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Study of refrigerant flow consistency and tolerance control of a distributor for air conditioner

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Abstract. In the residential air-conditioning system, a refrigerant distributor is a device that connects the outlet of an expansion valve to each evaporator coil circuit when paired with a multi-circuit evaporator. The efficiency of the heat exchanger is significantly impacted by the two-phase refrigerant's distribution. Only when the distributor has consistent performance can the heat exchanger be utilized efficiently. Hence, the aim of this study is to identify the impact of manufacturing tolerance of the distributor for air conditioner on the flow consistency. Preliminary analysis for different rules of factors such as the installation angle, barrel diameter and branching angle are studied through Computational Fluid Dynamics (CFD) simulation to analyze the parameter sensitivity. Based on the mean value of the standard deviation of the mass flow rate and quality at each path, the distributor's performance is evaluated. It is found that the tolerance control on barrel diameter and installation angle will give significant impact on the flow performance, this is because the evaluation of standard deviation for mass flow rate and quality for these conditions are above average, that are 0.443 and 0.0161 respectively. On the contrary, a minimal influence is seen when the branching angle can be controlled within 1 degree tolerance. The following parameters' effect on flow consistency are presented in order of largest to smallest: barrel diameter, installation angle and branch angle. A thorough study on the performance for the existing distributor is conducted and the tolerance of the important geometrical parameters (i.e., barrel diameter and branch angle) and working condition (i.e., installation angle) are identified.

Keywords: Air conditioner, Flow mechanism, Mal-distribution, Manufacturing tolerance, Refrigerant distributor, Structural optimization.

1. Introduction

Air conditioners consume large amounts of electricity and the combustion of fossil fuels for electricity generation release pollutants that harm the environment and human health. Globally, the main source of greenhouse gas emission from human activity comes from the use of energy. Fossil fuel burning is responsible for almost two thirds of the world's greenhouse gas emission and statistic shows that total greenhouse gas emission in the year of 2019 displayed an increment of 6.59% since 2015 [1]. A further direct threat to the climate change posed by air conditioner is the releasing of potent heat trapping gases from refrigerant. Chemicals like hydrofluorocarbons (HFCs) have a capacity to trap heat in the atmosphere up to 12,000 times greater than carbon dioxide. Regarding these concerns, many studies have been conducted aiming at improving the coefficient of performance (COP) of air conditioning systems. The basic cooling technology behind air conditioning and refrigerators do not change significantly over the year, however, improvement of the air conditioning system's main components; such as compressors, fans and heat exchangers had alleviated the COP value [2].

Multi-channel heat exchangers which are composed of round copper tubes for refrigerant flow passage and aluminum fins for air passage is widely used in various refrigeration system owing to the superior heat transfer performance and low pressure drop. The most prevalent issue exists in the application is the non-uniform distribution of two-phase refrigeration in each circuit, or commonly known as maldistribution. This directly affects the thermal efficiency of the heat exchanger. Choi et al. [3] showed that the capacity degradation due to refrigerant maldistribution can be as much as 30%. Refrigerant that flows through expansion valve is a mixture of saturated liquid and vapor, however the mixture is predominately liquid by weight. Since different phases will travel at different velocities, the gravity has a greater influence on the liquid portion of the flow than vapor which sometimes referred to as slip, and this will lead to maldistribution [4]. The flow of refrigerant often choses a pathway that provides the least resistance to forward motion as illustrated in figure 1 [4], thus, the ratio of liquid at each path will not be consistent and might resulted in an earlier dry out for paths that have smaller liquid mass flow rate. Therefore, consistency in distribution performance will greatly impact the energy usage in air-conditioner system.

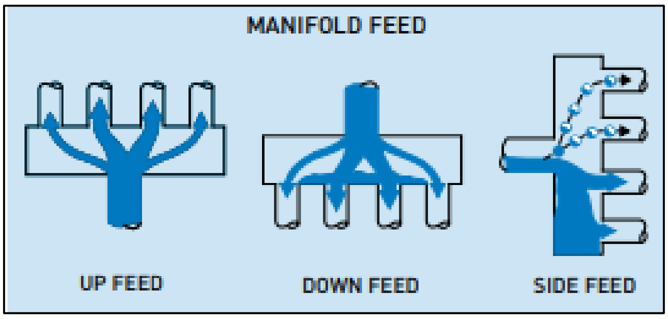


Figure 1. Visualization of flow distribution at different orientation [4].

For the purpose of a uniform distribution of a two-phase refrigerant to improve the evapoarator performance, some research has been studied and to be divided into four categories. First of all, promoting the mixing of the two-phases refrigerant to improve the performance of the distributor. Yao et al. [5] had introduced two approaches to attempt to improve flow distribution. The first method is through homogenization of flow regime before distribution and the second is to create uniform rate by manual adjustment of the resistance of each circuit individually. The result highlighted the average deviation of capacity for each branch is the lowest when homogenization approach is implemented. The study had suggested the uniformity of the flows can be optimized when the flow regimes at the inlet tube is annular that can be achieved when the flow has lower quality and relatively high mass flow rate despite the distributor's orientation. The uniformity of mass flow rate, liquid quality at the evaporator inlet, and capacity of each circuit will reflect the performance of the distributor.

Zhang et al. [6] investigated the influence of main parameters of the distributor on the distribution uniformity. The weightage of the dimension for the mixing cavity can be ordered as follows, where diameter has greater effect than the length followed by the cone angle. Hence, two optimized distributor are proposed, the Taguchi optimzed design and the hemispherical optimized distributor to enhance the distribution uniformity. The result shows that the standard deviation of temperature had a decrease rate of 4.6% under rated condition while the hemispherical optmized distributor shows a greater decrease rate of 36.5%. However, the uniformity of the distribution becomes worse when the distributor is tilted where hemispherical has a significant effect at this scenario.

