Extended Abstract "Measurement of Velocity and Phase Fraction in Dispersed Two-Phase Flow"

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Abstract
This paper contains measurements of velocities by Laser Doppler Velocimetry (LDV) and phase fractions by Gamma Densitometry. To avoid optical problems in the LDV measurements due to refraction, the dispersion is refractive index matched to the transparent pipe material.

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.

2 EXPERIMENTAL SETUP

2.1 MATCHED REFRACTIVE INDEX SYSTEM

In order to avoid the reflection problems at the inner pipe wall and the fluid interfaces, a matched refractive index system was established to provide full optical accessibility for LDV in a dispersed flow. The system included a pipe section of Duran 50 glass, two different oils and a (strong) water soluble solvent mixed with a small fraction of distilled water. All together the mixture of the two oils and the water/solvent mixture should match the refractive index of Duran 50 glass which is 1.473.

In order to obtain the exact refractive index the mixing procedure were performed in the test rig by adding the components in small portions. Firstly, the oils were mixed and then the water solvent were added giving a non transparent mixture. Then finally, small portions of distilled water were added (total about 5 %) and the dispersion became more and more transparent . To record the refractive index we used a refractometer and in addition the laser was set up to penetrate the test section. The penetrated beam could then be observed on a white paper on the other side of the test section. As the water/solvent phase approached the refractive index of the oil mixture, the diameter of the penetrated beam was observed to shrink to about the same diameter as in front of the test section. At 25 ^{o}C the water/solvent phase has a density of about 1100 kg/m ^{3} and a viscosity of 2 cP while the oil mixture has a density of 900 kg/m ^{3} and a viscosity of 4 cP. This gives a density ratio of 1.2 and a viscosity ratio of 2 which is in the correct range concerning oil and gas production.

2.2 TWO-PHASE RIG

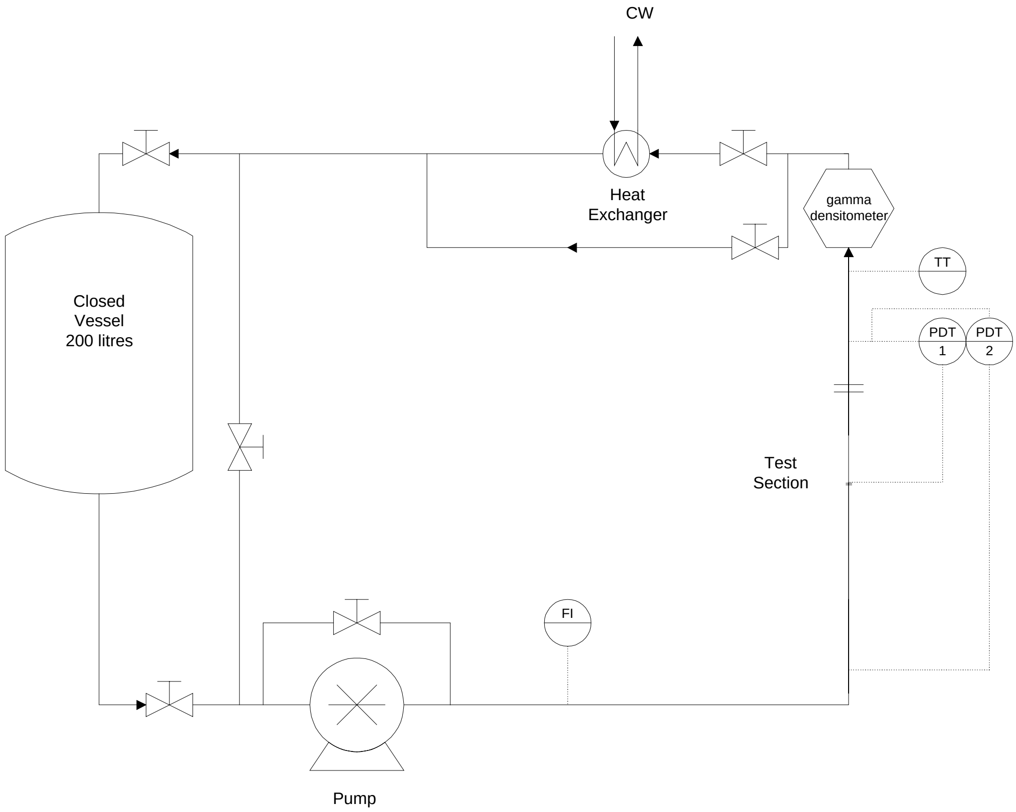

Figure 1: The two-phase rig.

