
Khalid M. A., Tawfeeq Wasmi M. Salih, Ahmed A. Ayash

Abstract
The improvement of oil extraction needs to know what factors that effect on the behavior of oil. This paper studies the unsteady-state homogeneous approach of two-phase flow in vertical oil extraction pipe. The model used to predict the flow pattern is determined theoretically, while that used for void fraction is taken from empirical relation. The set of equations adapted in FORTRAN-90 program to calculate the output values. The comparison with experimental results gave good closing, where the absolute percentage difference in void fraction value is about (22%) for \((\alpha < 0.5)\) and (10%) for \((\alpha > 0.5)\). In other hand, the absolute percentage difference in gas superficial velocity is about (18%). It is also observed that slug period numerically long than that in experimental.

Keywords
Two-Phase Flow, Flow Pattern, Void Fraction, Homogenous Flow, Oil Extraction

Nomenclature
- \(d\): Tube Diameter
- \(G\): Mass Velocity
- \(P\): Pressure
- \(q\): Heat Transfer
- \(t\): Time
- \(u\): Velocity
- \(x\): Dryness Fraction
- \(\rho\): Density of Fluid
- \(\mu\): Viscosity of Fluid

1. Introduction
The term 'two-phase flow' is applied to single fluid such as vapor and water or mixtures of different fluids having different phases, such as air and water, or oil and natural gas. Sometimes even three-phase flow is considered, such as in oil and gas pipelines where there might be a significant fraction of solids. Vertical upward two-phase flow in pipes is
found commonly in industries involving oil and gas production, water treatment, nuclear reactors, and geothermal systems [Brill and Beggs, 1991]. Whether the two-phase flow exists in the form of different components or occurs as a result of phase change caused by evaporation or condensation of a single fluid, the void fraction (volume of gas to total volume of mixture) is an important parameter in the analysis of pressure drop, heat transfer, and mass transfer. To predict the void fraction in vertical upward two-phase flow with reliable accuracy, methods to estimate it correctly and accurately are essential [Monhan et al., 2010]. The regimes encountered in vertical flows include Bubble Flow, where the liquid is continuous, and there is a dispersion of bubbles within the liquid; Slug or Plug Flow where the bubbles have coalesced to make larger bubbles which approach the diameter of the tube; Churn Flow where the slug flow bubbles have broken down to give oscillating churn regime; Annular Flow where the liquid flows on the wall of the tube as a film (with some liquid entrained in the core) and the gas flows in the centre; and Wispy Annular Flow where, as the liquid flow rate is increased, the concentration of drops in the gas core increases, leading to the formation of large lumps or streaks (wisps) of liquid[Wallis, 1969].

2. Previous Work
Esmaeilzadeh and Abbasi [Esmaeilzadeh and Abbasi, 2005] introduce a numerical analysis to calculate the heat transfer coefficient during boiling based on the two-phase annular single component of refrigerants (R-134a and R-12) in a vertical pipe. The conservation equations of mass, momentum, energy have been solved through a numerical finite volume method. The numerical results for R–113 show a good agreement with the available experimental results reported by the others investigators.

Kendoush et al. [Kendoush et al., 2006] measured local oil volume fraction by using the auto-transformer technique in stratified oil–water flow. A non-flow oil–water system was used for calibration of the flow system. The results were compared with the capacitance technique. It was found that this technique is suitable for measuring the phase cut for liquid–liquid two-phase oil–water flows, with an error not exceeding ±8% for an oil volume fraction of more than a half.

Abdulkadir et al. [Abdulkadir et al., 2010] reports the results of an experimental study of the gas-liquid multiphase flows experienced within a vertical riser using an air/silicone oil mixture within a 6 m long riser. The superficial air velocities studied ranged from 0.047 to 2.836 m/ s, whilst maintaining a liquid superficial velocity at 0.047 m/ s. Measurements of time average radial void fraction were obtained using a wire mesh sensor (WMS). The data recorded over an interval of 60 seconds. For the range of flow conditions studied, the average void fraction was observed to vary between 0.1 and 0.9. An analysis of the data collected concluded that the observed void fraction was strongly affected by the superficial gas velocity.