Pu et al. [7] proposed a new design structure of the inlet pipe based on the opimization strategy of the infleunce degree of each factor on the mixing of the liquid-gas refrigerant. Several factors are selected to investigate the influence on refrigerant distribution, including the distance from the elbow to the inlet of the distributor, installed angle for distributor, and etc. The simulation result shows that the new distributor has reduced the phase separation greatly as compared to the original-design of distributor which lead to better mixing effect of the refrigerant. Hence, standard deviation of the mass flow rate and quality are both smaller than 1%.

Li et al. [8] proposed a new design of base distributor by utilizing a spherical surfaces and reduced the depth of the chamber. Based on the experimental result, spherical based tend to improve in a more symmetric circulation patterns and phase distribution. The average of uneveness of flow distributor for spherical base is only 9.7% which is slighly lower than cone base distributor.

An investigation on double-barrer distributor done by Zhang et al. [9] proved that a wider and higher barrel will promotes the form of reflux pattern which benefits in distribution performance. They had concluded that the most influential condition paramter in distribution perfromance is mass flow rate, where the performance increase parallely with the increase in mass flow rate. This is also agreed with the statements made by other scholars where they had concluded the effect of mass flows rate on distribution plays a crucial role in cooling capacity in air conditioner [10,11]. The cooling capacity increase 12% than the original system when the mass flow rate increase from 1.33 kg/s to 2.05 kg/s [10].

The second way is to develop annular flow pattern for two-phase refrigerant flowing in the distributor. Wu et al. [12] had proposed a new distributor design which has tested by visualized experiment. The new design has a T-shape connection that is nearly parallel to the center axis of the outlet tubes so the refrigerant flow will be even for all outlet tubes. The result shows that the proposed distributor has significant reduction in unevenness than those of the conventional dsitributor by 19.8% and 60.9% respective for horizontal and vertical installation. However, uniform annular flow fails to achieve identical flow behaviour under lower gas and liquid fow rate due to lower momentum to overcome the effect of gravity, this is later proven by Liang et al. [13], Ishii et al [14] and Wang et al. [15]. The stratification of the two-phase flow can be observed when the mixture flow through the bend pipe, this is due to the action of centrifugal force on liquid phase. The direction of gravity that is towards Y axis caused more liquid to distribute near the inlet of the distributor whereas maldistribution is severe at +Z direction, hence the direction of gravity plays a role in distribution uniformity in the multi-pass distributor [14].

Some other scholars proposed another method to optimize the performance of refrigerant distribution by ensuring the inlet quality or the flow rate at the branch tube of the dsitributor are stable [14,16]. The research from Yoshioka et al. [16] evident that the distribution for the refrigerant is significantly influenced by the change of the refrigerant flow coditions. Hence, an optimization on the geometrical parameters of the distributor was proposed to ensure the distribution remains stable over the various operating range. It was found that the diameter of the distributor is most influential to the performance of the distributor followed by the length of the distributor and inserting length of the branch tube. According to the calculation of the unevenness with respect to the levels of the geometrical result, a new distributor is designed. The result for the optimized distributor shows that the variation of the inlet quality and flow rate distribution reduced in a significant amount compare with the conventional distributor. Fay [17] have different approach to promote consistent flow rate and quality at each branches' inlet, which is by installing small valves on feeder lines to adjust the resistance of the flow rates in order to give equal superheats. This will further enhance the distribution while the system runs. The results shows that the coefficient of performance (COP) and capacity increased from the most maldistributed condition.

In conclusion, from previous study several drawbacks are identified regarding the research on the refrigerant flow distribution:

- There are few researches about the maldistribution on commerical type single split air-conditioner

- Few paper investigated the effect of inclination angle on refrigerant flow distribution condition
- The optimization should be more realistic for a realistic and practical application
- Previous investigation on refrigerant maldistribution rarely focus on refrigerant as working fluid
- Few papers utilized R32 in simulation to validate the performance of the proposed design
- Current study do not emphasize on tolerance control that contribute in consistency of air conditioning performance.

There are few papers discussed about the tolerance impact on the performance consistency. Hence, the above-mentioned drawbakcs will be addressed in this paper. The flow distribution at the commercial type air-conditioner will be explored. Moreover, the influence of distributor geometrical parameters is analyzed based on the finding from other scholars where optimization is made based on the evaluation. The influence of the inclination angle will be studied as the installation of the distributor might be varied due to the compact size of unit. This is to ensure a more practical and realistic application despite the change in flow condition. Using R32 as working fluid to explore the effects on two-phase flow in simulation software to visualize the mixture behaviour in distributor.

In conclusion, the purpose of this research is to identify the manufacturing tolerance of the distributor, with a focus on the barrel diameter, branch angle and installation angle, as these parameters are agreed in majority papers to have significant influence on the two-phase refrigerant flow performance in distributor.

2. Methodology

The structure of the distributor is diverse hence processing a new type of sample takes a long time. Therefore, numerical analysis (i.e., simulation) is preferable in preliminary study on structural optimization to reduce product manufacturing costs.

2.1. Physical Model of the Distributor

A commercial-type air conditioning distributor is explored, optimized, and the specific dimension are determined according to the designed engineering drawing provided by DRDM [18]. The isometric view of the distributor and the computational domain for the simulation are shown in figure 2. The dimension for the inlet tube diameter and the length is 8.32 mm and 50 mm respectively, other important parameters such as the barrel diameter and height are summarized in table 1. An 180°-elbow is installed before the distributor, and the refrigerant will flow sequentially through the barrel before distributed to each branch. The distributor has six paths (branches) connected with external tubes with equivalent diameter and length.

