Wedge design for high-temperature clamp-on ultrasonic flow measurement

Chuangnan Wang[1] and Tim Stevenson[1], [1]Ionix Advanced Technologies ltd, Leeds, UK

Background, Motivation and Objective

Determining flow rate for high-temperature fluids in a pipe is crucial for many process controls. Clamp-on flow meters offer flexibility with retro-fit to existing pipework, ease of re-locating and good measurement accuracy, however, current solutions often are unable to survive the continuous temperature required for measurement. Some units exploit a large waveguide to keep the active element away from the heat source, resulting in poorer signal quality and lengthy setup times. In recent years, the availability of high-temperature piezoelectric ceramics has allowed the development of ultrasonic transducers capable of constant operation at >200 °C. Replacement of the piezo in a conventional ultrasonic clamp on flow meter transducer does not solve the problem alone. The impedance mismatch between slower polymer wedges and faster metals of pipe construction gives incident angles which can satisfy Snell's law to offer high-amplitude shear mode conversion at the wedge-pipe interface. Above ~200 °C, polymer materials degrade, and the use of a metal wedge is preferred but suffer from requiring such high incident angles that most of the energy is reflected rather than transmitted to the liquid or converted to surface waves. In this paper, we introduce a metal wedge and transducer design for high-temperature flow measurement, from concept, simulation, complete transducer manufacture to testing. The design guidelines we learned from this process will be also presented.

Statement of Contribution/Methods

Metal wedges using internal longitude-shear mode conversion method, have been used. Conversion of longitudinal into shear wave within a metal wedge, by calculation, could achieve 95% efficiency and allow optimum wave propagation angles with useable signal to noise. The wedge design was optimized using finite element analysis and design rules. The optimum wedges were subsequently machined and assembled using commercial, temperature resilient HotSense™ transducer components and tested from room temperature to 380 °C continuously in both laboratory and field sites. Measurements were completed using commercially available ultrasonic flow meter units, with the traditional transducers replaced with the HotSense™ equivalent.

Results/Discussion

This wedge design combined with HotSense™ components, allowed assembly of pairs of 1 MHz, shear wave, 40-degree, wedge angle transducers, with a zero-flow delta time < 2 ns. This transducer was tested at 20 to 380 °C, achieving flow measurements with >30 dB SNR and >30 % bandwidth throughout the temperature range.