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NUMERICAL SIMULATION OF STRATIFIED OIL-WATER FLOW USING INTERFOAM

Gustavo Bochio[1,*] **& Oscar M. H. Rodriguez**[1]

[1]Department of Mechanical Engineering, University of São Paulo at São Carlos School of Engineering, São Carlos, SP, 13566-590

ABSTRACT

Multiphase flow of oil and water in pipes is a subject of great interest for the petroleum industry. Depending on the volumetric flow of each phase a number of different patterns can occur and, among them, the stratified flow pattern is of particular interest, because it is usually seem in horizontal pipelines. This paper presents simulations of this flow pattern using *interFoam*, a solver based on the VOF interface capturing method and available in OpenFOAM. The computational results are compared with experimental data and the predictions using an unidimensional model for global and local parameters of the flow, like pressure drop, water hold up and velocity profiles. The comparison shows good overall results for pressure drop and hold up, while the velocity profile tends to be under predicted. The CFD model is also evaluated by its capability to predict the position and shape of the fluids interface.

KEY WORDS: Stratified flow, CFD, Volume-of-fluid

1. INTRODUCTION

Many natural and industrial processes are composed of two phase flows. The stratified oil-water flow is of particular interest, because it is commonly seem in nearly horizontal pipes, like directional oil wells and pipelines.

*Corresponding Gustavo Bochio: gustavo.bochio@usp.br

A common approach to model stratified flows is the use of one dimensional methods based in Ishii and Hibiki (1975) two-fluid equations. Using appropriate correlations, these equations can be solved for stratified liquid-liquid flows (Brauner and Maron, 1992; Rodriguez and Baldani, 2012; Trallero, 1995) and is the most common way to predict pressure loss and hold up for this flow pattern.

With the advances in computational power and parallel processing, researchers started to study the possibility of using CFD to analyse fully three dimensional stratified flows (Berthelsen and Ytrehus, 2005; Issa, 1988; Mouza et al., 2001; Newton and Behnia, 2001). This approach gives more detailed results using less empirical data to its closure. The use of Volume-of-fluid (VOF), a interface capturing method, is very suited for stratified flows and was used in a number of studies (Ghorai and Nigam, 2006; Vallée et al., 2008).

In this work, stratified oil-water flow is simulated using *interFoam*, the VOF solver implemented in OpenFOAM. The results are compared with experimetal data from Elseth (2001) and with the one dimensional model of Rodriguez and Baldani (2012).

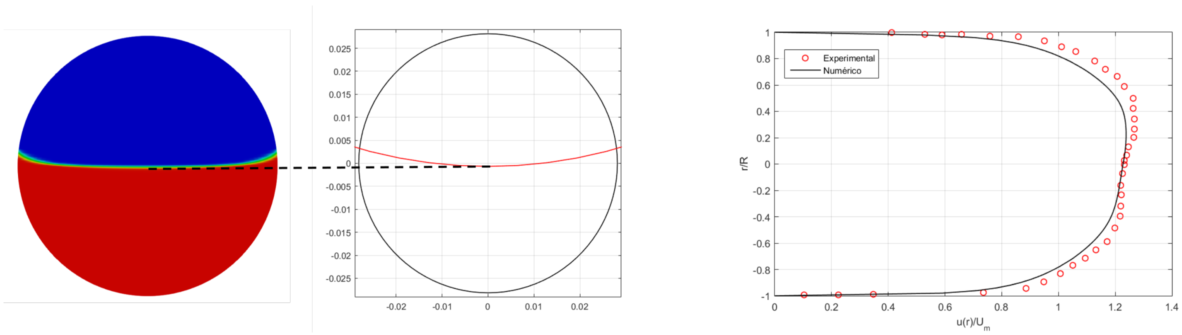
2. SETUP

The flow of oil ($\rho = 790\ kg/m^3$; $\mu = 0.00164\ Pa \cdot s$) and water in a pipe of stainless steel of $56.3\ mm$ of diameter is evaluated. *interFoam* solves transient RANS equations and a transport equation for the water fraction (α). PISO method is used to couple pressure and velocity and turbulence parameters are calculated using k-ϵ Launder-Sharma model. A structured O-H mesh is used in all the simulations, therefore a better control of elements number, size and quality is possible.

