Ultrasound for Non-invasive Fluid Droplet Detection inside a Sealed Container

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Ultrasound has long been known to be capable of measuring water level. Zero-degree ultrasound transducers may be used to send an L-wave through the fluid and receive a reflected signal from the fluid/gas interface surface. The level of the fluid is proportional to the sound wave time of flight to traverse the water path. This approach may even be used from outside the fluid containment wall by sending the wave through the tank or pipe bottom. The approach, however, does not work well if there is only a thin layer of fluid consisting of one or two millimeters or even only a few droplets. Surface waves are also known to be sensitive to the presence or absence of fluid on a surface. A surface wave may be transmitted a significant distance by a transmitting transducer and then received by a similar transducer. If the surface along the wave path is wet with even a few droplets of fluid, the surface wave may be significantly attenuated. Generating and measuring such a surface wave from the opposite side of a tank or pipe containment wall and separating the near-wall surface wave from the far-wall surface wave, however, is more challenging. An approach for producing a surface wave on the opposite side of a steel plate to sense the presence or absence of fluid is discussed. This approach is supported by 2-D finite element modeling of the measurement configuration and by empirical demonstration of the technique’s sensitivity. This technique was developed for measurement of a very small amount of fluid that may condense within a spent nuclear fuel canister after it cools for several years. Such small amounts of fluid are of concern for initiating stress corrosion cracking over the decades that these nuclear waste containment structures are expected to remain leak-free. Early detection of fluid would provide advance warning of potential cracks in time for mitigation or management of the waste inside that container. Other potential applications include any non-intrusive liquid container fluid detection, detection of fluid within inaccessible plena of aircrafts or other complex welded skin structures.