Mathematical modelling of utlrasound propagation in multi-phase flow

Transit-time ultrasonic flow meter is a well established and widely used method for measuring flow of fluids. It measures flow velocities by means of acoustics waves sent with and against the direction of the flow and comparing the transit times of the respective signals. This method can yields extremely accurate measurements in case of a single-phase flow condition. However, its application when multi-phase flow occurs remains to be a challenging task. The presence of the secondary phases, such as water with bubbles, typically violates the reciprocity of the -up and -downstream measurements, thus impairing the device accuracy. Development of new flow meter designs for these conditions based on a purely experimental approach is expensive both in terms of time and economy. An attractive alternative is the employment of a simulation tool.

A model able to simulate propagation of acoustic waves in ultrasonic flow meter under is presented in this work. The underlying numerical method reduces computational requirements both in terms of memory and number of operations while preserving high level of accuracy. The method is verified against analytical solutions and compared to experimental measurements yielding a good agreement. The model is subsequently used to simulate acoustic flow measurements over a wide range of different flow conditions. The results are compared to flow meter measurements conducted on an industrial flow rig. Due to the chaotic nature of the multi-phase flow, the received signals vary in both shape and total received energy. It is found that the simulation results agree with the experimental measurements when comparing deviations of these quantities and the presented model can be used to estimate flow meter accuracy under different fluid flow conditions.