Since our matched refractive index system consists of a strong water soluble mixture (and expensive as well !), we constructed a small volume test facility in order to handle this particular liquid. The overall layout of the facility is displayed in Figure 1. The rig consists of an enclosed vessel with a volume of 200 litre, including a mixer or blender to homogenize the oil and water phases. The vessel is connected to a pump that leads the dispersion into the test section which is a 6 m long horizontal pipe with inner diameter of 56.3 mm. The pipe material is stainless steel except for a 0.9 m long transparent section made from Duran 50 glass. This section provides optical access for LDV measurements and includes a rectangular box built around a cylindrical pipe.

On the test section two dP-sensors for measurements of pressure drops and a gamma densitometer for measurements of local phase fractions are mounted. In addition, mass flow, density and temperature are measured. Downstream the test section there is a heat exchanger that provides stable temperature during measurements.

For each set of experiment, a specific two phase mixture were put in the tank, and homogenized by the mixer before circulation started. By means of the density meter we were able to observe that the ratio between the phases in the test section was constant during the experimental period.

2.3 LDV SETUP

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 back scatter system which enables simultaneous measurement of axial (horizontal) and vertical velocity components. The LDV setup is described in Figure 2.

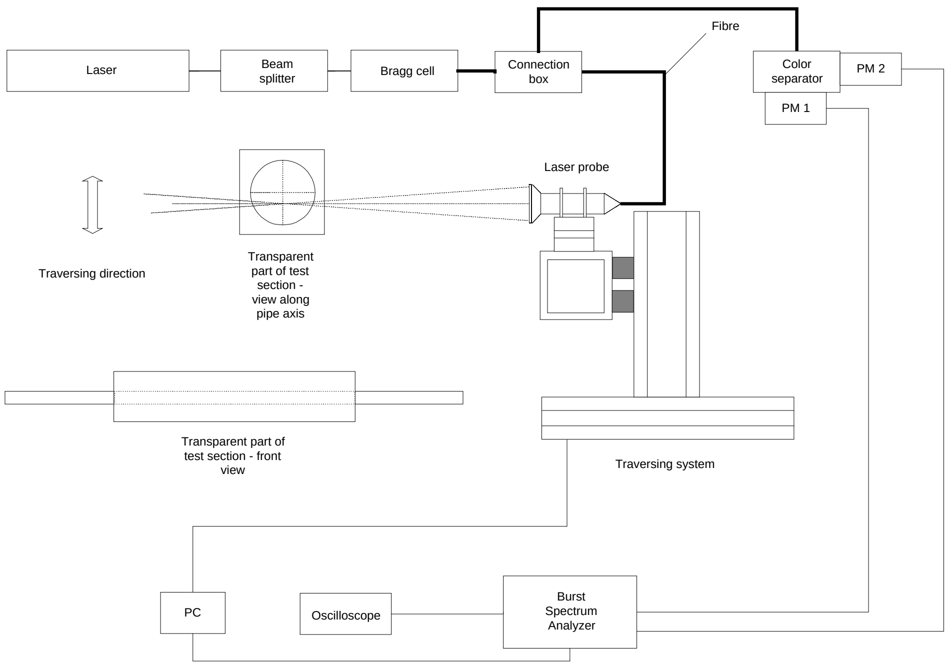

Figure 2: The LDV setup.

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 along 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 detector or photo multiplier. 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.

2.4 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 as 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 PRELIMINARY RESULTS

LDV measurements of a single water/solvent phase and two dispersions were performed. The mixture velocity was 1.54 m/s in all measurements. Figure 3a presents a comparison to the analytical solution for fully developed turbulent single phase flow in pipes. The velocities are normalized by a friction velocity based upon pressure drop measurements. Also presented are normalized fluctuating velocities, both axial (Figure 3b) and vertical (Figure 4a), for the dispersion of 30 wt% oil and 70 wt% water added solvent. Figure 4b presents the normalized Reynolds stress for this dispersion.

