Kerosene-Water Flow Pattern In T-Junction Vertical Diameter Ratio 0.5 (Variation of Inclination Branch)

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KEROSENE-WATER FLOW PATTERN IN T-JUNCTION VERTICAL DIAMETER RATIO 0.5 (VARIATION OF INCLINATION BRANCH)

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Keywords: phase separation, T-junction, flow patterns, downstream resistance.

Abstract The separation is one of the important processes in exploration and production oil technology. Phase separation across T-junction with orientation vertical up branch is simplicity method to achieve maximum efficiency, but useful information is rather limited. This paper is presented only for inlet flow pattern and T-junction flow pattern of kerosene water mixture with inlet diameter 36 mm and branch diameter 19 mm (diameter ratio 0.5) on the variation inclination branch are 30°, 60° and 90°. Regulating flow by closing valve at downstream was done to obtain three flow resistance in the downstream. The flow pattern obtained in this study were : stratified (ST), three-layer-13 (3L-13) , three layer-2 (3L-2), and three layer-3 (3L-3). The results of the phase separation is best achieved under conditions inlet flow pattern stratified (ST) and T-junction three layer-3 (3L-3) flow pattern, angle 90 ° and downstream resistance 6471 Pa.

1. Introduction

During the kerosene-water flowing in a pipeline and a t-junction, there will be changes to the interface between the two-phase flow and flow distribution characteristics, it will result in different flow pattern known as flow map [1].

In the two-phase flow, knowledge about the flow pattern is very important because will be used to predict the behavior of fluid flow. Determining of the flow pattern is not done by exact but based on visual interpretation of the flow conditions, so it is a subjective assessment for researchers.

Idealization direction of flow entering the t-junction branching can be seen in Figure 1. The flow is a mixture of kerosene water by density of kerosen 819 kg/cm^3 and water density of 998 kg/m^3.

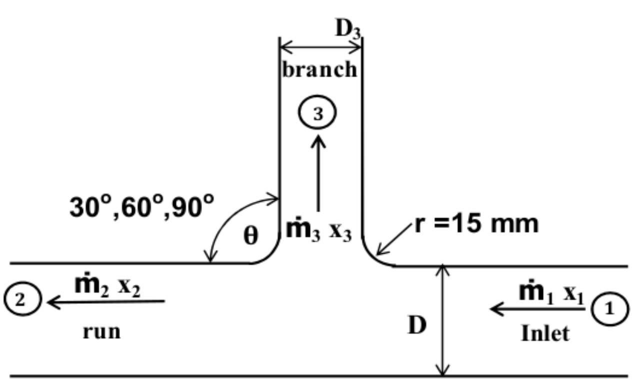

Figure 1.Schematic flow of kerosene-water
in the test section *T-junction* r_D 0.5

This study only discussed the direction of flow patterns in t-junction from inlet to run and branch. The flow patterns form were : stratified (ST) and three layer (3L), for three layer were grouped into 3L-1, 3L-13,3L-2 and 3L-3.
The phenomenon of phase separation produces an irregular distribution phase (maldistribution) caused by different flow patterns depending on the superficial velocity of each phase.

2. Literature

Wren et al [11] examined the distribution of fluid flow at the t-junction. During mixed fluid flow into the t-junction, it is not easy to predict how much liquid flowing into side arm and run arm as influenced by several variables: t-junction geometry, flow patterns in the upstream and slope side arm.

Shoham et al in a study of horizontal t-junction states that two-phase flow of gas and liquids from the inlet when entering t-junction will result deflection of flow so that the flow will be separated into line branching : branch and run [7]. Flow pattern associated with research is directional flow patterns in horizontal flow and vertical t-junction to a certain slope.

Angeli et al [1] examined the patterns of liquid-liquid flow using stainless steel and acrylic pipes with diameter respectively 24.3 mm and 24 mm. Flow patterns encountered are stratified, wavy Stratified, stratified with mixture interface (3L), disperse / mixture, disperse oil in water / water in oil. From the study concluded that both types of pipes have some differences, namely: the flow pattern on stainless pipe more easily disturbed / unstable than acrylic pipe, for stainless pipe roughness greater than acrylic. In the acrylic pipe, oil continuous flow pattern (stratified mixed / oil and three layer) is more dominant than the stainless pipe, it caused by the wettability of acrylic greater than stainless.

