

## The role of guided waves in advanced ultrasonic flow meters

Ultrasonic flow meters are applied to measure liquid flow velocity for a variety of applications in a diverse set of industries – e.g. the oil-and-gas, chemical, food, and semiconductor industries. Hence, flow meters need to function in a wide range of conditions and with many substances. Often, it is desirable for reasons of structural integrity, chemical resistance and safety, that the pipe in which the substance of interest flows is not punctured by the flow meter. In other cases the flow meter is of the clamp-on type and the meter is clamped on/around an existing installation. This type must be able to deal with the uncertainties in the pipe wall geometry and its properties. In these nonintrusive flow meter concepts guided waves play an important role: either a guided wave is used to measure the liquid flow velocity or the existence of guided waves is an important limiting factor in the flow meters performance. The key is to limit the number of spuriously generated guided wave modes by optimized hardware design, and to design the flow meter and its algorithm such that the wave type of interest can be isolated in all relevant conditions. These concepts will be illustrated by a number of examples. 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 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.