International Journal of Current Engineering and Technology
ISSN 2277 - 4106

Available at http://inpressco.com/category/ijcet

Research Article

Experimental Study and Effect of Two-phase Flow Distribution of Air and Water in a Parallel Flow Heat Exchanger with Reverse Downward Flow

Satish Choudhary[a], Bhupendra Gupta[a*], Anand Bisen[b] and Anil Kumar[c]

[a]Jabalpur Engineering College, Jabalpur, India
[b]Govt. polytechnic collage, Jabalpur, India
[c]MANIT Bhopal, India

Accepted 02 August 2013, Available online 15 August 2013, **Vol.3, No.3 (August 2013)**

Abstract

Two-phase flow distribution of water and air was experimentally investigated in a parallel flow heat exchanger comprised of two horizontal headers and twenty five vertical channels. Most of the flow in the header inlet was identified as stratified flow. Both upward and downward configurations were tested. The effect of tube protrusion depth was also investigated. It was observed that, for downward flow, most of the liquid was extracted from the frontal part of the header. For upward flow, on the contrary, significant portion of liquid was forced to rear part of the header. The air and water flow distribution are experimentally studied for a round header – flat tube geometry simulating a parallel flow heat exchanger. The number of branch flat tube is 25. The effects of tube outlet direction, tube protrusion depth and quality are investigated. The flow at the header inlet is identified as annular. For the downward flow configuration, the water flow distribution is significantly affected by the tube protrusion depth. For flush-mounted configuration, most of the water flows through frontal part of the header. As the protrusion depth increases, more water is forced to the rear part of the header. The effect of mass flux or quality is qualitatively the same as that of the protrusion depth. Increase of the mass flux or quality forces the water to rear part of the header.

Keyword: *Air flow measurement, Water flow measurement, Aluminum pipe, Downward flow, Experimental approach.*

1. Introduction

Aluminum heat exchangers consist of flat tubes of 5 mm hydraulic diameter and louver fins on the air-side. To manage the excessive tube-side pressure drop by small channel size, a number of tubes are grouped to one pass using a header (parallel flow configuration).

After this region the two-phases are separated (if no gas dissolves in liquid) and depends on flow rate and direction of the fluids flow forms one type of flow patterns which will be discussed in upcoming section. The higher velocity of gas due to lower density causes a continuous acceleration of the liquid phase. This difference in velocity is called slip velocity that affects the magnitude of hold-up.

2. Experimental Setup

The experimental set up used for this study is shown in Figure 2.1. The hydraulic diameter of the present flat tube is 5 mm, and the flow cross sectional area is 25 mm^2. The test section consists of the 16 mm Internal Diameter round upper and lower headers, which are 90 cm apart. This configuration was chosen to simulate the actual parallel flow heat exchanger. The headers were made from transparent rods for flow visualization. A 5 mm round hole was machined longitudinally in a circular rod, and twenty five flat holes were machined at the bottom for insertion of flat tubes. An aluminum plate, which had matching flat holes, was installed underneath the header as illustrated in Figure 2.1. Flat tubes were secured, and the protrusion depth was adjusted using O-rings between the header and

Figure 2.1: Experimental setup

Figure 2.2: Air and water separator

*Corresponding author **Dr. Bhupendra Gupta**, **Anand Bisen** and **Dr. Anil Kumar** are working as Asst Prof; **Satish Choudhary** is a student of Master of Engineering, Heat Power

the aluminum plate. Transition blocks were installed in the test section to connect the flat tubes and the 5.0 mm ID round tubes. The round tubes served as flow measurement lines. At the inlet of the header, 1.0 m long pipe having the same inner diameter as the header was attached. The tube served as a flow development section.

Figure 2.3: Water tank with pump

Figure 2.4: Air blower

Table 2.1 Components used in Setup

Sr.No.	Name of component	Specification
1	Air blower	15 amp.220 v ac
2	Water heater	1000 w
3	Water pump	65w
4	Water flow meter	½ inch Diameter
5	Air flow meter	½ inch Diameter
6	Air and water Separator	4 inch Diameter
7	Flexible pipe	15 mm Diameter
8	Thirteen valve	½ inch Diameter
9	Vertical square aluminum pipe	Thickness 1.5mm
10	Vertical circular aluminum pipe	Thickness 1.5mm
11	Inlet tank	40Liters
12	Outlet tank	25 Liters

3. Methodology

3.1. Downward flow

For flush-mounted configuration (h/D = 0.0, 0.25, 0.5), most of the water flows into the tubes at frontal part of the header. Almost minimum water flows from the twenty-first tube. Although the water flow ratio changed somewhat depending on the quality, the general pattern was quite similar. The effect of quality is addressed in a separate section. The air distribution is reverse of the water distribution. Almost minimum air flows for the first tube, and the air flow ratio increases to one at fifth tube. Slightly more air is supplied from the twenty-first tube.