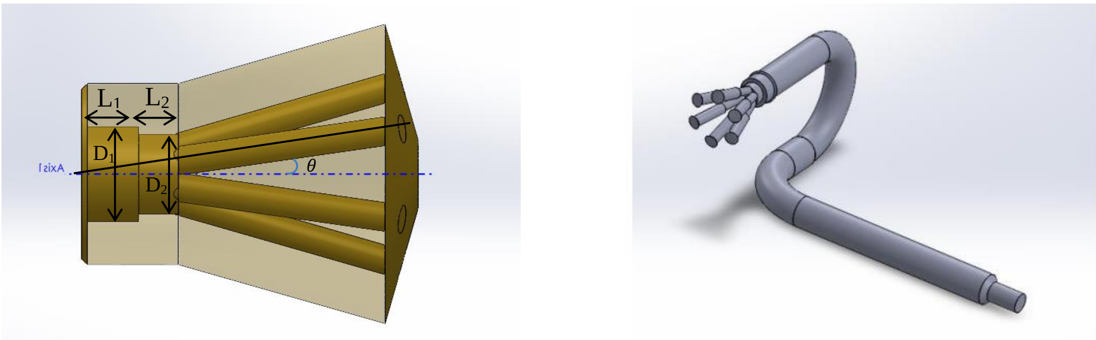


Figure 2. The (Left) isometric and (Right) fluid domain of a distributor [18].

Table 1. Main dimension of the distributor.

Dimension parameters	Symbols	Value
Diameter of inlet tube	D	8.32 mm
Bottom barrel diameter	D_1	9.52 mm
Top barrel diameter	D_2	7 mm
Bottom barrel height	L_1	5 mm
Top barrel height	L_2	3.5 mm
Branch angle	θ	16°

2.2. Numerical Model

The refrigerant flowing into the distributor is a mixture of saturated liquid and vapor, where the gas phase occupies most of the volume. As a result, the liquid phase is the discrete phase, and the gas phase is the main phase. The elbow of the inlet tube induces the phase mixture to develop into the stratified flow, while the two-phase fluid diffused into a homogenous flow inside the mixing cavity before distributed into the evaporator circuits. The Eulerian multiphase model is applied to describe the flow phenomenon (i.e., complicated flow process) since the volume fraction of the discrete phase is greater than 10% to 20%. Standard k-epsilon model, one of the major formulations of K-epsilon models, is selected as the turbulence model because it is suited for high Reynolds number to simulate the mean flow characteristic for turbulent flow conditions in ANSYS Fluent. The equations govern the transport of turbulent kinetic energy (k) and the rate of dissipation of the turbulent kinetic energy (ε), thus the behavior of turbulent flow is given in terms of these two properties in this model. This turbulence model is useful in this simulation because the flow is a free-shear layer and wall-bounded flow with relatively small pressure gradients [19]. Study had proven that this model gives a reasonable agreement between simulated and measured result. It is reliable due to its predictability and numerous variants, and it also offers good convergence and less memory-intensive. This model also considered in journals [6, 7, 9, 15].

2.3. Model Assumption and Boundary Conditions

The steady simulation has been made for a three-dimensional (3D) adiabatic flow and the flow is assumed as incompressible in liquid region. Hence, the density and viscosity of the refrigerant are constants. The impact of pressure drop in distributor and inlet pipe are relatively insignificant when compared with the flow experiencing in throttling valve, therefore it is assumed phase change does not occur throughout the flow process in distributor [7]. Based on the inlet mass flow rate, quality and the velocity of the refrigerant at the inlet pipe, the liquid-vapor mixture phase at the distributor has been deemed turbulent based on the evaluation of the Reynolds Number for performance test condition as shown in euqation (1). As long as the Reynolds Number is greater than 4000, the flow is regarded as turbulent.

$$Re = \frac{\rho V D}{\mu} \tag{1}$$

$$Re = \frac{1020.534 \left[\frac{\text{kg}}{\text{m}^3}\right] \cdot \left[\frac{\text{m}^3}{\text{s}}\right] \cdot 0.00832\ [\text{m}]}{0.000134994\ [\frac{\text{kg}}{\text{m} \cdot \text{s}}]}$$

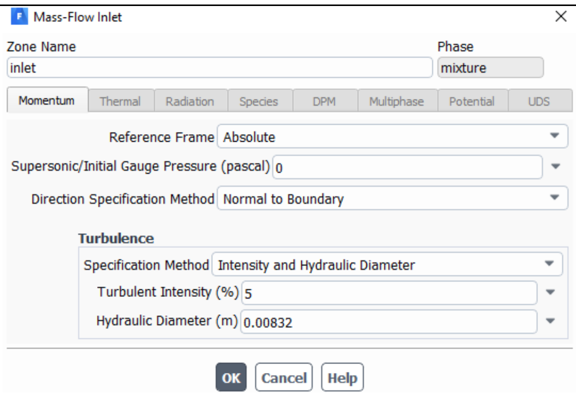
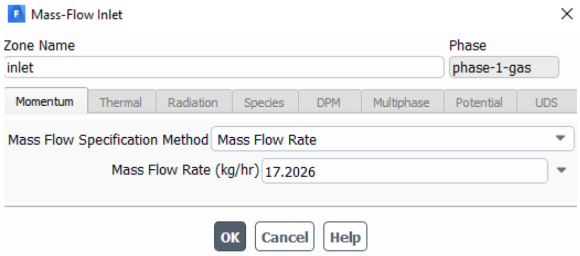
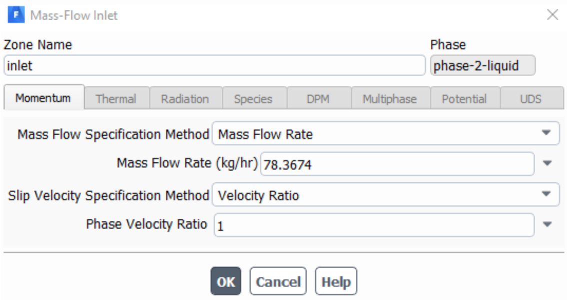
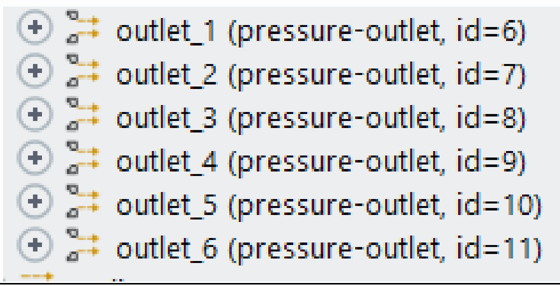
$$Re = 17{,}549$$

