A study on the homogeneous mixer applying helical structure for uniform flow distribution of vertical header with microchannel heat exchanger

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１．Researh Objective

Due to multiple branching microchannel tubes connected to a single header, non-uniform distribution occurs within the branching parallel flat tubes. This is referred to as the flow maldistribution. A consequence of this phenomenon is a poor heat transfer rate resulting from the dry-outs on some tube channels during evaporation or excessive liquid loading during condensation. The maldistribution is one of the interesting topics for the microchannel heat exchanger(MCHX). In this study, the homogeneous mixer is considered to achieve the uniform distribution for the vertical header, and its effects are investigated.

２．Major Research Results

2.1　The visualization of flow charateristics of helical structure of vertical header

To the goal, the operability of the test section in a range of conditions (R410A, 50 kg/h, 15 ℃) resembling the real functioning within actual plants is measured in terms of the main pressure drops, flow rate, and inlet vapor quality distributions at the front header, and qualitatively described with reference to the main influent phenomena, with reference to the video captured by means of direct visualization of the transparent window at the front header. The range of conditions targeted in the present work cover a partial loading characteristic range for the inlet mass flux, and inlet flow quality at 0.1 and 0.2 mainly.

Eventually, the data and observation gathered will be used to further redesign or integrate additional component in the test section particularly for the vertical header, to achieve a nearly ideal flow distribution.

Figures 1 show a snapshot of the visualization according to the experimental conditions. Due to the helical structured header's high height(490 mm), the entire two-phase flow cannot be visualized at once. Therefore, inevitably, images were taken for each branch section in the visualization unit located downstream of each branch channel. Also, due to the limitations of the three-dimensional helical structure, the front light source has to be applied, so there is a limit to the contrast of the captured visualization image.

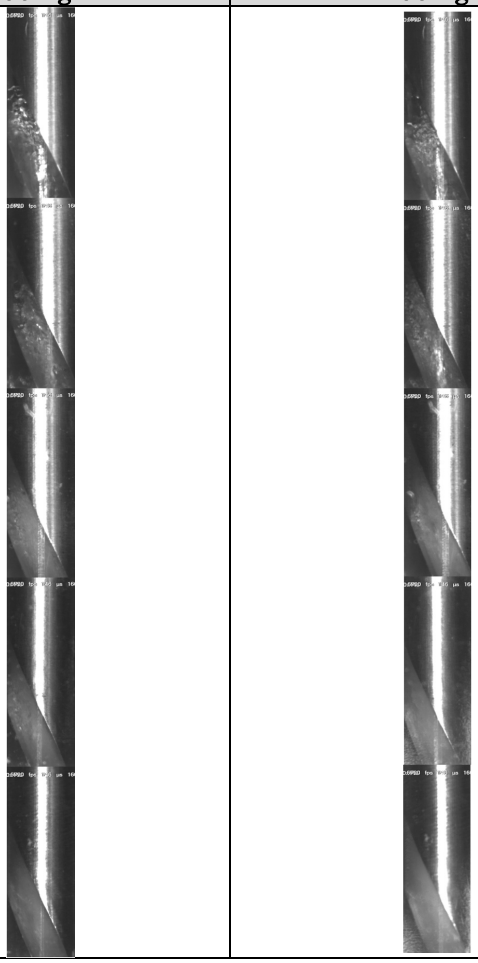
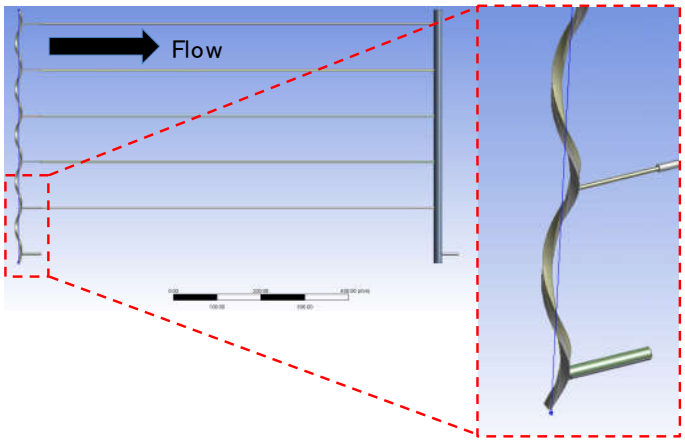
Tube Number	Same header outlet diameter set	
	X=0.1	X=0.2
	100 kg/h	100 kg/h
5		
4		
3		
2		
1		

Fig.1 Visualized flow of vertical header

2.2 CFD analysis of helical structure of vertical header

It is difficult to clarify the characteristics of the actual flow inside the header only with the visualization results. Therefore, in this study, CFD analysis was introduced to explain the flow characteristics inside the header.