The variation of air distribution is less significant compared with that of water. With the tube protruded into the header, the flow pattern changes significantly. As shown in the sketch, part of the incoming water impinges at the first protrusion, some of it is sucked in to the first tube, and the remaining water separates at the top, reattaches at the rear part of the header. The water, which bypassed the first protrusion, along with the water from upper part of the header, impinges at the second protrusion, part of it sucked in, separates at the top and reattaches at shorter distance compared with the first protrusion. The process is continued until no water is available. The reattachment length depends on the protrusion depth and quality.

4. Result and Discussion

4.1-Reverse downward flow

In reverse downward flow, the air and water are flow in the direction of downward and after that air and water are achieve in separator. Temperature at inlet is 50 °C., Temperature at outlet is 44.5°C.
Time taken during reading = 10 sec.
Temperature at inlet =50 °C
Temperature at outlet =44.5°C
H=witch insert in pipe
D= 16mm diameter of pipe

Table 4.1.1 Air flow in different h/d and Reverse Downward flow

Sr. No.	Channel no.	Air flow (m^3 /sec) At h/d = 0/16 =0.0	Air flow (m^3 /sec) At h/d = 4/16=0.25	Air flow (m^3 /sec) At h/d=8/16 =0.5
1	1-5	0.1	0.2	0.1
2	6-10	0.9	0.7	1.2
3	11-15	1	1.2	1.4
4	16-20	1.2	1.3	1
5	21-25	1.5	0.9	0.5

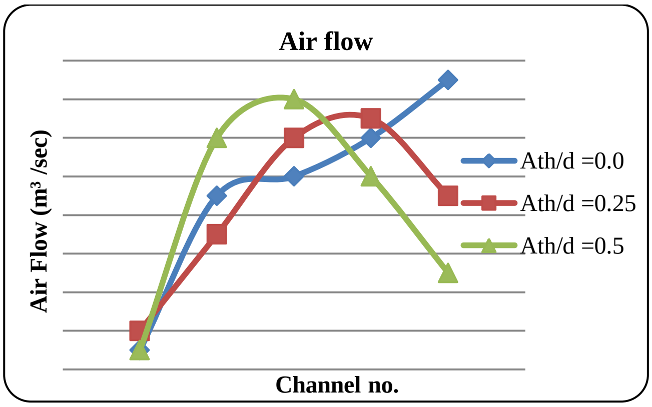

Figure 4.1.1: Air flow in different h/d and Reverse downward flow

Table 4.1.2 Water flow in different h/d and Reverse downward flow

Sr. No.	Channel no.	Water flow (L/ sec) At h/d = 0/16 =0.0	Water flow (L/ sec) At h/d = 4/16 =0.25	Water flow (L/ sec) At h/d = 8/16 =0.5
1	1-5	4	2.5	4
2	6-10	1	0.2	0.5
3	11-15	0.9	0.5	0.6
4	16-20	0.5	0.9	0.8
5	21-25	0.1	3.5	2.2

Efficiency

Temperature at inlet =50 °C
Temperature at outlet =44.5°C
ή= (Temperature at inlet - Temperature at outlet) / Temperature at inlet
= (50-44.5)/50 =11.00%

4.2 Reverse downward flow

In reverse downward flow, the air and water are flow in the direction of downward and after that air and water are achieve in separator.

Temperature at inlet are 60 °C.,

Temperature at outlet are 52°C.

Time taken during reading = 10 sec.