T - junction that serves as a two-phase flow separator, where simple assumptions about the quality in the *run* and the branch is the same because it comes from the same inlet is far from the reality of the matter, because the pattern of flow in the inlet greatly affect the performance of the phase separation occurring in the branch Azzopardi et al [2]. The study was conducted at the t-junction vertical upward, horizontal pipe with a diameter of 32 mm, a variation ratio of diameter 0.2, 0.4 and 0.6 and will be observed in the pattern of annular flow, churn and bubbly only.
In the annular flow pattern, liquid and gas are expected to come from the film layer can be separated into branch while drops are expected to flow straight into the run. Area to annular flow caused by the total liquid in the film of liquid that can be changed to any change in flow.
In churn flow pattern visible is dominated by liquid phase separation, the addition will increase the amount of liquid flow toward branch compared to the amount of gas.
In the bubbly flow pattern consists of liquid and gas bubble layer that is between liquid and fills the entire room. In this condition the liquid layer with an approximate value of momentum flux bubble and liquid core with a high momentum flux is expected to be separated at the branch.

Azzopardi et al [3] refine previous studies by adding the diameter ratio of 0.8 and 1. In general, the larger diameter ratio the more phases are separated in the branch. In fact, for the ratio of diameter 0.6, more liquid entering the branch than diameter ratio 1. This is attributed to differences in the axial length of the diameter of each side arm T-junction, these variables are very influential on the amount of liquid that separated at the branch.

Rodriguez et al [6] examined the flow pattern of mineral oil with a density of 830 kg/m^3 and brine density of 1060 kg/m^3, the 8.28 cm diameter pipe.The results showed that the flow pattern is observed in the form: Stratified, Stratified Interface with Mixture, Disperse oil in water and water, oil in water, Water in oil or oil in water Disperse, Stratified Wavy.

Research on dual continuous flow pattern at different inclination upward and downward, with a mix of speed ranges 0.7 - 2.5 m/s and the oil fraction 10% - 90% has been done by Lum [5]. The results showed some flow patterns that emerge at different slope (angles), namely: stratified wavy, plug flow, dual continuous and fully dispersed flow.
In a positive and negative slope flow regime disperse oil in water (D_{ow}) occurs in low J_{mix} and high oil fraction. In overall the dual flow continuous (DC) appearing at all inclinations, but appear less at

angles +10° and -5°. Plug flow pattern (PG) is found on the slope of +5° and +10° and the flow pattern of the spread will widen with increasing oil fraction and mixture velocity. Stratified wavy flow pattern (SW) interface at +5° will become wavy at +10° when the inclination increases from the horizontal position. Pattern Disperse oil in water (Do/w) often appear at an angle of +5° whereas Disperse pattern occurs in the slope of -5°.

Research on phase separation has been done Seeger et al [8] for the flow of air-water and water-vapor mixture flowing through the T-junction with a pipe diameter of 50 mm in the horizontal position, the vertical orientation of the branch up or down. Performance of phase separation depends on the orientation of the branch, the flow pattern in the inlet and mass quality. Phase separation is influenced by three factors : differences inertia of phase, the flow pattern in the inlet which is influenced by the velocity distribution and phase distribution in the cross section of the inlet. Distribution and phase velocity depends on the angle of the horizontal branch and the branch of the inlet diameter ratio (d_3/d_1). The effect of gravity on the branch also has an effect because certain slope reversal one phase flow can occur.

Ega [4] has been done on the effects of variations angle branch T-junction towards kerosene water separation characteristics. Variations used angle is 30°, 45°, 60° and 90°. Glass test section diameter of 25 mm and 12.5 mm side arm. From research result flow pattern were: Stratified (ST), Stratified Wavy (SW), Three Layer (3L) and Disperse (Do/w or Dw/o). Changes in flow pattern occurs with increasing superficial velocity. The results of the phase separation occurs best in Stratified flow pattern (ST) angle of 90°, 64% watercut and J_{mix} = 0.23 m/s.

The study of two-phase flow separation at horizontal T-junction for flow stratified wavy by variations branch slope have been conducted experimentally and theoretically by Penmatcha et al [9]. Experimental data obtained by variation upward branch: 1°, 5°, 10°, 20° and 35° and the branch downward variation: -5°, -10°, -25°, -40° and -60° to the horizontal position. On the downward slope, more liquid phase is directed to the branch and on the slope above -60° overall liquid phase will be directed to the branch. On the upward slope some of the gas is directed to the branch to separate the liquid from the flow. At 35° almost all gas is directed to the branch for each flow that entering T-junction.