Where,

ρ = 1020.534 kg/m^3, $V = 0.2790\,\frac{\text{m}}{\text{s}}$, μ = 0.000134994 kg/m·s, D = 0.00832 m

R32 is chosen as the working fluid where REFPROP 9.1 is employed to provides access to R32's physical properties. The inlet boundary condition was set as 95.57 kg/hr and 0.18 for inlet mass flow rate and the quality respectively. The outlet boundary condition was set as the pressure outlet and it is assumed all the outlets pressure are equal to the operating pressure. Hence, the entire surface was set stationary wall with no heat transfer based on the assumption. The summary of the boundary conditions is summarized in table 2.

Table 2. Boundary Conditions.

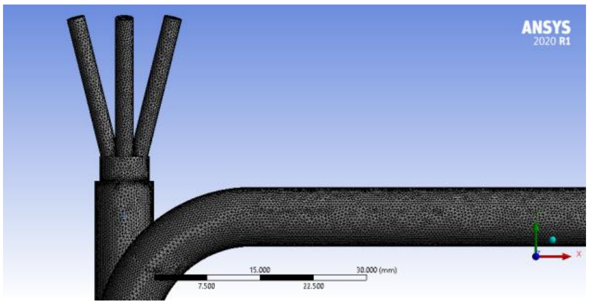
Boundary Conditions	ANSYS Fluent Interface
Inlet- mixture	
Inlet-gas	
Inlet-liquid	
Inlet-outlet	

2.4. Numerical Procedure

Fluent meshing of ANSYS FLUENT 2019 R1 was used to generate the poly grids. This research is a collaborated study with Daikin Research & Development Malaysia Sdn. Bhd. (DRDM), therefore the suitable mesh size and method for the distributor that is studied by the engineers were deployed in this study. Skewness and aspect ratio are selected to study the element quality. Result shows that mesh with 211,275 nodes is sufficient for computation and the average-skewness and aspect ratio of element is smaller than 5 and 3 respectively [15]. Since the element quality is more than satisfied, the authors agreed to not perform mesh independence test due to time constraints. Table 3 shows an overview of the mesh.

Pressure-base solver and steady state are employed for the calculation. SIMPLE is selected for the pressure spatial discretization to obtain a solution on a highly skewed mesh. Second-order upwind is for the momentum, volume fraction, k and epsilon to have a more accurate result.

Table 3. Summary of the mesh.

Attributes	Output
Mesh type	-Tetrahedrons -Patch independent
Mesh size	0.5 mm
Skewness	**Quality** Check Mesh Quality: Yes, Errors Target Skewness: Default (0.900000) Smoothing: Medium Mesh Metric: Skewness Min: 3.1963e-003 Max: 0.63244 Average: 0.14397 Standard Deviation: 0.12754
Aspect ratio	**Quality** Check Mesh Quality: Yes, Errors Target Skewness: Default (0.900000) Smoothing: Medium Mesh Metric: Aspect Ratio Min: 1.1792 Max: 5.1602 Average: 1.6984 Standard Deviation: 0.31168
Mesh output	

3. Result And Discussion

3.1. Pre-Study on Conventional Distributor

This section presents the influence of three factors on the distribution performance of the existing distributor. The standard deviation of the inlet quality and mass flow rate can be the index for the evaluation distribution performance because consistency in inlet qualities and mass flow rate at every branch tube and at different operating conditions will reflect the characteristic for a distributor. Hence, equation (2) and (3) of the standard deviation of mass flow rate and inlet qualities are:

$$\sigma_x = \sqrt{\frac{1}{N-1}\sum_{k=1}^{N}\left(x_{i,k} - \overline{x_i}\right)^2} \tag{2}$$

$$\sigma_m = \sqrt{\frac{1}{N-1}\sum_{k=1}^{N}\left(m_{i,k} - \overline{m_i}\right)^2} \tag{3}$$

where,

i = Path 1, 2, 3, 4, 5, 6, 7
n = no. of conditions
$\bar{x}$ = Average of inlet qualities of each outlet
$\overline{m}$ = Average of mass flow rate of each outlet.

The average of mass flow rate and quality of each outlet can be calculated as follow:

$$\bar{x} = \frac{1}{n}\sum\nolimits_{i=1}^{n} x_i \tag{4}$$

$$\overline{m} = \frac{1}{n}\sum\nolimits_{i=1}^{n} m_i \tag{5}$$

The distributor divides the refrigerant from inlet tube pipe into 6 feeder flows (8.32 mm inner diameter) and 6 evaporator circuits as shown in figure 3. Hence, the mean value of the standard deviation, $\bar{\sigma}$ over these six paths for each condition is compared to evaluate the distribution performance. The equation is expressed in equation (6).

$$\bar{\sigma} = \frac{1}{6}\sum(\sigma_1 + \sigma_2 + \sigma_3 + \sigma_4 + \sigma_5 + \sigma_6) \tag{6}$$

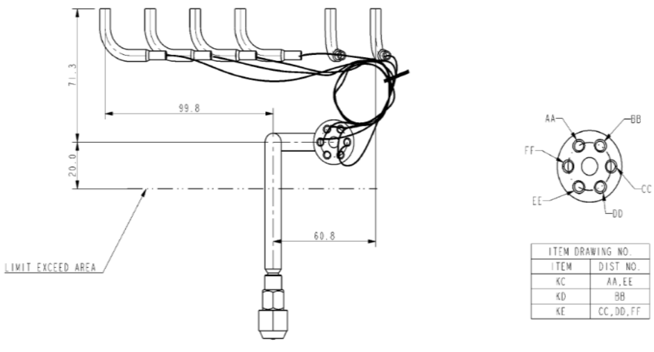


Figure 3. Test distributor.

