

## HEALTH ASSESSMENT AND COORDINATION OF SELF-SEALING STRUCTURES

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### ABSTRACT

A widely used subset of self-healing technologies is the self-sealing of fluid containment vessels. Challenges unique to sealing fluid or gas storage vessels include liquid or gas flow through punctures, often at high pressures. While most self-sealing technologies have been developed to date for low-pressure applications, such as aircraft fuel tanks, high pressure fluid containment applications are also of interest. Various sealants for fluid systems are available commercially. Automotive applications include additives for tires, cooling systems, and power steering hydraulics. These sealants can mitigate minor leaks or temporarily reduce moderate ones. This is comparable to the level of healing performance found in autonomous self-healing materials. Neither self-sealing additives nor self-healing materials provide information as to the cause, location, or severity of damage. Damage characterization coupled with coordinated self-healing material responses could create a more robust system overall. Complete damage response can be thought of as a five stage process including: detection, location, assessment, mitigation/healing, and prognosis. This project focuses on the first and third stages, detection and assessment of damage. Concepts are demonstrated using a test bed consisting of a low-pressure (700 kPa) pneumatic compressed air tank, an actuator-controlled puncture system, a sensing network with a multi-channel Acoustic Emission (AE) data acquisition and analysis system and pressure transducer, see Figure 1A. A removable bottom plate allows for easy prototyping of self-sealing control strategies.

The Physical Acoustics PCI-2 AE testing system registers an AE, or hit, whenever the signal crosses a pre-set threshold. When a hit is detected, it is time-stamped and several statistical features are generated to characterize the waveform associated with the hit. A simple method for damage detection uses the rate of AE hit detection, which works especially well in the case of leaking, which produces continuous AE generation. Event location using triangulation timing AE is also a demonstrated capability [1]. Event assessment requires more detailed signal processing. AE testing uses relatively few sensors to cover large areas. The challenge is to extract useful information on the source signal from the vast amount of data generated by AE testing.

The self-sealing pressure vessel test bed is outfitted 4 AE sensors. Three holes, with diameters of 0.9mm, 1.6mm, and 2.5mm, were drilled into the removable plate. AE data were collected for simulated leak and seal events on each hole. Seal events used a commercially-available passive sealant, Slime®. The AE data were exported to MATLAB for further analysis. Test variables include puncture size and the presence or lack of sealing agent. Data were collected using all four AE system channels over test trials consisting of puncture-with-leak and puncture-with-seal events for each hole size. Dataset length was limited to keep the number of hits comparable between leak and seal trials.

The AE dataset, consisting of many events described by numerous statistical features for relatively few test cases, is ideally suited for statistical pattern classification. Correctly classifying data based on the presence of sealing action or hole size shows that a signature unique to those scenarios is present within the data. First the dataset acquired for each test is classified according to hole size and presence or lack of sealing agent. Once classified according to test scenario, 10 percent of the total hits is

randomly selected for algorithm training. A feed-forward backpropagation neural network pattern recognition algorithm is created. The neural network is then used to classify the remaining 90 percent of the dataset. Comparison between the neural network pattern recognition algorithm classification and the known classification is easily visualized using Receiver Operating Characteristic (ROC) curves. Curves tracking the upper left hand corner indicate good classifier performance.

The first classification problem addresses classifying a hit as produced by a leak event or a seal event. All data collected, regardless of hole size or AE channel, are placed in those two categories. The ROC curves show the pattern recognition algorithm is reasonably capable of distinguishing leak from seal events based solely on the statistical features describing the hit, see Figure 1B. The second classification problem looks at determining the scale of damage repaired by a seal event. Data from seal tests are categorized according to hole size. The ROC curves show sealed hole size does produce loose trends in AE data, see Figure 1C. The degree of certainty displays a loose trend of inverse relation to sealed orifice size.

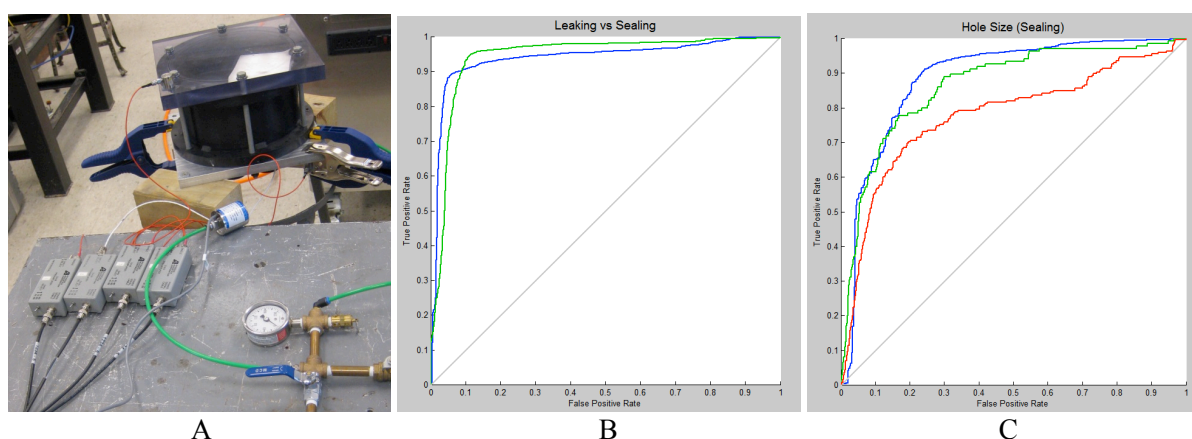


Figure 1: (A) Pressure vessel test bed, (B) ROC curve for leak/seal classifier performance, and (C) ROC curve for hole size classifier performance

The positive results for damage detection and assessment using AE and passive sealants may translate directly to autonomous self-healing materials. AE is a potential solution for monitoring damage and healing within self-healing materials. A complication with the pressure vessel test bed, and one that may be generic, is that AE monitoring can only detect and locate leaks and seals as they are formed. Once the sealing action completes, the source of AEs is eliminated. In order to be effective, AE monitoring must be full time. Upon detection, location and classification, it is also possible to use the information in a coordinated effort to seal leaks. One such approach uses electrocoagulation to assist the passive self-sealing methods, Figure 2.



Figure 2: Electrocoagulation

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## REFERENCES

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