Sotgia et al [10] conducted a study on the 7 pairs of pipes made of pyrex and plexiglass with a diameter range of 21 ~ 40 mm. The results showed that the flow pattern arises: *Disperse, Disperse-Annular transition, Anullar, Wavy Wavy Annular* and *Stratified.*

Flow Pattern Identification Method

There have been many methods to identify the flow pattern. Angeli et al [1] to identify the flow through a horizontal pipe in two ways: using high-speed video recorder to record the flow patterns and high frequency impedance probe to identify the local phase fraction. Lum [5] also used the same method of identification with Angeli. Penmatcha et al [9] conducted flow modeling to predict flow patterns that occur in the T-junction. Sotgia et al [10] to identify the flow pattern with a video camera or photography.

To identify the flow pattern resulting in branching T-junction, the researchers used Handycam recorder and photo stream flow patterns that occur in the T-junction during the process of phase separation of water kerosene lasts.Taking pictures and video streams carried on the front side of the test section, and taken the best conditions for each superficial velocity under variations corresponding test matrix research. Data of separation would be observed to the performance of kerosene-water phase separation.

Experimental Equipment

The composition of the experimental apparatus in this study can be seen in Figure 2.

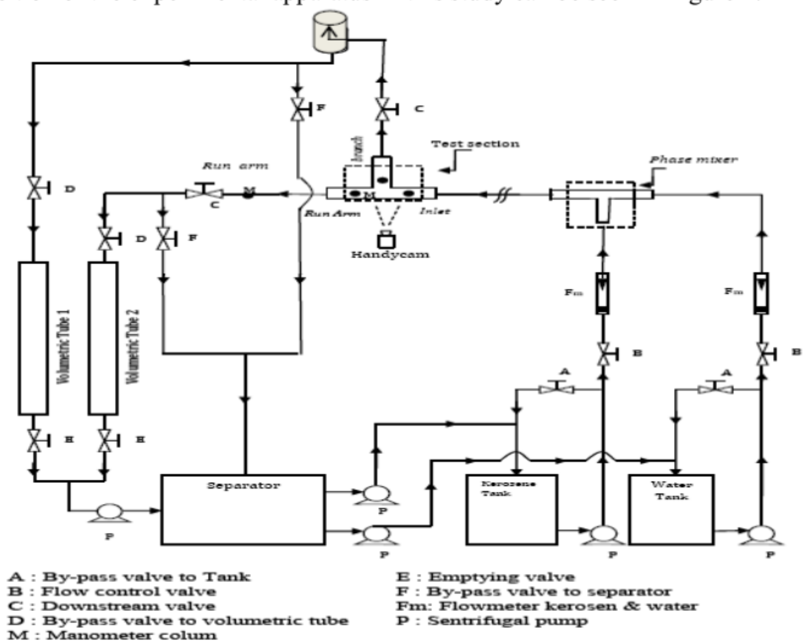

Figure 2. Experimental setup T-junction

Table 1. J_w and J_k Matrix Test

Jw (m/s)	Jk (m/s)	Watercut (%)
0,39	0,17	70
0,36	0,15	70
0,39	0,22	64
0,36	0,20	64
0,29	0,17	64
0,39	0,26	60
0,29	0,20	60
0,20	0,14	60
0,36	0,26	58
0,29	0,22	58
0,23	0,17	58
0,23	0,25	49
0,20	0,22	49

water was flowing first according to J_w value i.e table 1 to mixing area and go to the test section (T-junction), then recirculated to water tank. After water fully entry in the chanel of system, kerosene flows then according to J_k value and mixed together water in the mixing area and recirculated again in the each tank. The value of J_w and J_k regulated by each flowmeter of kerosene and water, with range on the minimum until maximum values. After then mixed fluid enter test section (T-junction) and flow out to branch and run section. On the downstream give three flow resistance to allows kerosene flowing more/maximum in branch section.

Research Results

Some of the flow pattern was observed in the T-junction $r_D = 0.5$ angle 30^o, 60^o and 90^o deg are presented in Figure 3 through Figure 8.

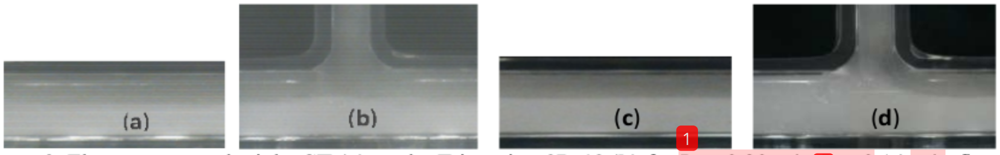

Figure 3. Flow pattern at the inlet **ST** (**a**), at the T-junction **3L-13** (**b**) for J_w = 0.20 m/s, J_k = 0.14 m/s, flow resistance R_2 (5743 Pa), Flow pattern at the inlet **ST** (**c**), at the T-junction **3L-3** (**d**) for J_w = 0.20 m/s, J_k = 0.14 m/s, flow resistance R_3 (6471 Pa) all for $\theta = 90^o$