The structure of the distributor has a significant impact on the refrigerant distribution. To assess the severity of the flow behavior, four different conditions are proposed as summarized in table 4 to study the impact of these factors on refrigerant flow consistency.

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Table 4. Simulation conditions.

Condition	Flowrate	Quality	Installation angle	Barrel diameter	Branch Angle
J1 (Base)	95.57	0.18	0	7	16
J2	95.57	0.18	-10	7	16
J3	95.57	0.18	0	8.32	16
J4	95.57	0.18	0	7	17

As seen in figure 4, the distributor's outlets are labelled in an anticlockwise direction starting from Outlet_1 to Outlet_6 and the mass flow rate and fluid quality at each path in all simulation conditions are illustrated in figure 5 and figure 6. Outlets 2 and 3 have the highest mass flow rate despite the change in simulation conditions. These two adjacent outlets are located on the left side of the distributor as shown in figure 4. On the other hand, the paths with the least amount of mass flow, outlets 5 and 6, are situated across from the paths with highest mass flow. Outlets 1 and 4 are aligned to the vertical axis of the distributor, the mass flow rate at these paths is relatively uniform. The inlet quality trend is in direct opposition to the mass flow rate. Since the quality is derived by dividing the gas's mass flow rate with total mass flow rate, hence the greater the total mass flow rate, the lower the inlet quality.

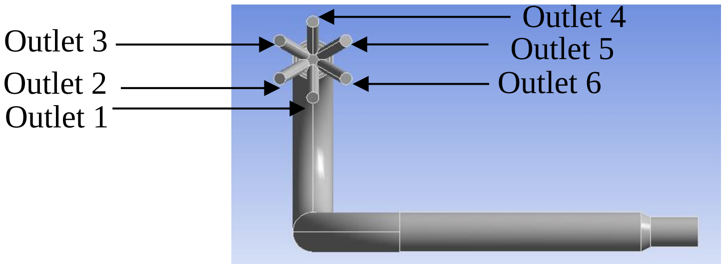


Figure 4. Orientation of the outlet paths.

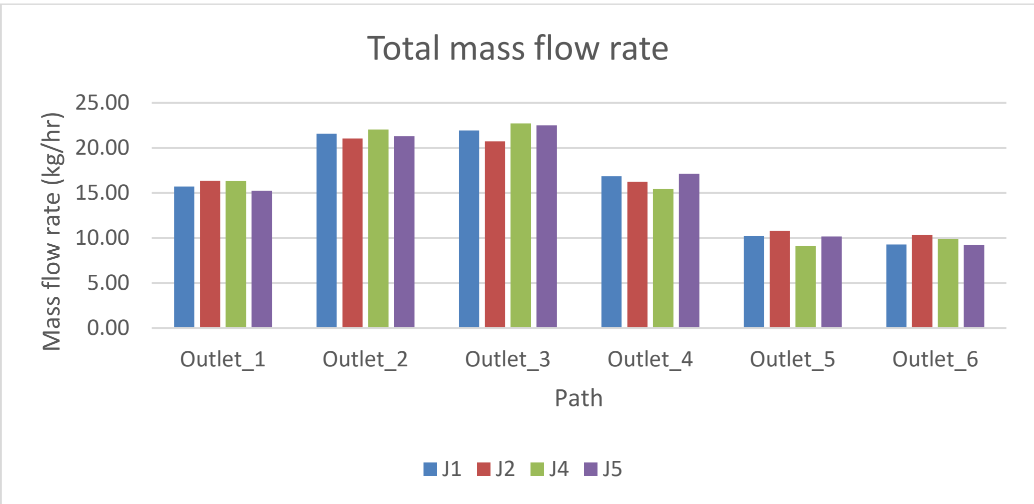


Figure 5. Total mass flow rate at each path of different simulation conditions.

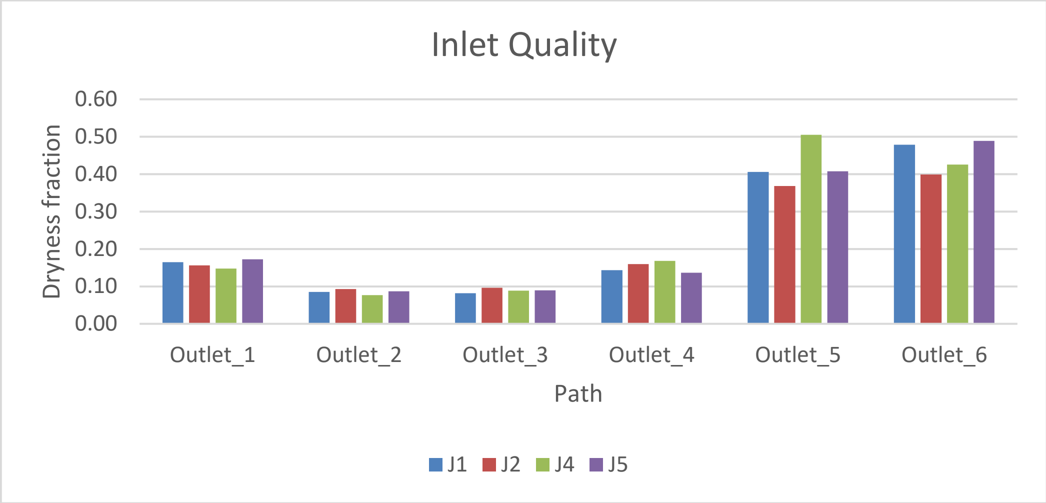


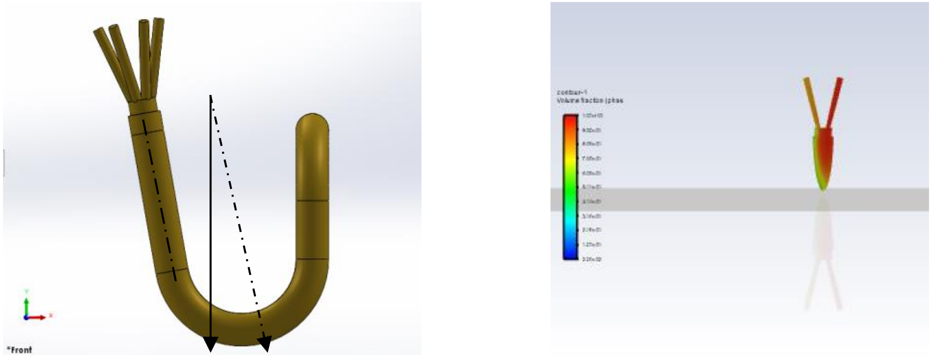
Figure 6. Inlet quality at each path of different simulation conditions.

