Development of an annular mist flow generating device for air-water flow

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Abstract. Annular mist flow generating device is being developed to generate annular mist flow of air and water to simulate two phase flow pattern in the evaporator. The annular mist flow generating device is use for experimental study of the air water flow behaviour that simulates the two phase flow of refrigerant. Annular mist flow at inlet of the dividing header will provide better air water distribution to the branches. The annular mist flow generating device shall be designed using computer aided drawing (CAD) software. Then, fabricate the annular mist flow generating device. After that, the annular mist flow generating device will be test experimentally by visual observation of the air water flow pattern. The air superficial velocity and water superficial velocity use in this experiment is 1.0m/s - 5.0m/s and 0.015m/s - 0.045m/s respectively. The test channel had a horizontal header with a square cross section of 20mm x 20mm and length of 290 mm with 10 upward branches. In this experiment the air water flow patterns is observed and recorded using digital camera. It was found that the device generate annular mist flow at frontal of the dividing header. This experiment proved that the device is capable of generating annular mist flow within the design range of air and water superficial velocities.

1. Introduction
An annular mist flow generating device is a device use to generate an annular mist flow pattern. Annular mist flow is creating by high gas superficial velocity and low liquid superficial velocity [1]. In annular mist flow, the gas phase is travel in the centre of the tube and surrounded by liquid phase as wavy film around the pipe wall [1]. Annular mist flow is a very important flow regime in many industrial including chemical processing plants, air conditioning, refrigeration system and nuclear reactors [2]. In this project, annular mist flow generating device is use to generate a simulated two phase flow pattern of refrigerant by using air water flow. Besides, annular mist flow generating device is fabricated to modelled the mist flow generated in compact evaporators used in automobile air conditioning system [3][4]. Air water flow is spray from generator to the dividing header to generate a mist flow before the air water flow distribution to the branches (refrigerant tubes) [3][4]. Gas-liquid distributions to the branches are greatly influenced by the flow pattern in the dividing header. The annular mist-flow inlets have batter uniformity of the water distribution compare with other flow pattern [5].

2. Literature review
2.1 Two phase flow pattern
The two phase flow pattern can be classifier base on the flow configuration, by their character, the
distribution of the interfaces and the mechanisms dominating pressure drop and the flow heat and
mass transfer [6].

Annular (A), High velocity of gas flow at the centre of the pipe is surrounded by the low velocity of
liquid flow around the pipe wall with some liquid drop in the centre of the tube. Include annular mist
and wavy annular [2].

2.2 Flow pattern detection
There are two main type of the method to detect the flow pattern. The first type is void fraction
detection. Void fraction is using hot wire probe, photon attenuation technique and conductance probe
to detect the flow pattern. Besides, void fraction also includes the visualization test, which is using a
transparent pipe and high speed camera to capture the flow pattern and motion.

The second method is pressure fluctuation detection. This method is using spectral distribution of wall
pressure fluctuations to determine the flow pattern. But this method can’t clearly distinguish some of
the flows.

The void detection method more accurate and better then pressure detection method because void
detection more closely related to fluid distribution.

2.3 Flow pattern prediction
To predict the flow pattern is map the experiment data and transition boundaries on two dimensional
or dimensionless maps.

2.3.1 Dimensional coordinate’s maps
The basic types of coordinates use is superficial velocities, mass superficial and momentum flux.

2.3.2 Dimensionless coordinate’s maps
Dimensionless coordinate’s maps use dimensional group use as coordinates. This is use to predict the
physical variable that affect the flow pattern. The dimensional parameters of the isothermal
incompressible condition as below: [7].

Gas and liquid superficial velocity (\(j_g, j_l\))
Gas and liquid density (\(\rho_g, \rho_l\))
Gas and liquid viscosity (\(\mu_g, \mu_l\))
Pipe diameter (D)
Pipe roughness (\(\varepsilon\))
Pipe inclination angle (\(\beta\))
Acceleration of gravity (g)
Liquid surface tension (\(\sigma\))
Solid liquid gas contact wetting angle (\(\gamma\))

This all variable will affect the flow pattern but the entrance geometry does not affect the flow pattern.

2.4 Gas superficial velocity
This gas superficial velocity (\(j_G\)) is referring to gas velocity in a pipe with
no liquid phase present. If the liquid present in the pipeline will cause the velocity of the gas become
higher due to the reduction area in the pipe [8].
\[ J_G = \frac{\dot{Q}_G}{A} = \frac{G}{\rho_G} \chi = \varepsilon u_G \]  

(1)

2.5 **Liquid superficial velocity**

This liquid superficial velocity \( J_L \) is referring to liquid velocity in a pipe with no gas phase present. If the gas present in the pipeline will cause the velocity of the liquid become higher due to the reduction area in the pipe [8].

\[ J_L = \frac{\dot{Q}_L}{A} = \frac{G}{\rho_L} \chi = \varepsilon u_L \]  

(2)

2.6 **Spray nozzle**

A spray nozzle is a device that uses to dispersion the liquid phase into a spray. Spray nozzle can classify as twin-fluid, swirl, hydraulic, rotary, ultrasonic, electrostatic, and many more. To create the annular mist flow can use atomization spray or two fluids nozzles [9].

