2.2. General view of Microchannel Heat Exchangers

In recent years, a very important contribution on increasing the performance of the heat exchangers has taken place, sometimes to levels once inconceivable, obtained by using nano-technologies which have allowed the production of a new generation of compact heat exchangers with micro-channels. Micro-channel heat exchanger tube is one of these kinds of heat exchangers in which the working fluid flows through a plurality of passages with hydraulic diameter less than few mm (typically 0.2 to 0.01mm).

Recently Train et al (2012) too described micro-channel heat exchangers having the greatest advantage of providing a large heat exchange surface in a very small volume. Also, at very small sizes, the processes of heat and mass transfer occurring are very effective. These types of heat exchangers provide high heat transfer coefficients and thus they are more compact than the conventional ones.

Through recent study, the table below depicts the advantages and disadvantages of MCHX.

Table 2.1: Advantages and disadvantages of Microchannels

Features	Advantages	Disadvantages
Hydraulic diameter	0.01mm-0.2mm small diameter tubes leading to high heat transfer area per operational volume unit	High pressure losses due to small size; requires use of high pressure.

	High heat transfer coefficients	
	For same dimension, provide large heat transfer flux	
Cost	May become cost-effective along with the development of modern nano-technologies series production	High price resulting in limited use
Design	Machine tools involved lead to point by point processing; reduction of energy consumption and material	Limited knowledge involving engineering methods at this scale
		New methods of calculating heat transfer and pressure drop needed; papers show difference between the obtained results from macro-scale calculations.
Efficiency	More than the conventional fin tube evaporator heat exchangers	
Compactness	More compact if MCHX used as evaporator than conventional fin tube heat exchangers.	
Speed of air-flow in evaporators		It is very less as 0.5-1.5 m/s; requires large heat transfer area.
Channel structure in evaporators		Difficult as refrigerant at inlet of is two phase.

2.3. MCHX used in Laboratory

These heat exchangers, typically consists of plurality of micro-channel passages attached horizontally in between two headers which are placed vertically, and corrugated fin stacks interposed between the tubes. Generally, all of these members are made up of Aluminum.

Kim *et al.*, (2010) proposed a evaporator design which consists of two heat exchanging (HX) units. Both placed vertically adjacent to each other, and consisting of two headers each. Micro-channel tubes connect the two headers, and corrugated pins stack is placed between micro-channel tubes. Refrigerant flows from first bottom header to first top header through the micro-channel tubes. From First top header, refrigerant is carried to second top header via return tubes. Here accommodation for change of phase is taken care of. Then from second top header, refrigerant is carried to second bottom header via micro-channel tubes and then it is taken to outlet pipes. Based on the similar lines, the model at HPL has been developed.

2.4. Summary of Literature Review

Under this section, the literatures showed the basics of heat exchanger and highlighted the salient features of the MCHX used as evaporator, in the experiment done at HPL. The cross-flow Evaporator MCHX and the counter-flow condenser together constitute an integrated unit of room conditioning with added advantages. Heating water may accede to one of those advantages. Testing is going on and sand may be added in order to store the heat and transfer it from hotter body to the coolant.

3. CHAPTER 3
DESIGN PARAMETERS

3.1. Construction of MCHX

The micro-channel heat exchanger is used as an evaporator. There is a condenser unit nearby with a modified design as discussed further. There is also an inlet and outlet section for water flow. The refrigerant R22 charges and seals in the copper tubes. The plus point in this condensing unit is that the heat loss at condenser is directed to heat water, thus leading to water heating with expected temperatures of 70^{o}C.

