Pressure Drop Measurements of Oil(D130)-Water Flow in 6-inch Vertical Stainless Steel Annulus Pipe

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***Abstract*—Oil water two phase flows widely occur in chemical an petrochemical industries. The production of oil is associated with huge costs of transportation. Oil and water are produced and transported together in pipelines that have various degrees of inclination from the horizontal. The pressure drop of oil-water flow in inclined pipes is still subject of research.**

The present work has investigated the effect of inclination on pressure drop of oil (D130)-water two-phase flow in an inclinable 6 inch diameter stainless steel annulus pipe at different flow conditions. The working fluids used for experimental work are Exxsol mineral oil (D130) and potable water. Two-phase large scale inclinable flow loop was used to acquire data for different water cuts and fluid mixture flow rates. The range of liquid flow rates were selected to match the actual flow rates in real oil wells to reflect practical situations. Experiments were carried out for 90° inclination angle (with loop in vertical position). The oil-water flow rates were varied from 2000 to 12000 barrels-per-day (BPD) in steps of 2000. The water cuts (WC) were varied from 0-100% in steps of 20%. The effect of angle has found to be appreciable. For a given flow rate 8000 BPD, WC = 40%, for increase in angle from 0 to 90°, percentage increase in frictional pressure drop is about 26%. The findings of the study will be helpful in handling problems related to transportation of oil through inclined pipelines.

Index Terms-Multiphase flow-loop; Oil-water flow; Pressure drop; Water-cut; Inclined pipe

I. INTRODUCTION

The oil-water two phase flow is a complicated issue related to simultaneous flow of two physically immiscible fluids (such as: oil and water) in pipelines.

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Also, the widespread occurrence of multiphase flows in pipes is the motivation for research in this field (several upstream practical applications in the petroleum industry include oil–water two-phase flow phenomena).

The pressure drop of oil-water flow in pipes for different inclinations is still subject of research. Several articles are available in literature on the two-phase flow of oil and water in pipes.

In order to study the characteristics vertical oil-water two phase flows (in 20 mm diameter pipe), Du et al. carried out several experiments [1]. Flow pattern map of oil water for different superficial velocities have been shown. A research study on three phase flow in vertical pipes was performed by Descamps et al. [2] with emphasis on phase inversion. They concluded that the size of the gas bubble produced during experiments depends on water dispersion.

An experimental study on oil/water flow in horizontal and slightly inclined plexi glass tubes (with 21 mm ID, 9m long) was conducted by Domenico et al. [3]. The emphasis was on core-annular flow behavior, pressure drops, and oil hold-up measurements. Good agreement was noticed between experimental data and other models. High viscosity two phase liquid-liquid flow experiments in horizontal and slightly inclined pipes were conducted by Grassi et al. [4]. The results were validated against theoretical models

Also, experiments were conducted by Grolmann and Fortuin [5] with focus on liquid hold-up and pressure gradient in gas-liquid flow in slightly inclined pipes. Effect of inclination was found to be appreciable at low gas flow rates.

The effect of phase inversion on pressure gradient in dispersed flow of two immiscible (water and oil) liquids for steel and acrylic pipes (60 and 32 mm ID) for various mixture velocities conducted by Karolina et al. [6]. For all cases large increase in pressure gradient was observed before phase inversion, which sharply reduces after occurrence of new continuous phase.

Flow measurement of oil-in-water fluid flow is complex and challenging issue. A new method of two-phase flow metering has been proposed by Yousef et al. [7], which is based on the use of dual-modality system and multidimensional data fusion. To validate the proposed, experiments were conducted on a vertical upward oil-in-water pipe flow (50mm inner-diameter test section) at different total liquid flow rates spanning the range of 8–16 m3/hr.

The local flow characteristics of oil–water dispersed flow in a vertical upward pipe were studied experimentally for different oil-water velocity by Dongian et al. [8]. The typical radial profiles of interfacial area concentration, oil phase fraction, interfacial velocity, and oil pressure drops have been presented.

