Ultrasonic waveguide with periodic reflectors for measuring the temperature of hot chamber

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Abstract

This paper describes an ultrasonic waveguide concept using periodic reflectors to develop an ultrasonic temperature sensor. In this sensor development, a longitudinal wave mode "L(0,1)" is used concerning the pulse-echo approach. We have used copper wire (diameter 1.2 mm) to develop the ultrasonic temperature sensor. The periodic ultrasonic reflectors have been used to develop multiple temperature sensors along the length of the waveguide. Initially, the reflectors were created in such a way that 2, 3, and 4 notches, respectively, used separate waveguides for each case. A shear wave transducer is used in the experiment to transmit and receive L(0,1) wave mode while positioning the transducer at 0-degree orientation to each waveguide axis. In each case, we studied the sensor behavior concerning the reflected signals from notches based on the time of fight and phase shifts. Each sensor is tested at a uniform temperature inside the hot chamber, and the obtained signals are compared in all the cases. Ultrasonic waveguide sensors can measure parameters such as temperature, fluid level, material properties, etc. The waveguide sensor has no junction that can fail. In general, ultrasonic sensors are particularly useful in applications such as power plants, oil industries' pipeline monitoring, and structural health monitoring of structures.

Keywords: Ultrasonic waveguide, sensors, periodic reflectors, temperature, gratings,

1. Ultrasonic waveguide temperature sensor design with periodic reflectors

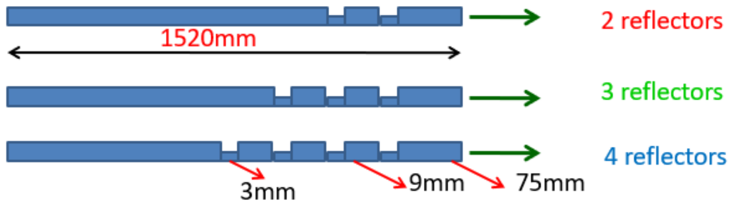

Figure 1. Shows the schematic diagram of period ultrasonic reflectors made in the ultrasonic waveguides.

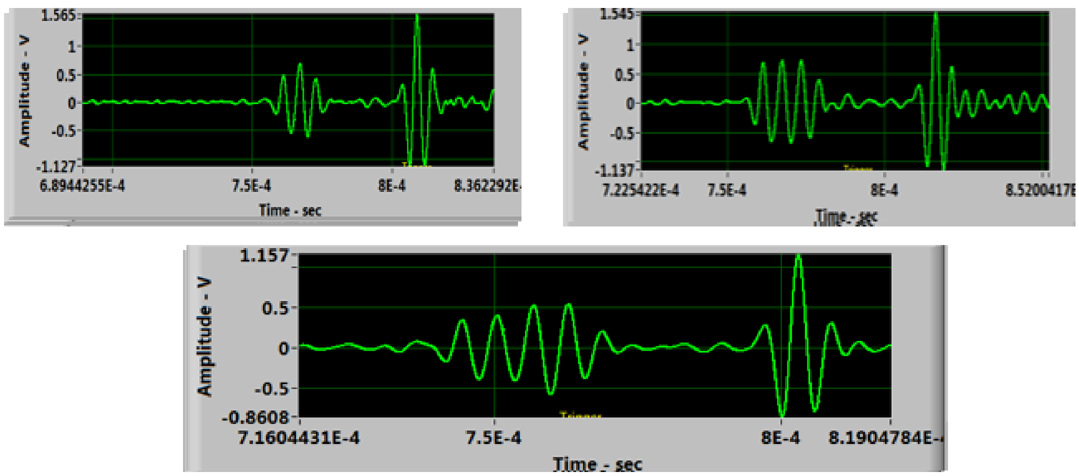

Figure 2. Shows the obtained A- scan signals from the period ultrasonic reflectors (2, 3, 4 gratings)

Fig. 1 shows the three waveguide sensors were designed with various ultrasonic reflectors for designing and developing ultrasonic waveguide temperature sensors. In this sensor development, we used a shear wave transducer to transmit and receive longitudinal wave modes, i.e., the pulse-echo approach. The ultrasonic signal behavior was changed while increasing the number of axisymmetric notch reflectors. The obtained A-scan signals are shown in Fig. 2, while the number of reflectors at each waveguide is increased. A separate experiment was performed at each waveguide using a material “copper round wire” as a waveguide. Later, the heating experiment was performed on each waveguide, while each waveguide was heated at a uniform temperature region of the inside hot chamber. In this context, we can further calibrate and measure the temperature of a high-temperature chamber using these waveguide sensors by following the reported procedures [1-8].

The length of the waveguide was oriented parallel (0^{o}) to the direction of particle vibration of the transducer for obtaining the L (0,1) wave mode. Typically, the waveguide's dimensions are selected based on non-dispersive frequency and types of wave modes due to group and phase velocities of the guided wave characteristics. Here, the L(0,1) wave modes are utilized to develop ultrasonic waveguides to make a temperature sensor. The length, reflectors dimension, gage length, and velocities of waveguides were considered to design and avoid the overlap of signal reflections from each reflector, the end of each waveguide and the corresponding A-scan signal plot, as shown in Fig. 2. We need to calibrate the ultrasonic sensor concerning difference in time of flights (δTOF) at various temperatures [refer: 2-6] around the bent waveguide's horizontal portion (57 mm) of the sensor.

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