2.6.1 **Two fluid nozzles**

The process of two fluid nozzles is when the high velocity gas is pressure and contact with liquid steam in order to atomize it [10]. After that the liquid jet breaks up due to momentum transfer from the gas to the liquid. This process is known as two fluid atomization and the nozzles of the process is known as two fluid nozzles [10]. There is much type of the two fluid nozzles such as air blast nozzle, prefilming air blast, plain jet air blast nozzle, air assist nozzles and effervescent nozzles. The gas and liquid phase can contact either inside or outside the atomizer which is classify as internal and external mixing nozzle respectively.

2.6.2 **Nozzle material**

Nozzle can made from metal and plastic such as brass, nylon, nickel alloys, stainless steel, ceramic, PTFE and PVC. To select the material to construct the nozzle is base on the properties of the liquid use and the temperature of the surrounding.

3. **Research methodology**

3.1 **Design identification**

External mix air blast atomization nozzle can create annular mist flow [11]. The mechanic of air blast atomization is the liquid is injected into an annular co-flowing gas stream, which breaks up due to gas-liquid momentum transfer [12]. The types of nozzles of interest in this research is air blast atomizers with the gas and liquid that external mixing.

From the equation of superficial of liquid and gas found that the volumetric gas and water flow rates \( (\dot{Q}_G, \dot{Q}_L) \) and area outlet of the atomization nozzle will influence the superficial of the gas and liquid. The diameter of gas and liquid of the atomization is design to have same cross sectional area for both gas and liquid outlet of the generator.

3.2 **Material choose**

Brass is choosing as material to fabricate the generator. This is because brass easy to machine, low cost of machining and good heat conductor.

3.3 **Fabrication**

The annular mist flow generator is fabricating by using CNC milling machine and lathe machine.

3.4 **Flow inlet conditions**

The air superficial velocity, \( J_A \) and water superficial velocity, \( J_W \) will affect the flow regime. The gas and liquid superficial velocities are determine based on the quality \( x \) and mass flow rate of the R-134a
refrigerant in real evaporator and they are 1.0 -5.0 m/s and 0.015-0.045m/s [6]. For the R-134 refrigerant flow in real evaporator, range of quality x =0.2-0.7 and mass flow rate M =40-160 kg/h. Besides, the temperature using in this research is room temperature which about 25 °c.

3.5 Test apparatus
The experiment apparatus to test the annular mist flow generator is show at Figure (1) Air and water flow rate is control by gas flow meter and liquid flow meter before supply to the test channel that show in Figure (2) The test channel is made of transparent acrylic plate. The test channel has square cross section of 20mm x 20mm and length 290mm which is set as horizontal with 10 branches upward.

Figure 1. Experiment apparatus.

Figure 2. Test channel with 10 upward branches in (mm).

4. Result and discussion

4.1 Design and fabrication
Figure 3 is the outer 3D design of the annular mist flow generator by using CAD software. Figure 4 is the basic 2D drawing with dimension (mm) of the generator connecting with the air and water resources. Figure 5 is about the Detail 2D sketch with dimension (mm) of the generator which the precision is important on generating the the annular mist flow. Figure (6) is about the final product of annular mist flow generator after fabrication.
Figure 3. Annular mist flow generator in 3D sketch.

Figure 4. Basic 2D sketch with dimension (mm).

Figure 5. Detail 2D sketch with dimension (mm).
4.2 Experiment result

This experiment is carrying out to proof that the designed generator can generate the annular mist flow with different air and water superficial velocities. Figure 7 shows a typical visual data of annular mist flow pattern that air superficial velocity at 1.0m/s and water superficial velocity at 0.015m/s. The annular flow is form before the 1st branch of the header. Figure 8 shows the visual data of air superficial velocity at 3.0m/s and water superficial velocity at 0.015m/s, the annular flow is form at the 1st branch of the header. Figure 9 is when the air superficial velocity at 5.0m/s and water superficial velocity at 0.015m/s, the annular flow is form before the 2nd branch of the header. From the figures show that when increase the air superficial velocity the water film will become thin and more water will force to rear part of the header.
4.3 Effect of the superficial velocity

Figure 10 the water superficial velocity is set as constant and the air superficial velocity is varies at 1.0m/s, 3.0m/s and 5.0m/s. To study effect of the air superficial velocity to the flow pattern when using the annular mist flow generator. When the air superficial velocity increase as the water superficial velocity is constant, air flow that reaches the no. of branch will also increase.

![Figure 10](image)

Figure 10. No. of branch versus superficial water velocity.

5. Conclusion

An annular mist flow generating device has been designed, fabricated and proved that can generate annular mist flow by experimental study. The air superficial velocity use in this research is 1.0m/s, 3.0m/s and 5.0m/s. The water superficial velocity use in this research is 0.015m/s, 0.03m/s and 0.045m/s.

When increase the air superficial velocity the water film will become thin and more water will force to rear part of the header

When the air superficial velocity increase as the water superficial velocity is constant, air flow that reaches the no. of branch will also increase.

Acknowledgments

Authors wish to acknowledge School of Mechatronic Engineering, Universiti Malaysia Perlis for the lab facilities. Special thanks to those who contributed to this project directly or indirectly.

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