The impact of uphill and downhill pipe inclinations on the flow patterns, hold up and pressure gradient during two-liquid phase flows various mixture velocities and phase fractions has been explored experimentally by Lum et al. [9]. It was observed that the oil to water velocity ratio was higher for the upward than for the downward flows but in many cases, oil was flowing faster than water for all inclinations.

Our previous studies [10-11] on multiphase flows concentrated on 4 inch diameter stainless loop/pipe. Flow rates were varied from 4000 to 8000 barrels-per-day (BPD). The present paper places emphasis on 6 inch diameter stainless vertical annulus loop. The working fluids are Exxsol D130 Mineral Oil and water. The inlet oil-water flow rates are varied from 2000 to 12000 BPD (to mimic field conditions). Water cuts (WC) have been varied from 0-100%. The research facility of previous papers and present research is same but flow loops are of different sizes. The flow characteristics change appreciably with change size of the loop. The pressure drop of oil-water flow in inclined pipes is still subject of research. The findings of the study will be helpful in handling problems related to transportation of oil through inclined pipelines. The paper focuses attention on challenges involved in transportation of oil in vertical 6 inch diameter stainless annulus pipes. Considerable papers related to smaller diameter pipes are available in literature but papers related bigger diameter loops are not available.

In the wake of the above literature review, currently no studies are available on frictional pressure drop measurements of oil (D130)-water two-phase annulus flow in vertical 6 inch diameter stainless annulus steel pipe at different inclinations (at different flow conditions). This is the motivation for the present experimental study and it places emphasis on the effect of flow rates, water cuts, and inclination angles on pressure drop measurements of oil (D130)-water two-phase flow. In this work, attention has been focused on pressure drop measurements of oil (D130)-water two-phase flow in a vertical 6 inch diameter stainless steel pipe (at different flow conditions). Experiments were carried out for 90° inclination angle (with loop in vertical position) for different water cuts 0%, 20%, 40% 60% 100%. The oil-water flow rates at the inlet were varied from 2000 to 12000 BPD in steps of 2000.

II. Experimental Setup

The Oil-water two phase experiments were conducted at the large scale multiphase flow laboratory of King Fahd University of Petroleum and Mineral, Dhahran, Saudi Arabia [10].

The schematic diagram of the flow loop is shown in Figure 1. Experimental set-up includes: four centrifugal variable speed pumps [2 pumps for water (WP) and 2 pumps for oil, (OP)], 6 inch stainless loop, a horizontal separator tank (WOST), which acts as storage tank, two level indicators for oil and water each. The loop is constructed on swinging platform (inclination can be varied from 0°-90°). The flexible connection (FC) helps in positioning loop at any given angle.

The loop is instrumented with a turbine type oil flow meter (OFM), a turbine type water flow meters (WFM), line pressure transmitter (LPT), two flow differential pressure transmitters (DP1 and DP2). Details of the loop components and instruments are given in Table 1. [11].