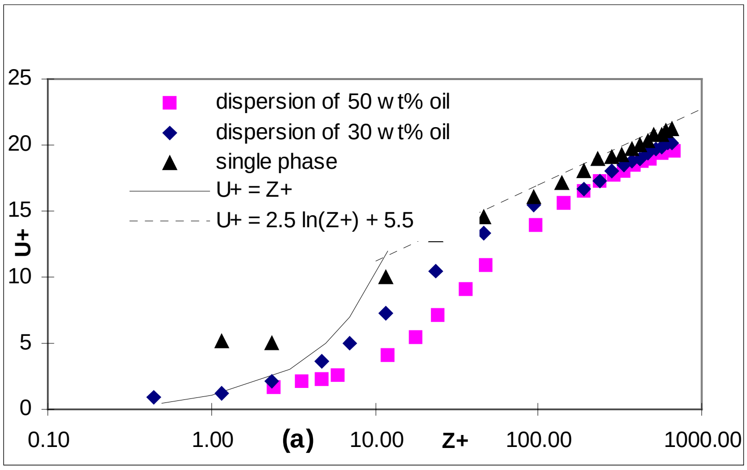

Figure 3: (a) Measurement of axial velocity in water/solvent phase only and in two dispersions, compared to the analytical solution for single phase pipe flow. Plotted in normalized quantities.

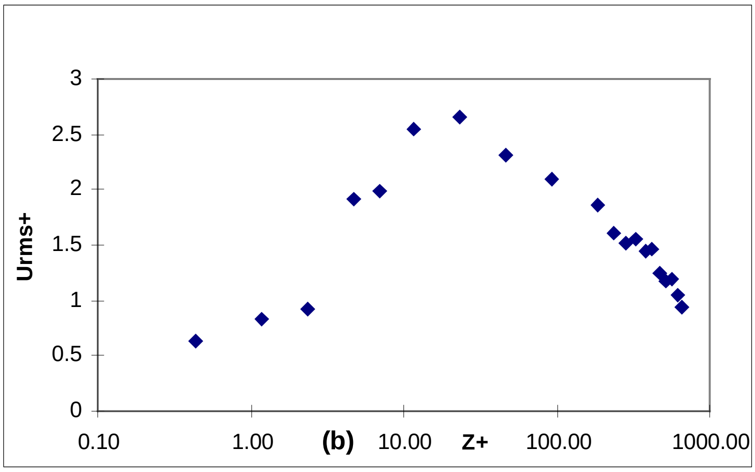

Figure 3: (b) Normalized axial velocity fluctuations for dispersed flow of 30 wt % oil.

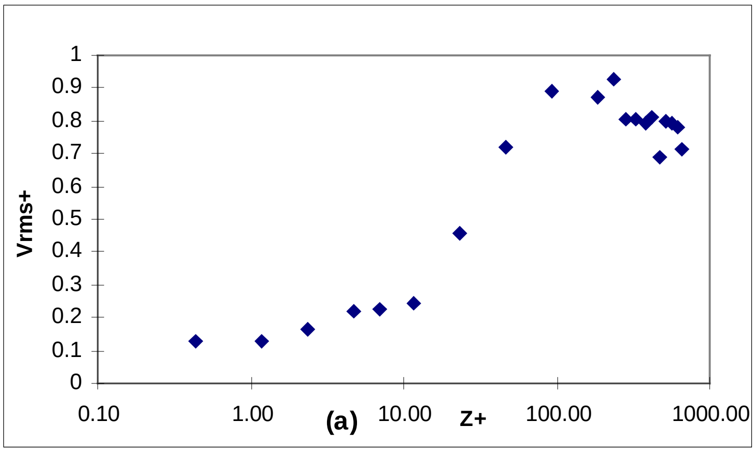

Figure 4: (a) Normalized vertical velocity fluctuations for dispersed flow of 30 wt% oil.

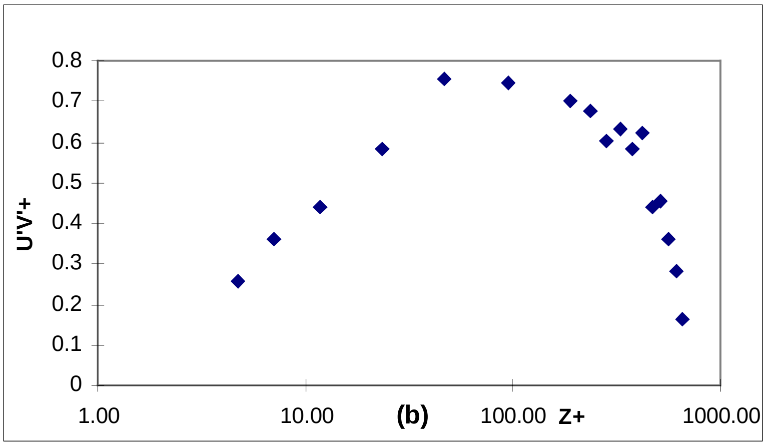

Figure 4: (b) Normalized Reynolds stress for dispersed flow of 30 wt% oil.