Temperature at inlet =60 °C

Temperature at outlet =52°C

H= witch insert in pipe

D= 16mm diameter of pipe

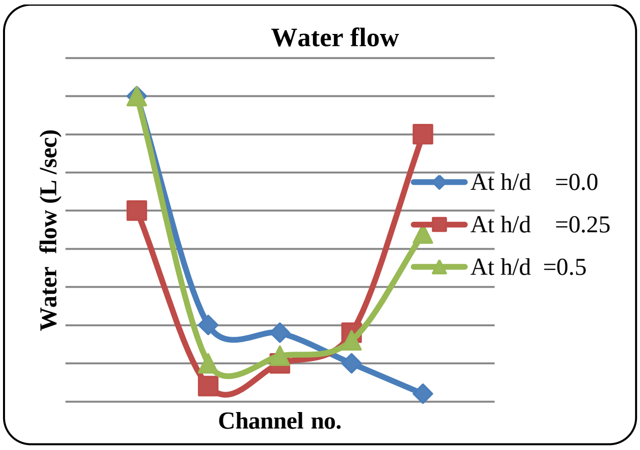

Figure 4.1.2: Water flow in different h/d and Reverse downward flow

Table 4.2.1 Air flow in different h/d and Reverse downward flow

Sr. No.	Channel no.	Air flow (m^3/sec) At h/d=0/16 =0.0	Air flow (m^3 /sec) At h/d= 4/16 =0.25	Air flow (m^3 /sec) At h/d =8/16 =0.5
1	1-5	0.2	0.3	0.25
2	6-10	0.9	0.8	1.2
3	11-15	1.2	1.3	1.5
4	16-20	1.3	1.4	1.2
5	21-25	1.6	1.0	0.6

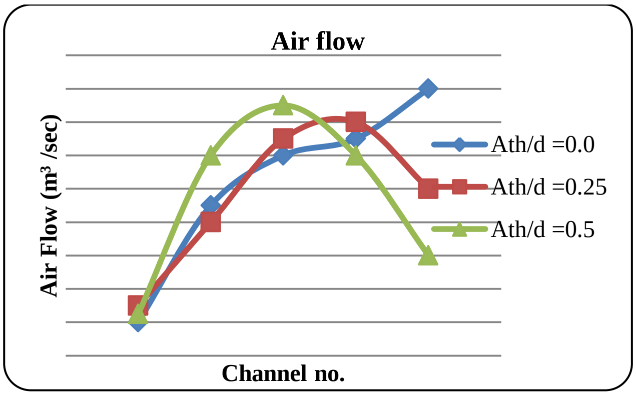

Fig. 4.2.1 Water flow in different h/d and Reverse downward Flow

Table 4.2.2 Air flow in different h/d and Reverse downward flow

Sr. No.	Channel no.	Water flow (L/ sec) At h/d = 0/16 =0.0	Water flow (L/ sec) At h/d = 4/16 =0.25	Water flow (L/ sec) At h/d = 8/16 =0.5
1	1-5	4.5	2.6	4.5
2	6-10	1.2	0.3	0.5
3	11-15	1.0	0.6	0.7
4	16-20	0.6	1.2	0.9
5	21-25	0.2	3.6	2.4

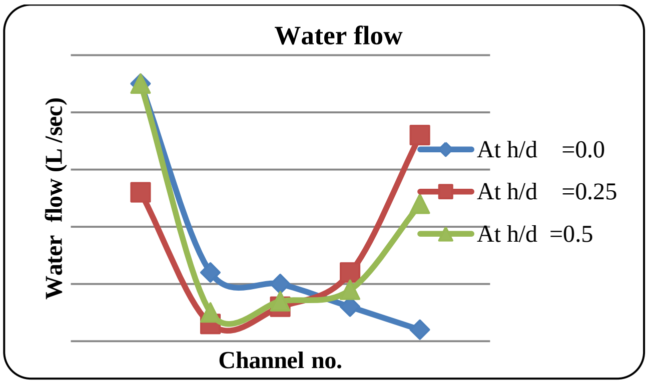

Fig. 4.2.2 Water flow in different h/d and Reverse downward flow

Efficiency

Temperature at inlet =60 °C
Temperature at outlet =52°C
ή= (Temperature at inlet - Temperature at outlet)/ Temperature at inlet
= (60-52)/60 =13.33%

4.3 Reverse downward flow

In reverse downward flow, the air and water are flow in the direction of downward and after that air and water are achieve in separator. Temperature at inlet is 70 °C. Temperature at outlet is 62.2°C.
Time taken during reading = 10 sec.
Temperature at inlet =70 °C
Temperature at outlet =62.2°C
H=witch insert in pipe
D= 16mm diameter of pipe

Table 4.3.1 Air flow in different h/d and Reverse downward flow

Sr. No.	Channel no.	Air flow (m^3/sec) At h/d = 0/16 =0.0	Air flow (m^3/sec) At h/d = 4/16 =0.25	Air flow (m^3/sec) At h/d =8/16 =0.5
1	1-5	0.2	0.6	0.2
2	6-10	1.0	0.9	1.2
3	11-15	1.3	1.6	1.6
4	16-20	1.4	1.7	1.4
5	21-25	1.7	1.5	0.7