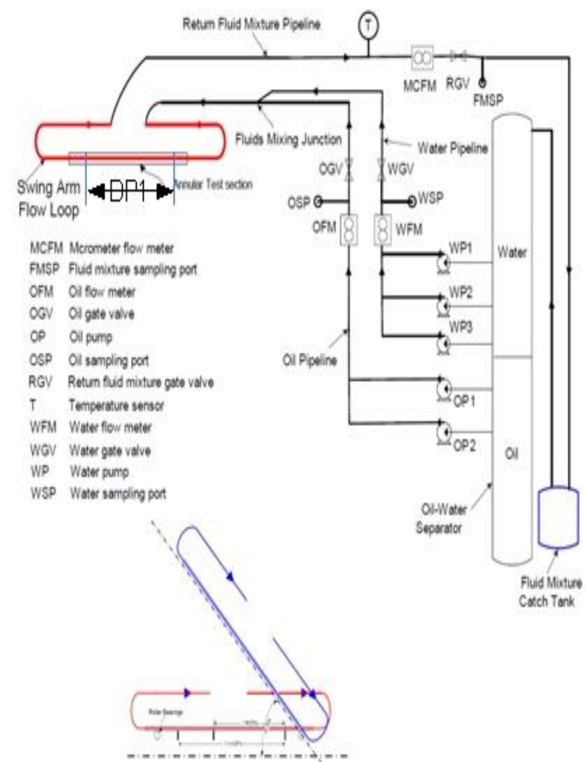

Figure 1. Details of equipment of the flow loop

TABLE I. Details of equipment of the flow loop

Items	Manufacturer	Model	Capacity/Range	Accuracy/Error
Four pumps (two water, two oil)	NEWAR FLOW SERVE	50-32CPX200	35 m3/hr	-
Two turbine flow meter	Omega	EF10	±10 m/s	±1.0 %
Line pressure gauge	ROSEMOUNT	AOB-20	0-7 bar	±0.25%
DPT1	ROSEMOUNT	300S2EAE5 M9	0-70 inches of water	±0.1%
DPT2	ROSEMOUNT	300S2EAE5 M9	0-12 inches of water	±0.1%
Four pumps (two water, two oil)	NEWAR FLOW SERVE	50-32CPX200	35 m3/hr	-

III. Experimental procedure

In-order to validate the pressure drop measurements against available empirical models, experiments were performed for water-only and oil-only single phase.

In this regard, water was pumped in the loop using centrifugal pumps. Required volume flow rate was attained by varying speed of pumps through variable speed drives and also by regulating oil globe valve (OGV) and water globe valve (WGV) of oil and water flow streams respectively. Turbine flow meters installed on the discharge line of the pumps were used for measuring the flow rates. Return gate valve (RGV, Figure1) of the loop is throttled to set the required outlet pressure (e.g. 1 bar or 2 bars).

The experiments were carried out for a given flow rate and differential pressure measurements were recorded along 1m annulus pipe length (after achieving the steady state flow condition). The experimental data was recorded using CR 1000 data logger. The above procedure was repeated for oil-only flow experiments.

The friction factor was calculated from the experimentally obtained pressure drop and this friction factor was compared with friction factors obtained from Blasius and Zigrang & Sylvester 1985 correlations. A good agreement has been noticed specifically with the Blasius friction factor. The related equations and graphs are reported in our earlier studies [10-11].

IV. Results and discussions

Oil-water two phase flow experiments were carried out for 90° inclination angle and for different water cut ratios (0%, 20%, 40%, 60% and 100%). The oil-water flow rates at the inlet were varied from 2000 to 12000 BPD.

A. Effect of water-cut on oil-water pressure drop for different flow rates

For a given angle (θ = 90°), the effect of water cut for different flow rates on pressure drop is shown in Figure 2. As it can be seen from Figure 2, the frictional pressure drop has been found to increase from WC=20% to WC=40% (for most of the flow rates). For a given flow rate, the FPD is maximum at WC=40%. This could be due to phase inversion. Also, it can be observed from Figure 2 that at any given WC, the FPD increases with increase in flow rate. For a given water cut WC=40%, increase in BPD from 6000 to 8000, percentage increase in frictional pressure drop is about 45%.

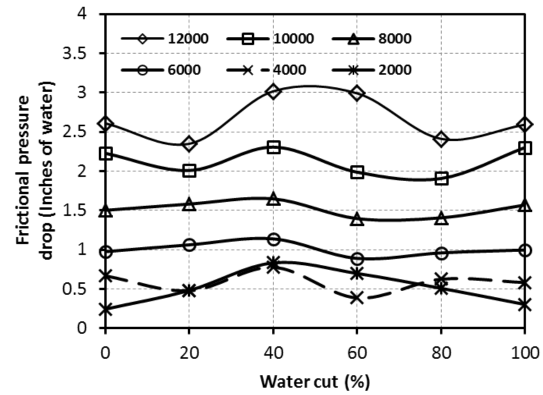

Figure 2. Effect of water cut on Frictional pressure drop for different flow rates for oil-water flow (90deg).

