The role of guided waves in advanced ultrasonic flow meter design

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Background, Motivation and Objective

Ultrasonic flow meters are used to measure the liquid flow velocity in a variety of applications for a diverse set of industries – e.g. the oil-and-gas, chemical, food, and semiconductor industries. Thus, flow meters operate with a large range of liquids and under a wide range of conditions. The ideal future ultrasonic flow meter is accurate, calibration free, liquid velocity (profile) independent, and can accurately measure more parameters than the liquid flow velocity alone (e.g. density, viscosity or mass flow). Often, a non-intrusive flow meter design is preferred for reasons of structural integrity, chemical resistance and safety. A variant of the non-intrusive flow meter is the clamp-on flow meter, which is clamped on an existing installation. As the pipe wall geometry and properties are usually only roughly known, this type of flow meter has to be able to deal with said uncertainties. In these non-intrusive flow meter concepts guided waves play an import role: either one or more types of guided waves are used to measure the liquid flow velocity or the presence of guided waves is an important limiting factor in the flow meter's performance. As a flow meter is a layered structure combining liquid, (anisotropic) elastic and viscoelastic components the full complexity of elastic wave propagation should be taken into account in its design process.
This talk focuses on the design process of non-intrusive ultrasonic flow meters. A special emphasis will be placed on guided waves – their possibilities in this context, and how to either selectively generate, isolate or suppress these in a broad range of measurement conditions through integrated hardware and algorithm design.

Statement of Contribution/Results/Discussion

A number of examples will be presented to illustrate some of the challenges, concepts and solutions. Two of our flow meter designs based on guided waves will be discussed: firstly, an ultrasonic liquid velocity meter based on evanescent waves developed in cooperation with Bronkhorst High-Tech. And secondly, an ultrasonic mass flow meter combining evanescent waves to measure the liquid flow velocity and torsional waves to measure the liquid density.
Moreover, two flow meter developments based on compressional waves, where the flow meter performance is limited by the presence of guided waves, will be discussed. Firstly, a rheology sensor for Non-Newtonian liquids, which combines pressure sensors with an in-line, non-intrusive ultrasonic tomographic velocity profile meter. And secondly, a clamp-on liquid flow meter based on matrix transducers. The latter development is a project executed at the Acoustical Wavefield Imaging Group at the Technical University of Delft.