The aim of the present work is to study unsteady-state homogeneous approach of two-phase flow in vertical oil extraction pipe. The model used to predict the flow pattern is determined theoretically, beside that, an empirical relation is used for void fraction. The set of equations adapted in FORTRAN-90 program to calculate the output values.

3. Mathematical Model
It is known that the analysis of unsteady two-phase flow is rather difficult, so a model of linearization of the conservation equations has been developed.
The continuity equation for one-dimension homogenous two-phase flow is [Brill and Beggs, 1991]:
\[
\frac{\partial \rho_m}{\partial t} + \frac{\partial (\rho_m u)}{\partial z} = 0
\]
(1)

The momentum equation is [Brill and Beggs, 1991]:
\[
\rho_m \left( \frac{\partial u}{\partial t} + u \frac{\partial u}{\partial z} \right) = -\frac{\partial p}{\partial z} - \rho_m g \cos \theta - \frac{C}{A} \tau_w
\]
(2)

Where:
C = Circumference (m)
A = Cross-Sectional area (m^2)

\( \theta \) = Inclination Angle (deg)

\( \tau_w \) = Shear Stress at the wall (Pa)

also, the energy equation is [Brill and Beggs, 1991]:
\[
\frac{\partial}{\partial t} \left[ \rho_m \left( h - \frac{p}{\rho_m} + \frac{u^2}{2} \right) \right] + \frac{\partial}{\partial z} \left[ \rho_m u \left( h + \frac{u^2}{2} \right) \right] = \frac{1}{A} \left( \frac{\partial q}{\partial z} - \frac{\partial w}{\partial z} \right) + \rho_m u g \cos \theta
\]
(3)

Where:-

\( e \) = Internal Energy (J/Kg)
\( h \) = Enthalpy (J/Kg)

From thermodynamics considerations we have:
\[
e = h - \frac{p}{\rho_m}
\]
(4)

Substitute equation (4) into (3) yields:
\[
\frac{\partial}{\partial t} \left[ \rho_m \left( h - \frac{p}{\rho_m} + \frac{u^2}{2} \right) \right] + \frac{\partial}{\partial z} \left[ \rho_m u \left( h + \frac{u^2}{2} \right) \right] = \frac{1}{A} \left( \frac{\partial q}{\partial z} - \frac{\partial w}{\partial z} \right) - \rho_m u g \cos \theta
\]
(5)

Hence:
\[
\left( h + \frac{u^2}{2} \right) \left[ \frac{\partial \rho_m}{\partial t} + \frac{\partial \rho_m u}{\partial z} \right] + \rho_m \left( \frac{\partial h}{\partial t} + u \frac{\partial h}{\partial z} \right) + \rho_m u \left( \frac{\partial u}{\partial t} + u \frac{\partial u}{\partial z} + g \cos \theta \right) = \frac{\partial p}{\partial t} + \frac{1}{A} \left( \frac{\partial q}{\partial z} - \frac{\partial w}{\partial z} \right)
\]
(6)

Substitute equation (1) and equation (2) into equation (6) yields:
\[
\frac{\partial h}{\partial t} + u \frac{\partial h}{\partial z} = \frac{1}{\rho_m} \left( \frac{\partial p}{\partial t} + u \frac{\partial p}{\partial z} \right) + u \frac{C}{A} \tau_w + \frac{1}{\rho_m A} \left( \frac{\partial q}{\partial z} - \frac{\partial w}{\partial z} \right)
\]
(7)
Oil Extraction applications of equation (7) consider the flow in straight tube evaporator in which the pressure changes and viscous forces are small [Wallis, 1969], so neglect the terms where \((w, \tau_w\) and \(P\)) be found.