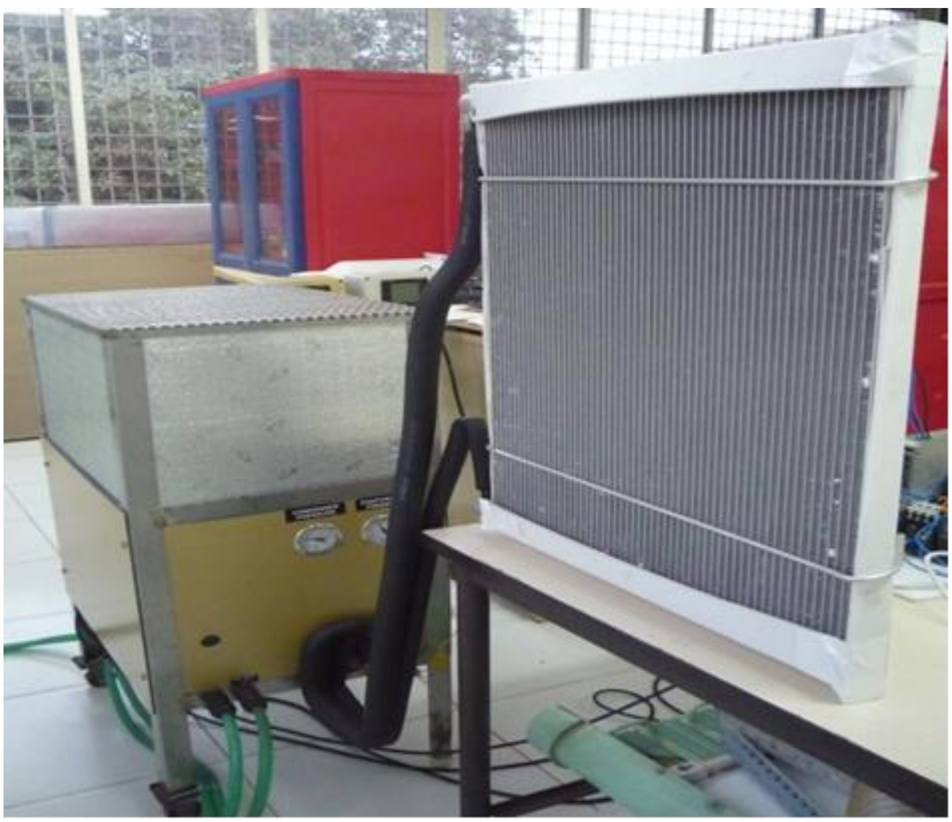


Fig.3.1: MCHX set up in HPL laboratory, IITB

3.2. MCHX Evaporator

The kind of evaporator used here is the Delphi MCHX Evaporator which is a specially designed evaporator capable of performing both cooling and heating functions. It can provide air at a desired temperature in either residential or commercial settings.

Benefits

- High efficiency
- Aluminum construction yields high durability and is easy to recycle
- Corrugated fins enhance turbulence that increases the heat transfer rate by increasing area of contact.

Fig.3.2: MCHX as evaporator

Typical Applications

The Evaporator is suitable for use in:

- Residential air conditioning/heating (indoor units)
- Commercial cooling/heating applications (rooftop units)

- Refrigeration applications, including retail food storage and bottle cooling
- Transportation (e.g., refrigerator trucks)
- Heating units

Performance Advantages

The MCHX Evaporator uses brazed aluminum construction and is based on the unique micro channel technology, which consists of three components: a flat micro channel tube, corrugated fins and two refrigerant manifolds joined together in a single coil. The design provides greater efficiency than traditional mechanical tube and fin heat exchanger designs.