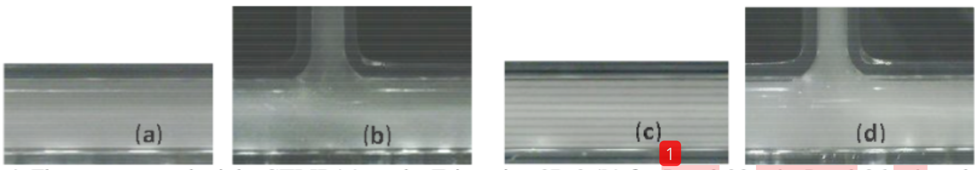

Figure 4. Flow pattern at the inlet **STMI** (**a**), at the T-junction **3L-2** (**b**) for J_w = 0.39 m/s, J_k = 0.26 m/s and flow resistance R_2 (7491 Pa), Flow pattern at the inlet **STMI** (**c**), at the T-junction **3L-3** (**d**) for J_w = 0.39 m/s, J_k = 0.26 m/s and flow resistance R_3 (8373 Pa), all for $\theta = 90^o$

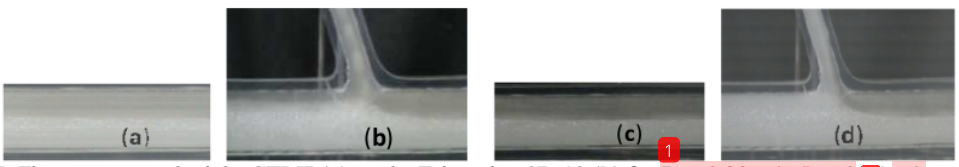

Figure 5. Flow pattern at the inlet **STMI** (**a**), at the T-junction **3L-13** (**b**) for J_w = 0.20 m/s, J_k = 0.14 m/s and flow resistance R_2 (5743 Pa), Flow pattern at the inlet **STMI** (**c**), at the T-junction **3L-3** (**d**) for J_w = 0.20 m/s, J_k = 0.14 m/s and flow resistance R_3 (6471 Pa), all for $\theta = 60^o$

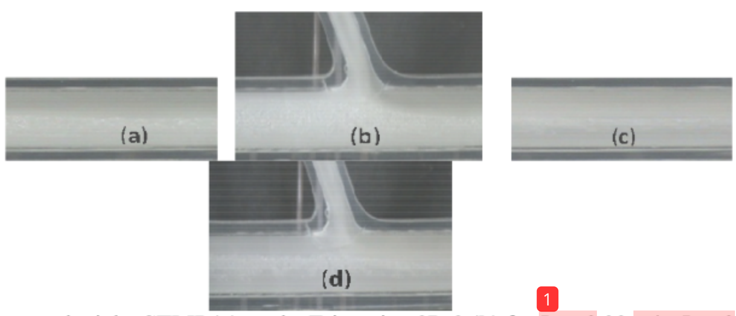

Figure 6. Flow pattern at the inlet **STMI** (**a**), at the T-junction **3L-3** (**b**) for J_w = 0.39 m/s, J_k = 0.26 m/s and flow resistance R_2 (7491 Pa), Flow pattern at the inlet **STMI** (**c**), at the T-junction **3L-13** (**d**) for J_w = 0.39 m/s, J_k = 0.26 m/s and flow resistance R_3 (8373 Pa), all for $\theta = 60^o$

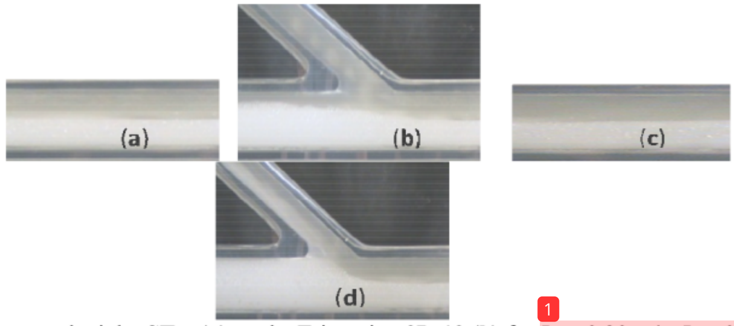

Figure 7. Flow pattern at the inlet **STw** (**a**), at the T-junction **3L-13** (**b**) for $J_w = 0.20$ m/s, $J_k = 0.14$ m/s and flow resistance R_2 (5743 Pa), Flow pattern at the inlet **STMI** (**c**), at the T-junction **3L-3** (**d**) for $J_w = 0.39$ m/s, $J_k = 0.26$ m/s and flow resistance R_3 (6471 Pa), all for $\theta = 30^o$