Assume no work done, equation (7) becomes:

\[
\frac{\partial h}{\partial t} + u \frac{\partial h}{\partial z} = \frac{1}{\rho_m A} \left( \frac{\partial q}{\partial z} \right)
\]  \hspace{1cm} (8)

if the wall heat flux is denoted as \((\varphi)\), the heat transmitted per unit length is:

\[
\frac{\partial q}{\partial z} = \pi d \varphi
\]  \hspace{1cm} (9)

Where for circular tube
\[
A = \frac{\pi}{4} d^2
\]  \hspace{1cm} (10)

Substitute equation (9) and equation (10) into equation (8) yields:

\[
\frac{\partial h}{\partial t} + u \frac{\partial h}{\partial z} = \frac{4\varphi}{\rho_m d}
\]  \hspace{1cm} (11)

From thermodynamics,
\[
h_m = h_l + x h_{lg}
\]  \hspace{1cm} (12)

\[
\theta_m = \theta_l + x \theta_{lg}
\]  \hspace{1cm} (13)

Mixing of equation (12) and equation (13) into equation (11) leads to:

\[
\frac{\partial x}{\partial t} + u \frac{\partial x}{\partial z} = \left( \frac{\theta_l}{\theta_{lg}} + x \right) \Omega
\]  \hspace{1cm} (14)

Where:
\[
\Omega = \frac{4 \theta_{lg} \varphi}{dh_{lg}}
\]  \hspace{1cm} (15)

The left hand side of equation (14) can be written in total derivative as [Wallis, 1969]:

\[
\frac{dx}{dt} = \left( \frac{\theta_l}{\theta_{lg}} + x \right) \Omega
\]  \hspace{1cm} (16)

Solving by Integrating factor result:

\[
x = \frac{\theta_l}{\theta_{lg}} \left( e^{\Omega(t-t_o)} - 1 \right)
\]  \hspace{1cm} (17)

Where
\(T_o = \) Time required for starting of evaporation \((x=0)\)
The calculated value of quality is increased from (0) up to (1) by the time. The flow pattern after that can be found by vertical flow regime map of Hewitt and Roberts (1969) [Wolverine Data Book, 2007], where:

\[
G_g = \frac{x M}{A} \\
G_l = \frac{(1-x) M}{A}
\]

(18) \hspace{2cm} (19)

The updated properties can be calculated from [Wolverine Data Book, 2007]:

\[
\vartheta_m = \vartheta_l + x \vartheta_{lg} \\
\rho_m = \frac{1}{\vartheta_m} \\
\frac{1}{\mu_m} = \frac{x}{\mu_g} + \frac{1-x}{\mu_l}
\]

(20) \hspace{2cm} (21) \hspace{2cm} (22)

The related void fraction (\(\alpha\)) can be found from empirical relation extracted from [Rouhani and Axelsson, 1970]:

Fig. (1) Vertical flow regime map of Hewitt and Roberts (1969) [Wolverine Data Book, 2007]
Also, the superficial velocities can be defined as:

\begin{align*}
\alpha &= \frac{u_g^*}{C_o(u_g^* + u_l^*) + u_g m} \\
C_o &= 1 + 0.2 (1 - x) \\
u_g m &= 1.18 (1 - x) \left[ \frac{g \sigma (\rho_l - \rho_g)}{\rho_l^2} \right]^{0.25}
\end{align*}

(23) \quad (24) \quad (25)

Also, the superficial velocities can be defined as:

\begin{align*}
{u_g^*} &= \frac{C_g}{\rho_g} \\
{u_l^*} &= \frac{C_i}{\rho_i}
\end{align*}

(26) \quad (27)

4. Results
4.1 Program Structure

The mathematical procedure of the calculation is shown in Figure (2) as flowchart where the flow properties at the interface are defined. The main equations were solved for each time step until the matching conditions are met. The data recorded over an interval of 60 seconds in order to compare with that denoted in the reference of [Abdulkadir et al., 2010].
4.2 Numerical Results

The operation conditions are listed in table (1) where the depended properties of Kirkuk oil are taken from the reference of [Kendoush et al., 2006].
Table (1) Operation conditions

<table>
<thead>
<tr>
<th></th>
<th>Operation conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil temperature</td>
<td>( T = 300 \text{ K} )</td>
</tr>
<tr>
<td>Tube diameter</td>
<td>( d = 70 \text{ mm} )</td>
</tr>
<tr>
<td>Oil density</td>
<td>Surface tension of oil</td>
</tr>
<tr>
<td>Wall heat flux</td>
<td>Oil viscosity</td>
</tr>
</tbody>
</table>

Table (2) represents flow patterns at various flow velocities that obtained theoretically. It observed that bubble flow duration is very short this also denoted in numerical study of Kitagawa and Yamamoto [Kitagawa and Yamamoto, 2001]. We can say if the velocity increased the flow pattern close to steady as annular flow.