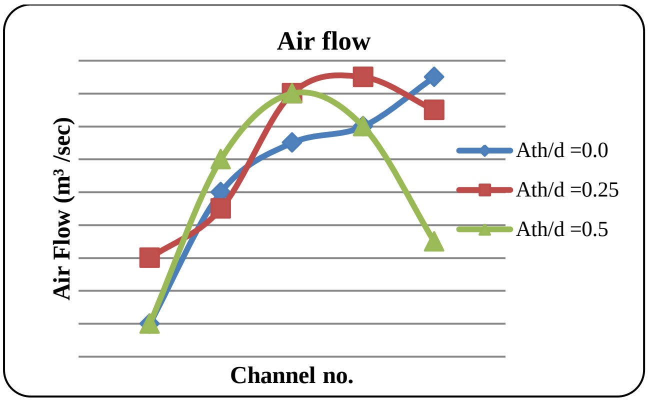

Figure 4.3.1: Air flow in different h/d and Reverse downward flow

Table 4.3.2 Water flow in different h/d and Reverse downward flow

Sr. No.	Channel no.	Water flow (L/ sec) At h/d = 0/16 =0.0	Water flow (L/ sec) At h/d = 4/16 =0.25	Water flow (L/ sec) At h/d = 8/16 =0.5
1	1-5	3.4	2.7	2.4
2	6-10	1.2	0.3	0.8
3	11-15	1.0	0.6	0.9
4	16-20	0.7	1.2	1.0
5	21-25	0.2	3.6	1.6

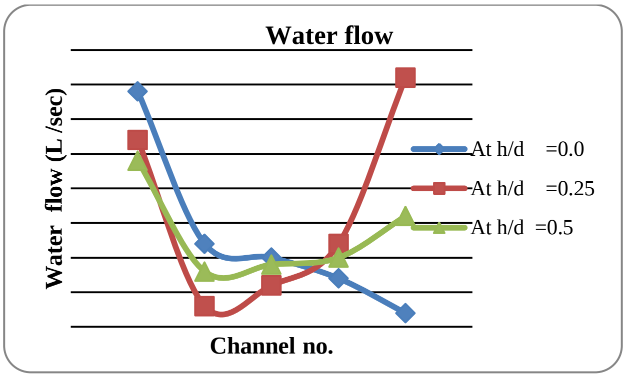

Figure 4.3.2: Water flow in different h/d and Reverse downward flow

Efficiency
Temperature at inlet =70 °C
Temperature at outlet =62.2°C
ή= (Temp. at inlet -Temp. at outlet) / Temperature at inlet
= (70-62.2)/70 =11.14%

4.4 Reverse downward flow

In reverse downward flow, the air and water are flow in the direction of downward and after that air and water are achieve in separator. Temperature at inlet is 80 °C., Temperature at outlet is 71.2°C.
Time taken during reading = 10 sec.
Temperature at inlet =80 °C.
Temperature at outlet =71.2°C
H=witch insert in pipe, D= 16mm diameter of pipe

Table 4.4.1 Air flow in different h/d and Reverse downward flow

Sr. No.	Channel no.	Air flow (m^3/sec) At h/d = 0/16 =0.0	Air flow (m^3/sec) At h/d = 4/16 =0.25	Air flow (m^3/sec) At h/d =8/16 =0.5
1	1-5	0.2	0.7	0.2
2	6-10	1.0	1.0	1.3
3	11-15	1.4	1.7	1.7
4	16-20	1.6	1.9	1.6
5	21-25	1.8	1.6	0.8

