Ultrasonic Waveguide Sensors for Fluid level Sensing and Temperature Measurements using L, T, F Wave modes

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ABSTRACT

This paper describes the ultrasonic waveguides concept using bent and helical configurations to measure the fluid level and temperature measurements. The longitudinal L(0,1), torsional T(0,1), and flexural F(1, 1) wave modes were propagated simultaneously in these waveguides using pulse-echo (PE) and through transmission (TT) techniques using the shear transducer. Initially, we utilized Finite Element Method (FEM) to understand waveguide's wave propagation behavior while immersed in various fluids. We conducted level sensing experiments concerning the amplitude drops and time of flight shift of the received sensors' (L,T,F) signals and identified that F mode was better sensitivity. The sensors' error analysis was studied using all three wave modes, and the average error was 2.5 % -5.4 % from level sensors. Next, we used the L(0,1) wave mode propagates in one bent waveguide, and another bent waveguide was subjected to T(0,1) mode simultaneously in both waveguides using a single shear transducer for measuring the hot chamber temperatures. The ultrasonic sensor was calibrated/tested in the furnace based on time of flight shift with conventional thermocouples. These sensors can be used in highly flammable or hazardous regions, such as fuel tank level sensing, melter temperature, and viscosity measurement, especially in the oil and gas industries.

Keywords: Ultrasonic waveguide, Sensors, Fluid level, bent and helical waveguides, FEM, Temperature.