Two models for the simulation of multiphase flows in oil and gas pipelines

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In o_shore petroleum engineering, the multiphase production technique has become a standard method for the exploitation of marginal fields. The multiphase production technology consists in conveying untreated wellhead e_uent through a single pipeline either to an existing processing platform or to on-shore processing facilities. Transient phenomena can be caused by changes in the inlet flow-rates or exit pressure, but they can also be related to instabilities induced by the pipe topography. Indeed, the severe or terrain slugging is a periodic phenomenon due to liquid accumulation at the low points of a pipe, leading to a temporary blockage. Periodically the upstream pressure increases and generates liquid slugs, for which the instantaneous flow-rate increases to several times the nominal flow-rate. In that context of multiphase production, the interest lies mostly in relatively slow transients associated to the transport and subsequent release of slugs at the receiving facilities. The fluid convection is then slow compared to pressure waves propagation, leading to low Mach flows. The correct predictions of pressure drop, liquid hold-up and flow regime are vital to design a multiphase transport system, i.e., pipeline, multiphase pump and downstream process facilities. Therefore, various 1-D multiphase flow models and corresponding numerical schemes have been studied and implemented in simulators.

In this talk, we present two of these models. The first one is the so-called Drift Flux Model consisting of a mass conservation equation for each phase, a momentum conservation equation for the two-phase mixture and an algebraic slip relation. This model is hyperbolic and includes three characteristic waves, one relatively slow associated to the void fraction propagation and two fast waves associated to pressure waves. The set of equations is discretized with a Finite Volume scheme where the numerical flux is written as a centered term stabilised with a viscous one. As we are interested in low Mach number flows, the time scheme combines an explicit time integration for the slow wave and a linearly implicit one for the fast waves. This scheme allows the use of a time step that is governed only by the slow waves velocity thus keeping a good accuracy for these waves.

For the second model, the assumption of small Mach number is taken into account in the development of the model itself. Indeed, the e_ect of pressure waves is neglected, yet the phases are considered to be compressible. The momentum time derivative and flux terms are neglected in the momentum conservation equation. The pressure drop is then reduced to a static force balance. Associated with the mass conservation equations and a slip relation, this pressure drop equation leads to a system that has one finite wave velocity and a double infinite one. On this ground, the model is qualified as mixed hyperbolicparabolic. The numerical scheme used to discretize the equations is a Finite Volume one and accounts for these particular features.

We present typical cases relevant to oil and gas pipeline transport applications, and we compare the response of the two models.