Extended Abstract " Measurement of Velocity and Phase Fraction in Stratified Oil / Water Flow "

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Abstract

This paper contains measurements in stratified oil/water flow of local mean velocity and velocity fluctuations by Laser Doppler Velocimetry (LDV) and local phase fractions by Gamma Densitometry. The measurements are compared with CFD simulations based on the VOF model.

1 INTRODUCTION

Production of oil from offshore reservoirs also implies the simultaneous production of free water. For many years the amount of free water produced was small and hence given little attention. However, in recent years water production has increased due to reservoir aging and more complex reservoirs. Todays and tomorrows offshore production includes long horizontal wells and multiphase transport over long distances. The pressure required to transport the fluids over long distances is highly influenced by the frictional pressure drop which can be significantly affected by the mixing properties of the oil and water phases. Understanding the complex nature of oil/water flow is important to build predictive design models with high accuracy. This is the motivation for this study of stratified oil/water flow in horizontal pipes.

2 THE EXPERIMENTAL SETUP

2.1 THE OIL/WATER RIG

The oil/water rig consists of an oil/water separator, oil and water storage tanks, two pumps and a 12 m long stainless steel test section of 2" (ID=56.3 mm). Basic instrumentation are volumetric flow, differential pressure and temperature, all monitored and stored by a computer. The oil used is a petroleum distillate (Exxol D60) with density 790 kg/m ^{3} and dynamic viscosity of 1.6 cP at 25 ^{o}C. The maximum flow rate of each phase is 300 litre per minute which corresponds to maximum Reynolds numbers of oil and water of 55000 and 110000 respectively. A brief schematic description of the oil/water test rig is presented in Figure 1. In addition to the basic instrumentation a LDV system was used to measure the local velocities, and a traversing gamma densitometer was used to measure local phase fraction within the pipe.

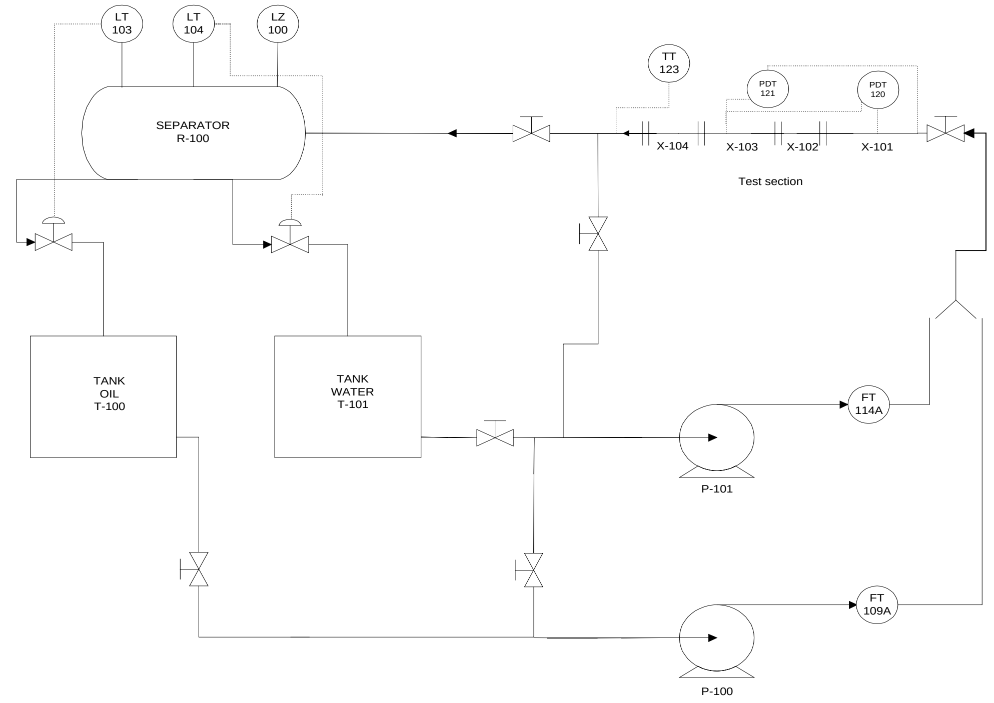

Figure 1: The oil/water rig.

2.2 LDV SETUP / LDV MEASUREMENTS

Laser Doppler Velocimetry (LDV) is used to measure local velocities and velocity fluctuations in the transparent part of the test section. The LDV setup is a two colour backscatter system which enables simultaneous measurement of axial (horizontal) and vertical velocity components. The LDV setup is described in Figure 2.