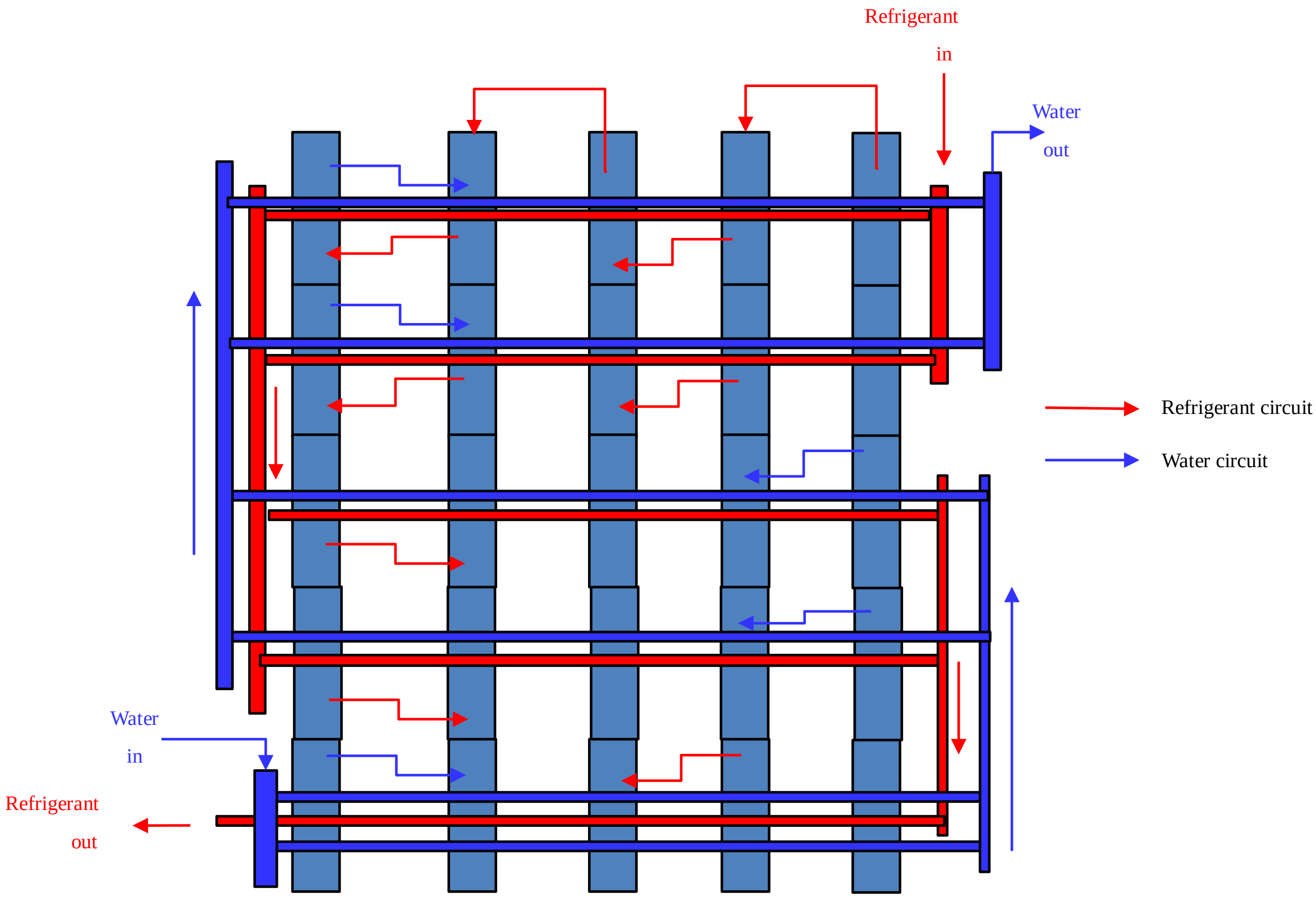
HPL lab at IIT Bombay has recently purchased one of such heat exchanger. It costs around 5000 INR and has about 9 fins per inch.

3.3. Condenser in MCHX Evaporator

There are Al Extrusions with 5 passages with 2 soft Cu tubes in each extrusion except the first one having 3 tubes. One per passage is used for refrigeration and one for water line. The one having 3 tubes has two water tubes including the middle one as refrigerant tube.

The condenser follows counter-current type heat exchanging i.e. 2 tubes of water and refrigerant enter the inlet but from opposite side while one tube of refrigerant (volume compensation) and two tubes of water exit but from the opposite sides. The upper tube contains water because the light refrigerant settles at bottom while the vapor refrigerant does at top; hence water is kept above. The tubes are placed in the 5th extrusion (central one) in each passage.