Table (2) Flow patterns for various flow velocities

<table>
<thead>
<tr>
<th>( t ) (s)</th>
<th>( u=0.05 \text{ (m/s)} )</th>
<th>( u=0.1 \text{ (m/s)} )</th>
<th>( u=0.15 \text{ (m/s)} )</th>
<th>( u=0.2 \text{ (m/s)} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>B</td>
<td>B</td>
<td>S</td>
<td>S</td>
</tr>
<tr>
<td>10</td>
<td>S</td>
<td>S</td>
<td>S</td>
<td>S</td>
</tr>
<tr>
<td>20</td>
<td>S</td>
<td>S</td>
<td>S</td>
<td>S</td>
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<td>30</td>
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<td>S</td>
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</tr>
<tr>
<td>40</td>
<td>S</td>
<td>C</td>
<td>C</td>
<td>C</td>
</tr>
<tr>
<td>50</td>
<td>C</td>
<td>A</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>60</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
</tr>
</tbody>
</table>

Where: B=Bubble, S=Slug, C=Churn, A=Annular

Figure (3) represents the void fraction values for various flow velocities. It observed terminally, that the values of void fraction are maintained at \( (0.92) \). Also it is cleared that the percentage increment difference is large in the range \( (0.2\text{-}0.75) \) for void fraction.

4.3 Comparison with Experimental Results

In lots of cases, the identified heat transfer correlations were derived empirically and based on a set of experimental data with a limited range of variables and liquid gas combinations. The numerical results of this study have been compared with experimental results of Abdulkadir et al. [Abdulkadir et al., 2010].

Figure (4) represents comparison between numerically and experimentally results for variation of void fraction with time. It observed that the numerical values increased as a polynomial function of one degree while experimental values are oscillated this also denoted by Nilanjana and associates [Nilanjana et al., 2003] result which suggest that FLUENT is well suited to assist in the design. By the time, numerically and experimentally values close each other at \( (\alpha=0.9) \). The average percentage difference between numerically and experimentally results is \( (22\%) \) for \( (\alpha<0.5) \) and \( (10\%) \) for \( (\alpha>0.5) \), these ratios is closed to that referred by Nicklin and associates [Nicklin et al., 1962].
Figure (5) represents comparison between numerically and experimentally results for variation of superficial velocity with time for both liquid and gas. It observed that the numerical values began to diverge from that of experimental by the time until an average percentage difference of (18%) for gas phase.

Figure (6) show the change of flow patterns with time. It looked that the bubble flow numerically begins early than experimentally. Also, the period of slug flow numerically continue for (37 sec), while is too short experimentally. The flow finally steady as annular flow this accompanied to that noted in Monahan and associates [Monahan et al., 2010] also Wongwises and Naphon [Wongwises and Naphon, 2000].

5. Conclusions

Generally, there are several results to be noticed from the numerical research according to the variation of time which can be listed below as:

1-Period of bubble flow is very short. Otherwise, the period of slug flow is too long.
2-Numerically and experimentally values close each other at ($\alpha=0.9$).
3-The average percentage difference between numerically and experimentally results is (22%) for ($\alpha<0.5$) and (10%) for ($\alpha>0.5$).
4-Numerical values of gas superficial velocity began to diverge from that of experimental by the time until an average percentage difference of (18%).
Fig. (4) Comparison between numerical and experimental results for void fraction at $u=0.05$ m/sec

Fig. (5) Comparison between numerical and experimental results for superficial velocity at $u=0.05$ m/sec
References


Fig. (6) Comparison between numerical and experimental results for flow patterns at $u=0.05$ m/sec