B. Effect of flow rate on oil-water pressure drop for different water-cuts

For a given angle (θ = 90°), the effect of flow rate on frictional pressure drop (FPD) for different WC is shown in Figure 3. As it can be seen from Figure 3, pressure drop increases with flow rate and WC. The FPD drop has been found to increase linearly with respect flow rate. For a given flow rate of 12000 BPD, for increase in water cut from WC 20 to 40, percentage increase in FPD is about 28%.

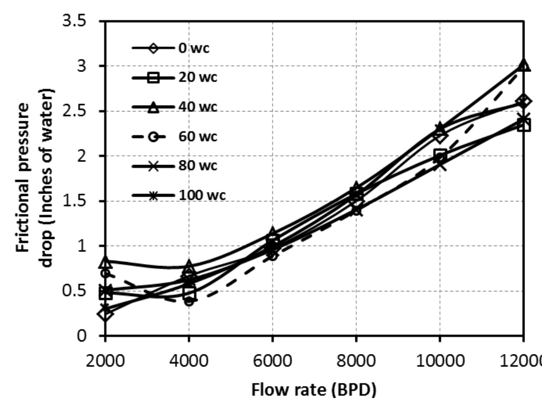

Figure 3. Effect of flow rates on Frictional pressure drop for different water cuts for oil-water flow (90deg).

C. Effect of inclination on oil-water pressure drop for different flow rates for given water cut

For the sake of brevity, the angle effect on FPD for different flow rates, only water cut (WC = 40%) has been presented.

For a given water cut (WC = 40%), the effect of inclination for different flow rates on pressure drop is shown in Figure 4. In general for all angles, pressure drop increases with flow rate and water cut. The effect of angle has found to be appreciable. For a given flow rate 8000 BPD, WC = 40%, increase in angle from 0 to 90°, percentage increase in frictional pressure drop is about 26%.

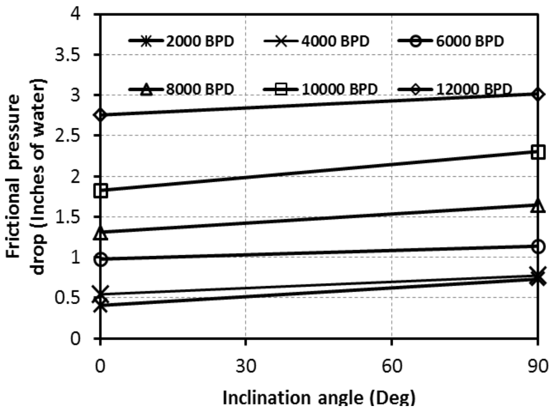

Figure 4. Effect of angle on Frictional pressure drop for different flow rates (for a given cut)

V. Conclusion

The present experimental work has focused attention on the pressure drop measurements of oil (D130)-water two-phase flow in a vertical 6 inch diameter stainless steel annulus.pipe at different flow conditions.

Experiments were performed for different water cut ratios (0%, - 100%). The flow rates at the inlet were varied from 2000 to 12000 BPD. In order to validate the experimental work, the measured pressure drops and friction factor of single phase oil and single phase water were compared with existing empirical relations and good agreement was noticed.

For a given flow rate, the FPD is maximum at WC=40%. This could be due to phase inversion. For a given water cut WC=40%, increase in BPD from 6000 to 8000, percentage increase in frictional pressure drop is about 45%. For a given flow rate of 12000 BPD, for increase in water cut from WC 20 to 40, percentage increase in FPD is about 28%.

The effect of angle has found to be appreciable. For a given flow rate 8000 BPD, WC = 40%, increase in angle from 0 to 90°, percentage increase in frictional pressure drop is about 26%.

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