3.2. Effect of installation angle on refrigerant flow behaviors

In practical application, it is difficult to ensure the distributor is installed vertically due to space constrain. Therefore, the inlet tube pipe connected to the distributor was tested in an angled position which is -10° away from the vertical axis. When the angled exists, liquid will accumulate on the side of the gravity direction due to the action of gravity. Gravity works on liquid and the flow velocities increase with slope gradient and flow rate; this will result in unevenness in distributing the two-phase refrigerant. Liquid tends to accumulate with the sides of the pipe inclined towards the gravity as gravity pulls things towards it, and this will result in refrigerant overcharge, that will cause the refrigerant to not switch between gaseous and liquid state, while some paths are overheated due to insufficient refrigerant and forces the HVAC unit to overwork.

The distributor is inclined on Y-Z plane as shown in figure 7(a). The gas phase distribution of refrigerant is depicted in figure 7(b). Since the liquid adhesive force is greater than its cohesive force, strong attractive force between the liquid molecules and tube molecules are formed. When two-phase fluid flows through the elbow bend, surface tension attracts water to the pipe wall. This is because the component of gravitational acceleration force acted perpendicular to the pipe wall is less than the surface tension that acted in opposite direction. Hence, the force pulling the liquid towards the pipe wall is more than the reactive force that pulls the liquid away from the wall. Therefore, the liquid is distributed more on the wall of the inclined pipe as visualized in figure 7(b).

The path tilted towards the action of gravity account larger portion of the two-phase refrigerant. The contour represents the volume fraction of gas inside the distributor. The angle has more impact on paths 3 and 5 while the impact on the path 1,2,4 and 5 is inconspicuous as shown in figure 8. In short, the present of installed angle will enhance inconsistency of refrigerant distribution because the standard deviation of mass flow rate, STD_m and quality, STD_x displayed notable value which are 0.55 and 0.0194 respectively.



(a) The model of distributor, J2 (b) Gas distribution

Figure 7. The effect of installation angle on refrigerant distribution.

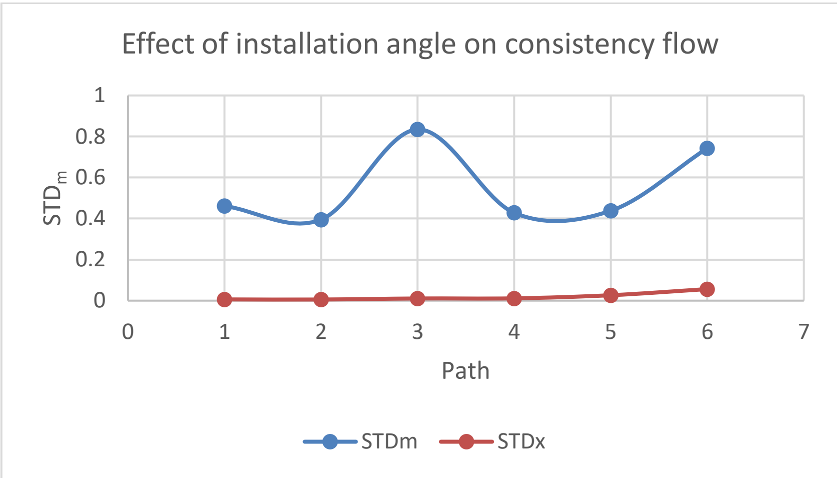


Figure 8. The relationship between installation angle and STD_m and STD_x.

3.3. Effect of barrel diameter on flow behaviors

The structure of the mixing cavity dominates the distribution performance of the two-phase fluid and the two main dimensions for a double-barrel distributors are illustrated in figure 9, including top barrel diameter and distributor angle. Past research has identified the influence of gravitational force will encourage the refrigerant to scatter towards the barrel wall, but in spite of that, some refrigerant will travel to the capillary tube without reflux which had led to mal-distribution among parallel paths. The presence of the elbow induces the phase mixture to develop into the stratified flow due to the action of inertia force. Therefore, the double-barrel is proposed to reduce the elbow effect in liquid and fluid phase separation.

For J3 condition, the top barrel diameter had increased from 7 mm to 8.32 mm as shown in figure 10(a). Hence, the characteristic of the double barrel diameter is suppressed since the top and bottom barrel diameter sharing the same dimension. The gas phase distribution of refrigerant is depicted in figure 10(b) and the corresponding STDs are showed in figure 11. The mean value of the standard deviation for mass flow rate and inlet quality across these 6 paths is 0.57 and 0.0247 respectively, which is the highest among other conditions. It can be considered that the change in barrel diameter has significant effect on the distribution of refrigerant. The large STD value indicates poor distribution performance, this phenomenon might be due to inappropriate dimension for top barrel diameter. Since top and bottom barrels have similar diameter, the change in structure make it easier for the fluid to flow out of the cavity directly without proper mixing of the two phases, effective reflux is not formed. Hence, further study is required to allocate the most optimum dimension for the parameter.