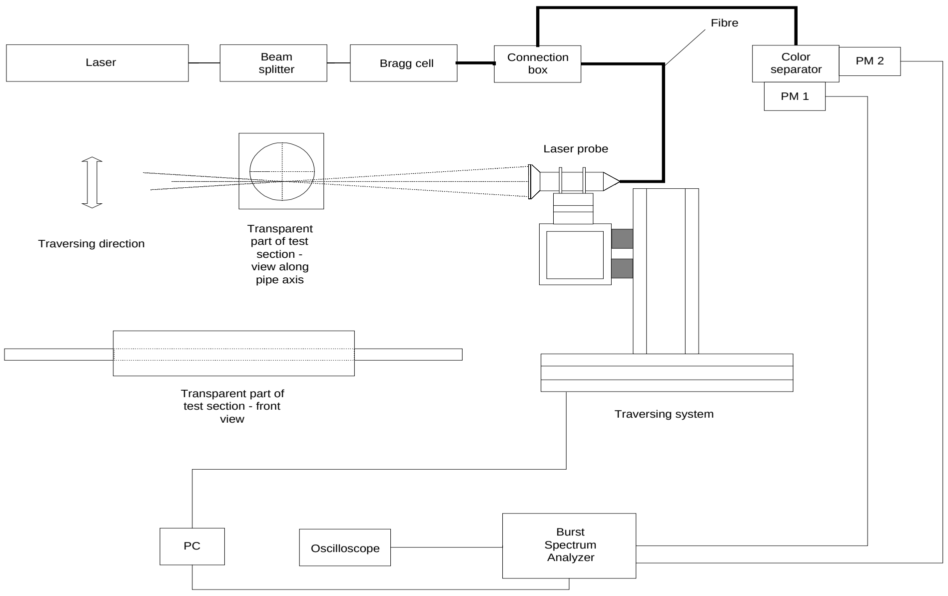

Figure 2: The LDV setup.

The light source is a 3W Argon-Ion Laser. From this the laser beam pass through a beam splitter and a bragg cell before entering the fibre optics. The power of each laser beam (two green and two blue beams of wavelengths respectively 514.5 and 488 nm) out of the probe is approximately 180 mW. The focal length of the front lens can be varied between 120, 160 and 310 mm. The laser probe which transmits the light is connected to a traversing system which allows measurements of local velocities across the pipe diameter to produce the entire velocity profile. The back scattered two colored light into the laser probe pass through receiving fibres into the color separator where it is split and reflected to each photo multiplier (detector). The output signal from the photo multiplier tubes is led into a Dantec "Burst Spectrum Analyzer". This unit is attached to an oscilloscope and a PC where data are stored and processed.

The transparent test section consists of a rectangular acrylic box wrapped around an acrylic pipe. The box is filled with transparent fluid with refractive index that match the material refractive index. Special attention is needed when measuring near the oil/water interface and the pipe wall. The oil/water interface creates optical problems due to reflection of the laser light. Hence CFD simulations are used to compliment the measurements in this region of the pipe. The position of the interface will vary with flow conditions. The cylindrical geometry of the flow section will also cause optical problems. These are diminished by the rectangular box filled with fluid. Nevertheless, the beams will be refracted when they pass through the inner pipe wall and enters the fluid. Each pair of beams are refracted differently and problems arises when the intersection volume of each beam pair is at different locations in the pipe. The two different measurement volumes, one for each velocity component, are then separated. In the middle of the pipe this is not a great problem, but when traversing vertically close to the pipe wall it is only possible to measure one velocity component at a time. CFD simulations will be used as an estimate for the measurements in this region of the pipe.

2.3 LOCAL PHASE FRACTIONS

A traversing gamma densitometer is used to obtain information about the local phase fractions. The source is a 45 mCi Am ^{241} and the detector is a NaI connected to a photo multiplying tube. Both the source and the detector was collimated to a 3 mm circular beam and the instrument could be traversed both in linear and angular position. Along with visual observations the flow regime could be established for different mixture velocities and oil/water ratios.

3 CFD SIMULATIONS

Computational Fluid Dynamics (CFD) is used in the analysis of the separated flow. The CFD code is Fluent and the model selected is the VOF (Volume of Fluid) model. This model is designed for two or more immiscible fluids where the position of the interface between the fluids is of interest, but not known. In the VOF model, a single set of transport equations is solved, and hence the transport equations are shared by the fluids that do not mix. The interface between phases is found by solution of a transport equation with no diffusion term, preventing diffusion across the interface (numerical diffusion can appear). Based on the solution of this special transport equation, the position of the interface is found. From the calculation of the separated flow, the velocity, the turbulence properties and the pressure fields are found in addition to the interface position. These simulated results are compared with the measurements.