If no water is flowing or any medium to absorb heat from refrigerant is absent, then also the refrigerant must be able to distribute heat uniformly within the extrusion.



3.4. Experimentation and testing

The steps taken during testing are as follows:

(a). Firstly calibrate the thermocouples with the help of calorimeter.

(b). Now, start the apparatus.

(c). Note down the flow rate reading on the rotameter, power reading (of fan when compressor is cut off and total when its not) through Energymeter.

(d).Note down the condenser and evaporator pressure readings along with the thermocouple terminals readings.

(e).Note down the condenser pressure at compressor cut-off.

The testing is still going on to get the desirable outcomes. The first set of readings didn't give the expected results. Water is not getting heated up significantly. Furthermore, the Aluminium plates are getting hotter instead. The observations pertaining to the last testing done on 04.07.2014 has been shown as below.

- ***Readings taken during testing***
    - ✓ Date 04/07/2014
    - ✓ Room temperature 22 ^{o}C
    - ✓ Water flow rate 1.75 lpm
    - ✓ Condenser pressure at compressor cutoff 350 psi
    - ✓ Controller min. temperature 15 ^{o}C

Table 3.2: Readings obtained by testing of MCHX evaporator unit

		Reading	(Calibrated)		Reading1	(Calibrated)		Reading2	(Calibrated)		Reading3	(Calilbrated)	
T1 T5	Evaporator Inlet	27.8	46	26	23.1	41.3	16.1	21.6	39.8	31.6	23.4	41.6	20.9
T7 T1	Evaporator Outlet	27.8	27.6	24.9	27.5	27.3	24.7	27.8	27.6	24.5	27.9	27.7	24.4
T4 T3	Condensor Inlet	28	44.1	26.2	27.6	43.7	69.8	27.6	43.7	65.4	27.5	43.6	63.2
T2 T6	Condensor Outlet	29.7	28.4	26.3	35.4	34.1	44.5	40.9	39.6	48.3	42.8	41.5	48.7
T3													
T6													
T5 T2	Water In	28.8	28.7	29	30.4	29.7	28.9	32.1	31.4	28.7	32.8	32.1	28.4
T8 T4	Water Out	9	27.5	28.9	9.7	28.2	30.7	10	28.5	31.6	10.1	28.6	30.2
Energymeter Reading			0.972	0.101		1.51	1.46		1.625	1.48		1.672	1.5
Condensor Pressure			110	90		250	70		320	325		340	340
Evaporator Pressure			120	90		60	50		68	80		70	70

4. CHAPTER 4
CONCLUSIONS AND FUTURE WORK

4.1. Conclusions

The results obtained are closer to the expected values but not fully accurate. Considering this to be the first testing ever done, the readings have been encouraging. The points so figured out conjure for better modifications. These modifications may be:

(i). To first double-check the flow of the condenser heat exchange as the water isn't heating up as expected and Aluminium plates are getting hotter instead. Hence the counter-flow arrangement should be well ensured of as it will comply with the best results to be attained. As already mentioned, this arrangement gives the best heat transfer rate as compared to parallel flow or cross-flow.

(ii). If the setup works satisfactorily, then matrix materials like sand (having high thermal conductivity of 0.06 kg/mK and large grit size of 3mm) must be introduced so as to serve the purpose of heat storage.

(iii). Meanwhile it must also ensure to minimise the problems involved because of MCHX as an evaporator. These issues have been discussed in the table. To resolve these issues, the low flow of air as 0.5-1.5 m/s in evaporator must be levelled with large heat transfer area.

4.2. Recommendations for future work

As nanotechnology is slowly mushrooming up, use of microchannels heat exchangers will foresee more innovative and techno-savvy creations. As concluded, they are better replacement for conventional fin-tube MCHX evaporators.

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