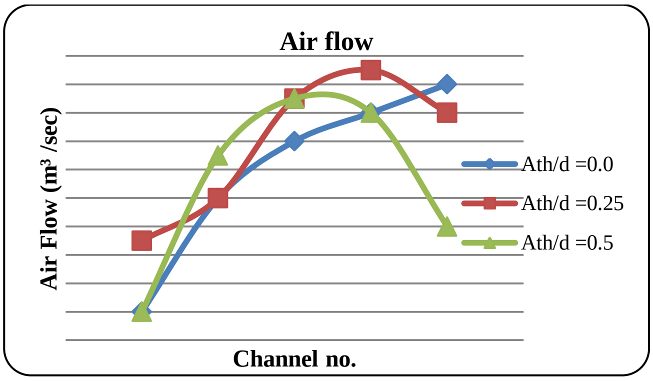

Figure 4.4:1 Air flow in different h/d and Reverse downward flow

Table 4.4.2 Water flow in different h/d and Reverse downward flow

Sr. No.	Channel no.	Water flow (L/ sec) At h/d = 0/16 =0.0	Water flow (L/ sec) At h/d = 4/16 =0.25	Water flow (L/ sec) At h/d = 8/16 =0.5
1	1-5	2.6	2.8	3.6
2	6-10	1.3	0.4	0.9
3	11-15	1.2	0.7	1.0
4	16-20	0.8	1.4	1.2
5	21-25	0.2	3.8	2.6

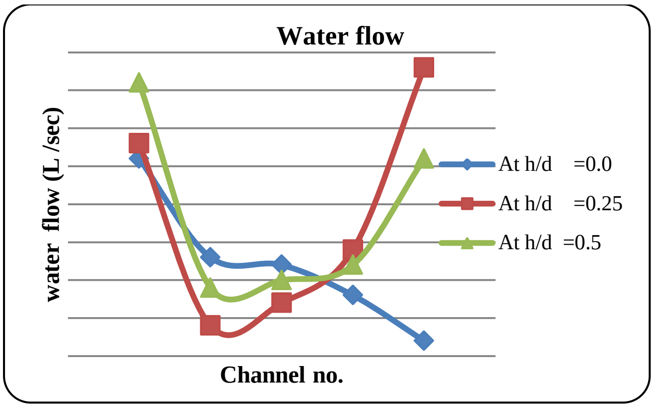

Figure 4.4.2: Water flow in different h/d and Reverse downward flow

Efficiency

Temperature at inlet =80 °C.
Temperature at outlet =71.2°C
ή= (Temperature at inlet - Temperature at outlet)/ Temperature at inlet
= (80-71.2)/80 =11.00%

5. Conclusion

1. In this study, the air and water flow distribution are experimentally studied for a heat exchanger composed of horizontal round headers and vertical 25 flat tubes. The effects of tube outlet direction, tube protrusion depth and quality are investigated.

2. The flow at the header inlet is annular. For the downward flow configuration, the water flow distribution is significantly affected by the tube protrusion depth. For flush-mounted configuration, most of the water flows through frontal part of the header. As the protrusion depth increases, more water is forced to the rear part of the header.

3. It is observed that the incoming water impinges at the protrusions, and the separated water reattaches at the rear part of the header. Using of Reverse downward flow we obtain maximum efficiency are 13.33% at Temperature at inlet =60 °C and Temperature at outlet =52°C.

References

A. Marchitto et.al. (2008)Experiments on two-phase flow distribution inside parallel channels of compact heat exchangers, *International Journal of Multiphase Flow*, 34 (2008) 128–144

Cho, H., Cho, K., Kim, Y.S (2003), Mass flow rate distribution and phase separation of R-22 in multi-microchannel tubes under adiabatic, New York, USA, pp. 1060–1065.

Fei, P., Cantrak, et.al (2002). Refrigerant Distribution in the inlet Header of Plate Evaporators, *SAE paper* 2002-01-0948,

Fossa, M. (2001) Gas–liquid distribution in the developing region of horizontal intermittent flows, *ASME J. Fluids Eng.* 123, 71–80.

Fossa, M., Guglielmini, G.(2002), Pressure drop and void fraction profiles during horizontal flow through thin and thick orifices,*J. Exp. Therm. Fluid Sci*, 26 (5), 513–523.

Hakan Demir et.al. (2009)Heat transfer of horizontal parallel pipe ground heat exchanger and experimental verification , *Applied Thermal Engineering* 29, 224–233

Hrnjak, P.(2004), Developing adiabatic two-phase flow in headers– distribution issue in parallel flow microchannel heat exchangers, *Heat Transfer Eng*, 25 (3), 61–68

Marlow E. Springer et .al.(1999) ,Entry region of louvered ®n heat exchangers, *Experimental Thermal and Fluid Science* 19, 223-23

Nae-Hyun Kim et. al.(2006) ,Two-phase flow distribution of air–water annular flow in a parallel flow heat exchanger,*International Journal of Multiphase Flow*,32, 1340–1353

Simin Wang et. al. (2010)Experimental investigation of header configuration on two-phase flow distribution in plate-fin heat exchanger ,*International Communications in Heat and Mass Transfer*,37, 116–120