4 PRELIMINARY RESULTS

A total number of 50 data set containing pressure drop and local phase fractions are recorded, and from these 10 data set with LDV measurements were recorded. An example of LDV measurement of axial velocity, U, and local phase fraction, Cw, is given in Figure 3. In this experiment the mixture velocity is 1.0 m/s and the water cut is 50 %. From visual observations and the local phase fraction measurements, we conclude that the flow pattern is stratified wavy with the oil/water interface slightly above the middle of the pipe. The interfacial thickness is about 6-8 mm which is bounded by the wave amplitudes.

The LDV measurements are obtained in a vertical diametrical scan cross the pipe section, starting from the top. As can be observed in Figure 3 the LDVsignals cannot be obtained in the interfacial area due to reflections. This can be seen as 8 mm of the scan is without velocity measurements. The local water fraction, Cw, is measured by gamma densitometry during the same flow conditions as in the LDV measurements. These results are also presented in Figure 3.

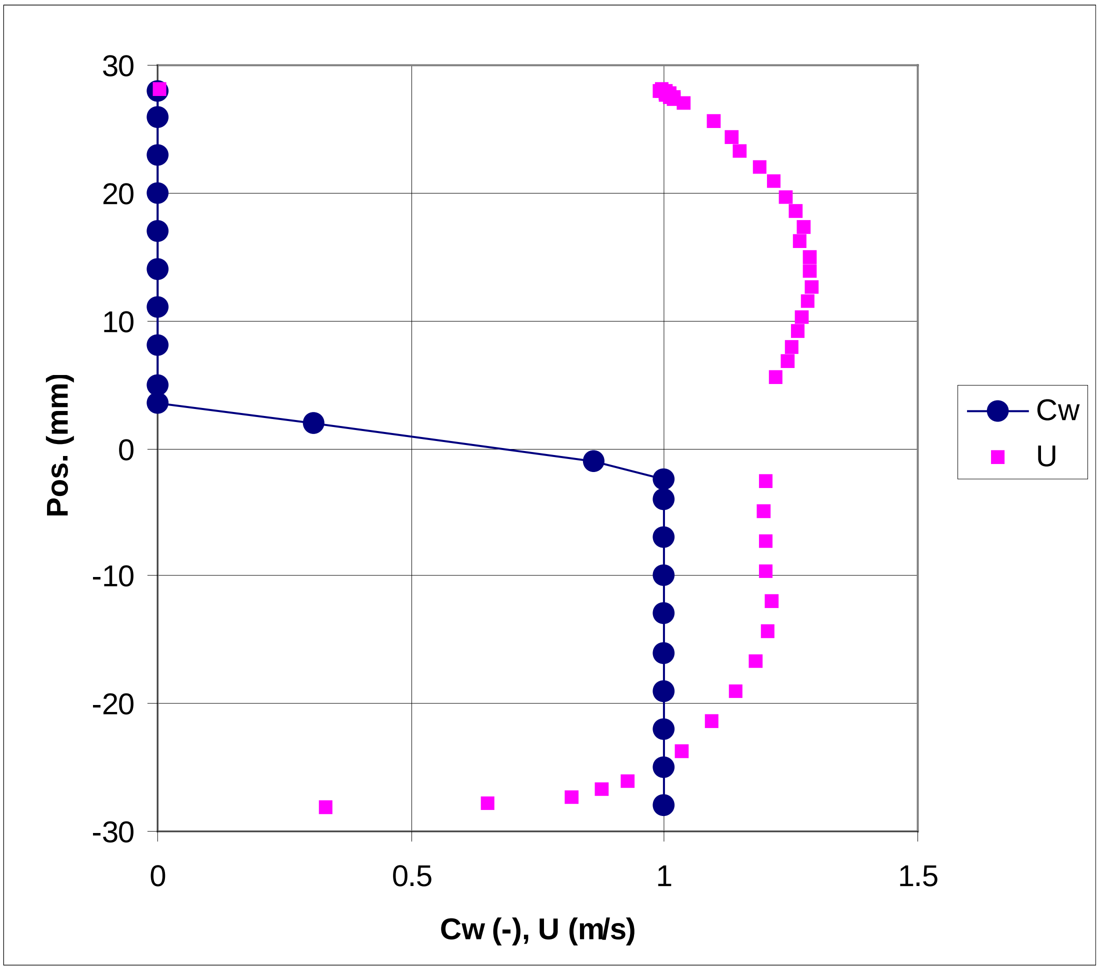

Figure 3: Measurement of axial velocity in stratified flow of Exxol D60 and water by LDV. Bulk velocity is 1.0 m/s and water cut is 50 %. Measurement of the local water fraction, Cw, by gamma densitometry is also presented.