Master thesis project:

Modeling of turbulent two-phase stratified flow

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Introduction

Many industries, e.g. oil and gas recovery, (nuclear) power generation, production of foods and chemicals rely on stable and predictable liquid-gas multiphase flows for safe transport and processing. Nowadays, cost-effective system design and operation rely indispensably on (flow) simulation technology.

In many applications, the two phases are transported simultaneously in a single pipeline system. When increasing the flow rates of the two phases the multiphase flow in the pipe will transfer from stratified, to wavy and finally to slug-flow. It is of high importance to be able to predict the transition between wavy and slug flow to be able to circumvent the impact of liquid slugs damaging the pipe system. This transition starts from a situation where waves are formed on the interface between the phases. Under unfavorable conditions the amplitude of the waves will grow until the waves touch the top of the pipe and slugs are formed.

Modeling immiscible incompressible two-phase flow

Models for describing the evolution of the interface between two immiscible phases have reached a high level of technology readiness. Especially on geometrically simple domains the interface can be accurately tracked while retaining mass conservation nearly up to machine precision.

In many cases the velocities in either of the two phases are so high that the flow becomes turbulent. Waves on the interface will influence the transition from laminar to turbulent and at the same time the turbulent fluctuations in the flow will influence the dynamics of the interface.

Therefore, it is essential to accurately describe the turbulent flow in the two phases. Modeling turbulent two-phase flow is an area of active research.

In single flow, the application of turbulence models based on the Boussinesq assumption is standard practice, with a gradual shift towards more advanced models, e.g. Reynold's stress models and Large Eddy Simulation.

The aim of the project is to get more insight in the current state-of-the-art of modeling turbulent two-phase stratified flow and identify the most suitable candidate model for inclusion in the multiphase flow models that are being developed in the Scientific Computing group of the Delft Institute for Applied Mathematics.

Research Questions

In the project the student should answer the following questions:

- What is the current state of the art for modeling turbulent incompressible immiscible stratified two-phase flow?
- What are the limitations of RANS models for this type of flow?
- How large are the computational resources required to solve LES models for stratified two-phase pipe flow?
- What is the most appropriate model for modeling turbulent incompressible immiscible stratified two-phase flow, taking into account the resources available and the intention to use the computational model to predict the onset of instability of the interface and the formation of slugs?

Research methodology

To answer the questions an elaborate literature survey will be performed. Additionally, a number of simulations will be done using OpenFOAM and the results will be compared with recent experimental data for stratified turbulent two-phase flow in a 10 meter long 0.05 meter diameter circular pipe.

Project outline

Literature survey (5 months, COSSE)

- Survey basic ideas behind RANS, Reynolds Stress and LES models
- Literature survey RANS models for stratified two-phase flow
- Literature survey LES models for LES stratified two-phase flow
- Estimate of computational resources for RANS, Reynolds Stress and LES models for pipe-flow test case.
- Formulation of recommendation for turbulence model.

Research project (6 months)

- Evaluation of the performance of the existing LES/Reynold's stress/RANS models in OpenFOAM for stratified two-phase flow, using the experimental data of Tummers.
- Mathematical design of an LES/Reynold's stress/RANS model for the two-phase flow model developed in the Scientific Computing group of DIAM.