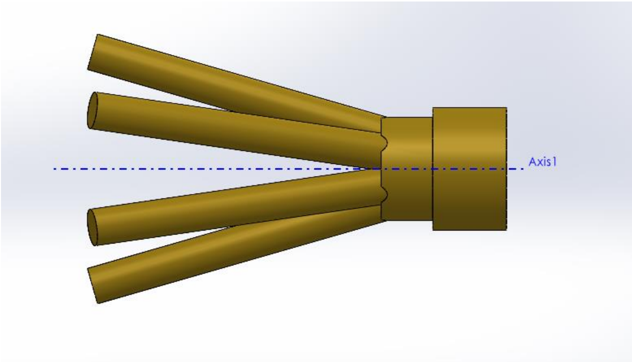
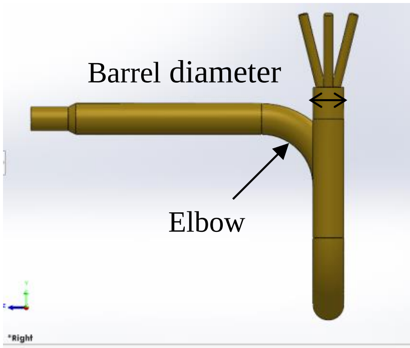


Figure 9. The structure of the double-barrel distributor for base condition.



(a) The model of distributor, J3

(b) Gas phase distribution

Figure 10. The effect of barrel diameter on refrigerant distribution.

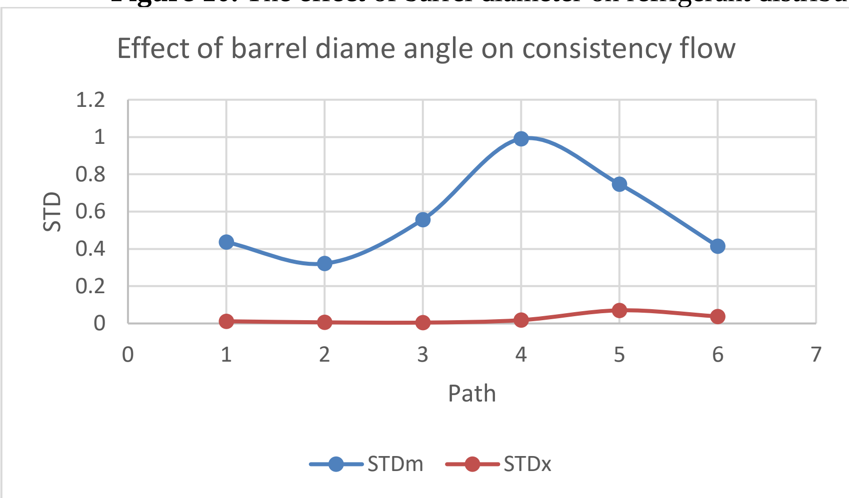


Figure 11. The relationship between barrel diameter and STD_m and STD_x.

3.4. Effect of branch angle on flow behaviors

The effects of angles between channels on flow distribution cannot be neglected; contrary, they may be critically affecting the flow. Under subcritical conditions, the flow of two-phase refrigerant is gravity-dominated and the phases tends to split unevenly between the branches and the straight arm. The preferential liquid movement at the branches is influenced by inertial, centrifugal force and the effect of gravitational acceleration. Basically, the effect of gravitational acceleration acts mainly on the liquid phase. The angle between the daughter branches' longitudinal axes is known as the bifurcation angle [20]. Symmetric bifurcations angle of 34° is constructed as shown in figure 12**.**

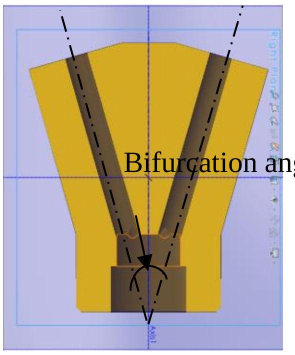
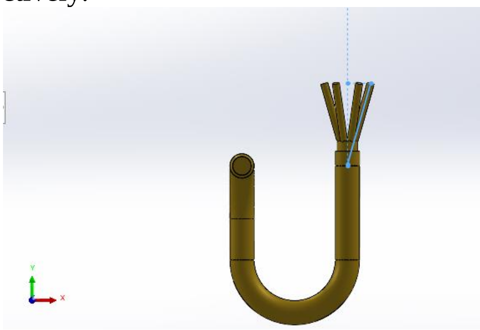
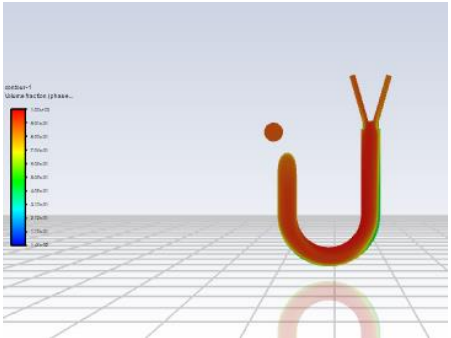


Figure 12. Cross sectional area of the distributor model symmetrical bifurcation.

To evaluate the sensitivity of the branch angle towards flow consistency, the branch angle of the outlet tube had increased from 16° to 17° as shown in figure 13(a). According to the balance of forces as illustrated in figure 14, when the angle between the horizontal axis of the distributor and the outlet tube decreases due to the increase in branch angle, less inertial force is required to overcome the gravity force. If the inertial force is denoted as F_i, the component of the inertial force will be expressed as $F_i \sin\theta$. Hence, lower vertical force is acted on the fluid when the angle decreases. In other words, the liquid will be easier to divert to the branched arm due to lower inertial force. This can be visualized in figure 13(b), where the phase stratification can be observed. Based on figure 15, it shows that the effect of branch angle on flow consistency is very minor where the STDs deviate insignificantly compared to other conditions. The mean value of STD_m and STD_X at this condition are 0.2008 and 0.0042 respectively.



(a) The model of distributor, J5



(b) Gas phase distribution

Figure 13. The effect of branch angle on refrigerant distribution.