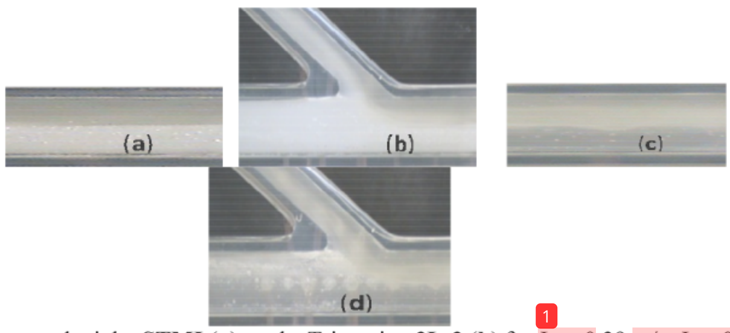

Figure 8. Flow pattern at the inlet **STMI** (**a**), at the T-junction **3L-3** (**b**) for $J_w = 0.39$ m/s, $J_k = 0.26$ m/s and flow resistance R_2 (7491 Pa), Flow pattern at the inlet **STMI** (**c**), at the T-junction **3L-2** (**d**) for $J_w = 0.39$ m/s, $J_k = 0.26$ m/s and flow resistance R_3 (8373 Pa), all for $\theta = 30^o$

The flow pattern in the inlet and T-junction was studied by observing flow through the transparent pipe and T-junction with video camera and the niked eye. By using Jw and Jk (Table 1), there were flow-pattern of stratified (ST), stratified with mixture interface (STMI) and stratified wavy (Sw) in the inlet and flow pattern of three layer-2 (3L-2), three layer-13 (3L-13), three layer-3 (3L-3).

At a low value of J_{mix} (J_w+J_k) and $\theta = 90^o$, flow pattern inlet shows : there is two layer in the flow with kerosen in the up and water in the bottom (stratified flow) i.e. figure 3.a and 3.c. Flow pattern in T-junction there is three layer with mixture interface layer between kerosen and water. Flow pattern in T-junction were : three layer-13 dan three layer-3 i.e. figure 3.b and 3.d. As the water or kerosene is increase (high J_{mix}) cause transition to other pattern occurs, increasing water and kerosen velocity leads to the formation of large kerosene drops at the interface. Flow pattern in the inlet changes from stratified to stratified with mixture interface and flow pattern in T-junction changes from 3L-13 to 3L-2 i.e. figure 4. The flow patern in figures 3 and 4 also significantly influenced by downstream resistance changes (from R_2 to R_3 with the diffrence value for difference velocity of water).

The figure 5 and 6 for $\theta = 60^o$, the flow pattern inlet forms as stratified with mixture interface i.e. figure 5.a, 5.c, 6.a, 6.c and T-junction pattern were 3L-13 and 3L-3 i.e figure 5.b and 5.d. As the increase of water and kerosen velocity also downstream resistance from R_2 to R_3 cause T-junction flow pattern changes from 3L-13 to 3L-3 and 3L-3 to 3L-13 i.e. figure 6.b and 6.d. This phenomenon could also be seen in figure 7 and 8 but there is difference in T-junction flow pattern in figure 8.d because the flow pattern changes from 3L-3 to 3L-2.

For all condition flow pattern, the downstream resistance changes from R_2 = 5743 Pa to R_3 = 6471 Pa at the low value of J_{mix} ($J_w + J_k$) and changes from R_2 = 7491 Pa to R_3 = 8373 Pa at the high value of J_{mix}. Increasing the value of downstream resistance can increase separation efficiency but the other condition this increasing value can decrease the efficiency because as the water velocity increased can push the kerosene layer flowing past to the run section.

In Figure 8.d could be seen any little white circle, a circle that is not part of the flow patterns but the tapp pressure in T-junction.

Conclusions

Identification of the flow pattern on the T-junction r_D = 0.5 angle of 30°, 60° and 90° has been conducted and concluded as follows:

1. For all inclination of branch, the behavior of the separation in T-junction is sensitive enough to the two-phase flow pattern in the upstream.
2. The variation of the flow resistance in the downstream influences the flow pattern and the separation result in T-junction.
3. For the same flow pattern and downstream resistance, there is more water enter to branch when the angle of branch is small.
4. Performance of phase separation is best achieved in the flow pattern 3L-3, because in this condition all kerosene from the inlet entering branch although there is still a bit of water come together.

Acknowledgements

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