

Continuous Wave Ultrasonic Doppler Modeling for Oil–Gas–Water Three-Phase Flow Velocity Measurement

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Abstract:

Oil–gas–water three-phase flow is the most commonly seen fluid in petroleum production and transportation process. Flow velocity measurement of each individual phase is important to estimate the production condition and monitor the operation safety. The continuous wave ultrasonic Doppler (CWUD) technique has a high potential to measure the velocity of multiphase flow in a non-intrusive manner. However, this technique lacks proper measurement models for three-phase flow velocity measurement. In this paper, a one-sided CWUD sensor with 1-MHz center frequency was used for transmitting and receiving the acoustical signal that contains rich flow velocity information of the dispersed phases. By analyzing the momentum balance between different phases and modifying a two-fluid model into three-phase flow, a novel theoretical model to estimate the individual phase superficial flow velocity was established. Experiments were performed in a 50-mm inner diameter pipe, and two typical flow patterns (water dominated dispersed plug flow, oil dominated dispersed plug flow) were generated by adjusting the inlet flow rate of the three phases. By analyzing the ultrasound signal, the flow velocity of dispersed phases can be extracted. After using proposed theoretical model, the phase's superficial velocities can be calculated. The results show that the mean relative error can achieve within 5%. The proposed theoretical model explains the characteristic and mechanism of ultrasound Doppler frequency shift in three-phase flow, which can be applied in similar flow conditions to obtain acceptable accuracy.

Published in: [IEEE Sensors Journal](#) (Volume: 18, Issue: 9, May1, 1 2018)

Page(s): 3703 - 3713

DOI: [10.1109/JSEN.2018.2812834](#)Date of Publication: 06 March 2018 

Publisher: IEEE

▼ ISSN Information:

Print ISSN: 1530-437X

Electronic ISSN: 1558-1748

CD-ROM ISSN: 2379-9153

Sponsored by: [IEEE Sensors Council](#)

► Funding Agency: