer panel and 8th for the 16-layer panel and centered in the middle of the panel.

The lay ups were infused under vacuum and cured for 24hrs.



**Figure 2: AXZON Temperature Sensor**

A white rectangular object with yellow tubes on a table

Description automatically generated

**Figure 3: Experimental Setup with reader and tag**.

Results

The sensors detected a distinctive exothermic peak characteristic of resin cure reaction with temperatures of 55.5 ˚ C for the 8-layer panel and 31.2 ˚ C for the 16-layer panel. The temperature peak as per the datasheet is between 60.0 - 82.0 ˚ C. The observed difference in peak temperatures between both panels is attributed to the temperature distribution profile during the infusion. The direction of heat flow, along the fabrics or transverse to the fabric, influences the temperature that the sensor can detect. In this case, heat distribution is reduced to flow transverse to the fabric. The sensor embedded in the middle of the fabric can only detect the core temperature when in contact with the resin and explains why the sensor embedded in the 8-layer GF panel senses the temperature change faster than the 16-layer where the fabric acts as a heat sink and reduces.

A red and blue graph

Description automatically generated

**Figure 4: (a) Heat distribution profile observed in the 8 Layer GF composite panel. (b) Heat distribution profile observed in the 16 layer-GF composite panel.**

Conclusion

While the variation in the exothermic peaks is associated with the heat distribution profile of the specimen, it is safe to conclude that RFID sensor has the capability to sense and record temperature. Further work will include the use of DSC to cross-verify exothermic signatures.

Also use an IR camera to track the heat dissipation profile for the VARTM process, varying the number of sensors and placement positions for optimization. Perform mechanical characterization of the manufactured panels.

Acknowledgements

Special thanks to the Department of Energy and IACMI for supporting this study.

REFERENCES

[1] “Non-Destructive Testing and Evaluation of Composite Materials/Structures: A State-of-the-Art Review” [Online]. Available: https://journals.sagepub.com/doi/epub/10.1177/1687814020913761. [Accessed: 18-Jan-2024].

[2] Nath, B., Reynolds, F., and Want, R., 2006, “RFID Technology and Applications,” IEEE Pervasive Comput., **5**(1), pp. 22–24.

[3] Costa, F., Genovesi, S., Borgese, M., Michel, A., Dicandia, F. A., and Manara, G., 2021, “A Review of RFID Sensors, the New Frontier of Internet of Things,” Sensors, **21**(9), p. 3138.

[4] Perret, E., 2014, *Radio Frequency Identification and Sensors: From RFID to Chipless RFID*, John Wiley & Sons.

[5] Karmakar, N. C., Amin, E. M., and Saha, J. K., 2016, *Chipless RFID Sensors*, John Wiley & Sons.