The 3D model and boundary conditions for CFD are summarized in Figure 2.



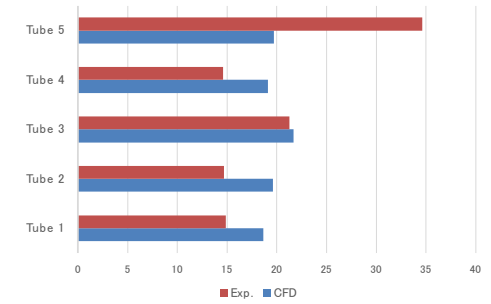
Material	R410a
Inlet	100 kg/(m²s)
Quality	0.2
Solver	Pressure-based
Time	Transient
Model	Multiphase(Volume of Fluid), Viscous(SST K-W)
Scheme	PISO, Geo-Reconstruct

Fig.2 CFD model and boundary conditions

It can be seen that the CFD results agree well with the experimental results, and it can be confirmed through Figure 3 that the gas and liquid phases are mixed due to the helical structure inside the vertical header at each tube position.

Mass flow rate: 100kg/h, Quality: 0.2

Tube No.	Experiment ···,···[kg/h]	CFD ···,···[kg/h]
5	34.63	19.72
4	14.58	19.11
3	21.28	21.68
2	14.66	19.59
1	14.86	18.63



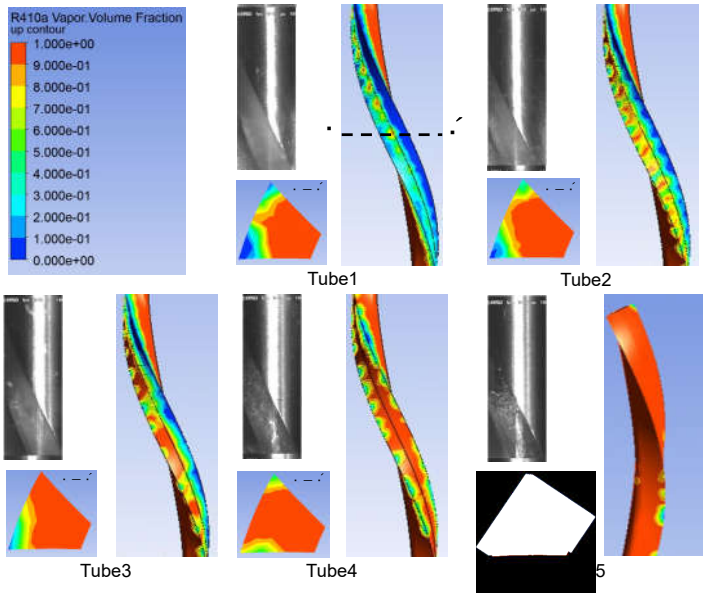


Fig.3　CFD result and comparison with experiment

In the case of the helical structured header, it can be considered that the helix structure inside the header shows a relatively uniform liquid flow ratio even when the inlet flow rate is increased, as observed above. Here we should pay attention to the physical meaning of the Dean number. Fluid flow in a Helix structure can be thought of as having a three-dimensional flow and as a superposition of a secondary flow (for the tube's cross-section) on a primary flow (flowing along a tube).

３．Collaborators

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４．Research Achivement

4.1　学術論文

Kim, M., Redo, M. A., Jeong, J., Saito, K., Lee, S., & Kim, H. (2022). Experimental Investigation of Two-Phase Flow Distribution with Different Vertical Header Configurations. *Energies*, *15*(21), 8320.

５．Issues and Prospect of Research Activities

There is a limit to the visualization analysis due to the characteristics of the helical structure having a three-dimensional structure, and there is a limit in that it is difficult to define the optimal point of the effect of helical mixing within the operating conditions of this

study. In the future, if the analysis according to the Reynolds number through the change of the structure of the header and the inlet condition is performed, it is expected that the vapor flow can also be evenly distributed.