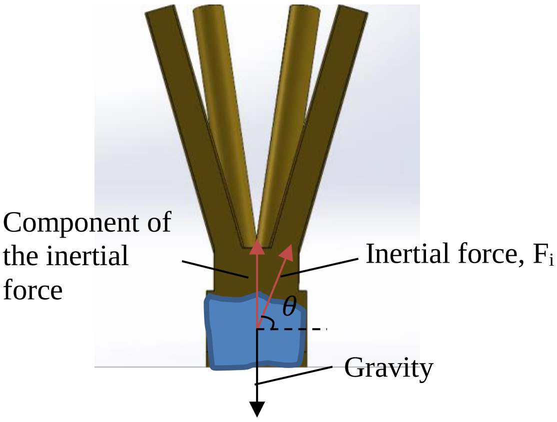


Figure 14. Forces acted on the flowing fluid in the distributor.

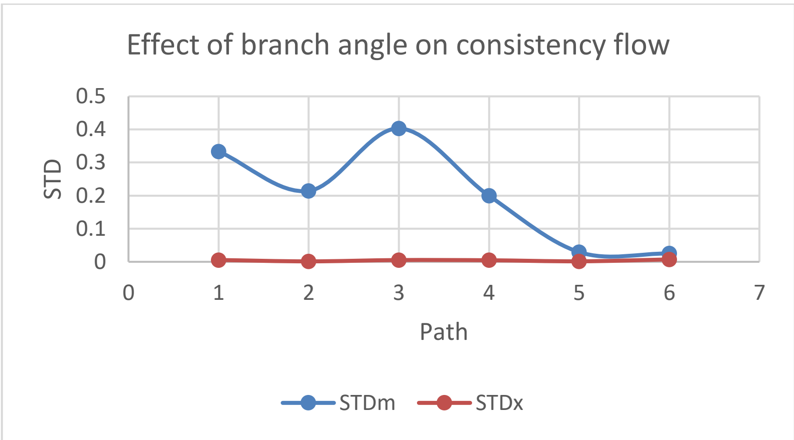


Figure 15. The relationship between branch angle and STD_m and STD_x.

By comparing the mean value of standard deviation for each condition with respect to J1 (base condition), condition J2 and J3 shows a significant impact on flow consistency as illustrated in figure 16**.** This shows that minor deviation on the installation angle and the change in barrel diameter can result in severe flow inconsistency. On the contrary, the effect of branching angle on flow consistency has been proven to be negligible. Therefore, this factor will be excluded from optimization stage.

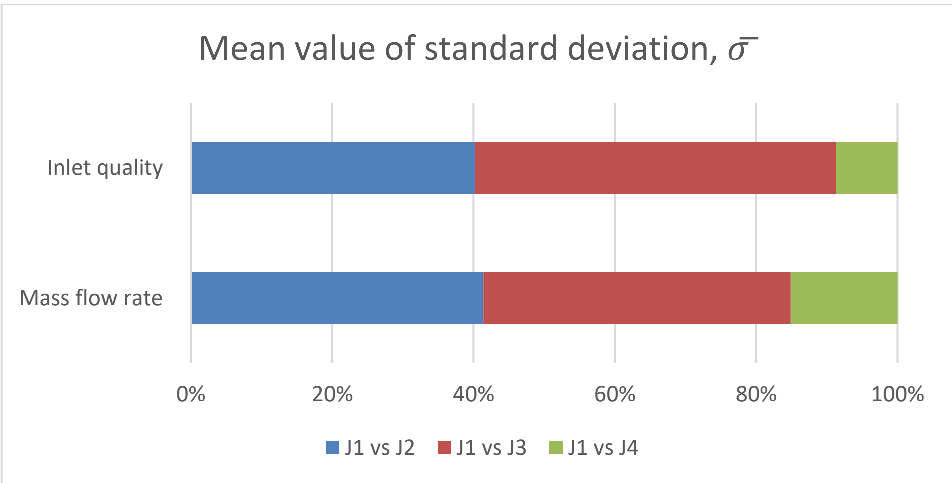


Figure 16. Mean value of standard deviation of each condition.

4. Conclusion

The problem of uneven refrigerant distribution has gain interest of researchers in recent years as it affects directly the performance of the evaporator. The inconsistency of maintaining the capacity tolerance at optimum level has degraded the air-conditioning performance. Therefore, a suitable distributor and tolerance control is necessary to maintain the capacity tolerance of an air-conditioner. This paper explored multiple structural factors on the consistency of two-phase refrigerant flow. Based on this, a thorough study on the existing performance for the existing distributor is conducted through numerical analysis. The major conclusion are as follows:

- Important geometrical parameters and working condition are identified.
  Based on the simulation result on the existing distributor, the main factors that contribute to inconsistency in refrigerant flow are defined. Four different simulations had carried out to identify the refrigerant flow distribution characteristic by varying the structural conditions. The influence weight of the parameters can be ordered as follows: > barrel diameter > installation angle > branch angle for STD_m and STD_X.

- Inclined distributor can deteriorate the performance of two-phase flow distribution.
  The relevance between the inclination angle and flow distribution is established through ANSYS simulation. Liquid is relatively easier to be influenced by gravitational force than gas. Hence, the distribution of liquid on the multi-path distributor is not consistent as they tend to flow to the paths that is inclined towards the gravitational force, as liquid always follows the path of least resistance. Hence, the irregularity when distributing the fluid into the evaporator circuit will cause the evaporator unit to overwork and thus the overall performance of the air conditioner unit is degraded.

- Proper dimensioning of barrel diameter can enhance the flow performance.
  Mixing cavity is an important chamber for the stratified flow to develop into homogenous flow. When the barrel diameter unable to control the tolerance within 1 mm, the consistency on flow distribution will be degraded.

- The size of the compartment limits the branch angle to some extent.
  The study on the branching angle on flow performance is carried out. Minor impact on distribution consistency is observed if able to control the tolerance of angle within 1 degree.

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