3. RESULTS AND CONCLUSION

Two cases were simulated, the first for $U_{os} = 0.34\ m/s$ and $U_{ws} = 0.34\ m/s$ (superficial velocity of oil and water). Figure 1 shows a good agreement between the interface shape and position for the CFD model and the 1D model (Rodriguez and Baldani, 2012). The velocity profile is well captured, with the exception of the regions of maximum velocity in both phases. This can be caused due to the assumption of turbulence isotropy. Table 1 shows a good overall agreement between experiments and CFD for pressure gradient and hold up. The 1D model was capable of providing slightly better results.

Figure 2 shows the same comparisons as before, for $U_{os} = 0.3075\ m/s$ and $U_{ws} = 0.1025\ m/s$. Overall, the results are good again, both for interface shape and velocity profile. Table 2 shows a bigger error between



(a) (b)

Fig. 1 $U_{os} = 0.34m/s$ e $U_{ws} = 0.34m/s$; (a)interface shape comparison: CFD and 1D model; (b)velocity profile comparison: CFD and experiments

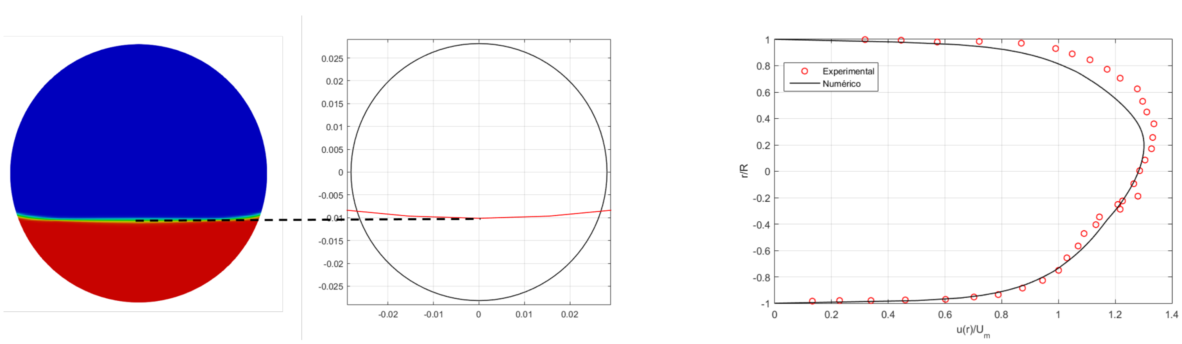
Table 1 Comparison between experiments, 1D model and CFD ($U_{os} = 0.34m/s$ e $U_{ws} = 0.34m/s$)

Fonte	$\partial P/\partial x$	ϵ_w
Experimental	$92,0\ Pa/m$	$0,515$
1D model	$95,2\ Pa/m$	$0,513$
CFD model	$99,4\ Pa/m$	$0,507$

experimental data and CFD (24.6%) for pressure gradient. A careful analysis of Elseth (2001) data indicates that this can be caused by the presence of entrainment or an experimental error. In this case, the CFD model shows better results than the 1D model.

4. CONCLUSIONS

The results show that *interFoam* is a good option to simulate stratified oil-water flows and can lead to good predictions of pressure gradient and hold up. While the 1D model can give good results too, it depends on correlations that have a limited range of applicability, also CFD offers detailed information of the flow



(a) (b)

Fig. 2 $U_{os} = 0.3075m/s$ e $U_{ws} = 0.1025m/s$; (a)interface shape comparison: CFD and 1D model; (b)velocity profile comparison: CFD and experiments

Table 2 Comparison between experiments, 1D model and CFD ($U_{os} = 0.3075 m/s$ e $U_{ws} = 0.1025 m/s$)

Fonte	$\partial P/\partial x$	ϵ_w
Experimental	$58,0\ Pa/m$	$0,288$
1D model	$38,0\ Pa/m$	$0,286$
CFD model	$43,6\ Pa/m$	$0,277$

analysed. In the future, wavy stratified flow and entrainment will be investigated too.

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