Dry coupled magnetostrictive transducers for robotic inspection of dry storage casks

**Background**
The lack of a national repository for used nuclear fuel has lead to the usage of dry storage casks as the de facto long term storage solution, the usage of which is prevalent throughout the United States (figure 2). Furthermore, as shown in figure 3, the usage of dry storage is only expected to increase over time. Because these casks were originally intended as only an interim measure, there is an urgent need to develop methods to monitor their structural health over the long-term. Additionally, when concerns about the susceptibility of these casks to cracking is considered, the need for inspection becomes even more apparent [1].

**Principles of operation**
Ultrasonic inspection is a well known method of non-destructive evaluation which works by measuring the response of ultrasonic waves propagating through a material. In through-transmission inspection, a transmitter and receiver are used to generate and detect waves in the material to be inspected. The presence of a crack or defect in the material will scatter some of the transmitted wave’s energy, reducing the strength of the response at the receiver (figure 4).

**Prototype construction and testing**
Using the basic transducer design in figure 5, we experimented with various configurations of materials and geometry. In order to gather relevant data, we used force sensitive resistors to measure applied force, and a Matec computer system to generate and measure ultrasonic waves. A testing rig was constructed to simulate the geometrical constraints of the interior of the cask (figure 6), and we experimented using deadweights, a pneumatic cylinder, and an air bladder (shown) to apply the force.

It was discovered early in the testing process that the performance of the transducer was very sensitive to the alignment of the components, and the method by which the foil was attached. To maximize performance, we designed an enclosure that would hold the components in alignment while still allowing the foil to float (figure 7).

**Robot design**
A robot is being designed for inspection, and it must deal with many challenges inside the cask, including tight confines, right-angle transitions, high temperatures, and radiation. A schematic of a representative storage cask is shown in figure 9, where the narrow ventilation channel between the MPC and overpack can be seen.

For our initial design, we consider only the geometrical constraints, and in figure 10, present a design for a prototype that can be assembled from COTS components. The robot needs to be articulated to navigate the bends in the cask, so each wheel is individually actuated. The robot is controlled via a tether, which also supplies electrical power and compressed air. For localization, ultrasonic rangefinders and a camera are equipped.

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**References**

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