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Influence of Ionic Fluid in Parallel flow in Shell and Tube Heat Exchanger

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Abstract*— Applications of heat transfer fluid are very essentials now a days to acquire wide range of application in Heat transfer Industries. Ionanofluids are a new and innovative class of heat transfer fluids which exhibit fascinating thermo physical properties compared to their base ionic liquids. This parallel flow work deals with the experimental investigation of thermal conductivity and specific heat capacity of ionanofluids as a function of a temperature and concentration of (1-Butyl-3-methylimidazolium chloride) (BmimCL) . Also, The BmimCL used as coolants in heat exchanger. The estimation of heat transfer areas for ionanofluids and ionic liquids in a model shell and tube heat exchanger reveal that ionanofluids possess superior thermal conductivity and heat capacity and require considerably less heat transfer areas as compared to those of their base ionic liquids. This paper deals with enhancement of more heat transfer through heat exchanger by using ionic fluid (BmimCL) in parallel flow as compared to only pure water.

***Keywords*—Ionic Liquid(BmimCL), Pure water(Distilled), Shell and tube heat exchanger, Arrangement of parallel flow.**

I. INTRODUCTION

It is possible to obtain ionic liquids with a variety of physical and chemical properties for specific applications. They have several unique properties such as wide electrochemical potential window for electrochemical processing, high chemical and thermal stability, very low vapour pressure, non-inflammability, high ionic conductivity high solvating capability, and very low corrosivity. The fluids that are traditionally used for heat transfer applications such as water, mineral oils and ethylene glycol have a rather low thermal conductivity and do not meet the growing demand as an efficient heat transfer agent. There is a need to develop new types of fluids that will be more effective in terms of heat exchange performance. 1-Butyl-3-methylimidazolium chloride is new kind of heat transfer fluids. These 1-Butyl-3-methylimidazolium chlorides appear to have a very high thermal conductivity and may be able to meet the rising demand as an efficient heat transfer agent. In the past decades, extensive research efforts have been devoted to ionic liquids which have proven to be safe and sustainable alternatives for many applications in industry and chemical manufacturing. The reality is that ionic liquids can be liquid at temperatures as low as -96 ^{0}C and some are liquid at over 400 ^{0}C. Furthermore, room temperature ionic liquids (RTILs) are frequently colorless fluid and easy to handle.

II. LITERATURE REVIEW

A. Shell and Tube Heat exchanger added in 1-butyl-3-mythylimidazolium chloride (BmimCl)

Thermal performance of heat Transfer devices can be improved by heat transfer enhancement technique. The ionic fluid mixing technique with different geometrical configurations have been used as one of the passive heat transfer enhancement techniques .Many researcher works on the heat transfer enhancement technique and having some passive result too. Author A.P.C. Ribeiro, et.al. [1] “Thermal Properties of Ionic Liquids and Ionanofluids” gives the important property of ionic liquid thermal conductivity and heat capacity of several ionic liquids and multi-walled nanotubes (MWCNTs)-ionanofluids as a function of temperature are presented and analyzed 1-butyl-3-methylimidazolium chloride [BmimCl] Shad pour Mallakpour et.al.[2] under the title Ionic Liquids as Environmentally Friendly Solvents in Macromolecules Chemistry and Technology with the increasing emphasis on the environment .Author Urszula Doman’ska [3] studied the Solubility’s and thermo physical properties of ionic liquids specially1-butyl-3-methylimidazolium chloride [BmimCl] studied its various property such as its solubility and thermo physical property ILs can be considered, in the majority of cases, as polar phases with their solvent properties being mainly determined by the ability of the salt to act as a hydrogen-bond donor and acceptor and the degree of localization of the charges on the anions. Author David B. Go et.al. [4] under the title of “Enhancement of external forced convection by ionic wind thus in this experiment author used ionic wind so instead of that fluid and in present experiment we used the ionic fluid as substitute and performed experiment an

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ionic wind is formed when air ions are accelerated by an electric field and exchange momentum with neutral air molecules, causing air flow. attar Al-Jabair [5] "Experimental study of thermal performance and heat transfer coefficients shell and helically coiled tube heat exchangers", HT2012-58004,Paisarn Naphon, et.al. [6] they work on the project of the "Heat transfer enhancement and pressure drop of the horizontal concentric tube with twisted wires brush inserts" according to their view In the present study, the heat transfer characteristics and the pressure drop of the horizontal concentric tube with twisted wires brush inserts are investigated.

B. 1-butyl-3-mythylimidazolium chloride (BmimCl) and Their Properties

Table I Properties of Ionic fluid

Characteristic	**Range**
Molar Mass	174.67 kg/k mole
Labeling Toxicity	Less toxic
Melting point	At room temp ^{0}C
Viscosity at 80 ^{0}C	146.8 MPa
Concentration	98% pure
Density at 80 ^{0}C	1.0528 g/cm^3
Electric conductivity	25 ^{0}C µ sec/cm at 25 ^{0}C
Heat conductivity at 60 ^{0}C	0.17 W/m K
Heat capacity at 80 ^{0} C	1.81 J/g K
Flash point	192 ^{0}C

C. Evaluation of the mean temperature difference in a heat exchanger: Logarithmic mean temperature difference (LMTD)

To design or predict the performance of a heat exchanger, it is essential to determine the heat lost to the surrounding for the analyzed configuration. We can define a parameter to quantify the percentage of losses or gains. Such parameter may readily be obtained by applying overall energy balances for hot and cold fluids.

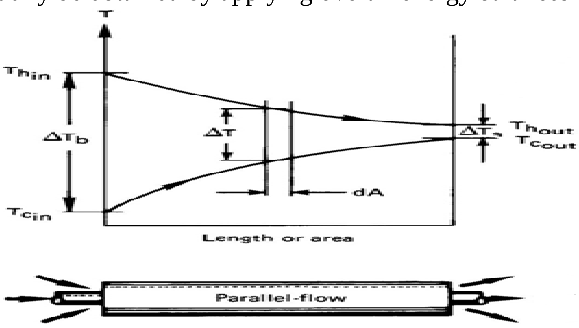

Fig. 1 The Temperature veriation through single passd heat exchanger [7]

III. EXPERIMENTAL SETUP

Table II Specification of Test Rig Shell & Tube Heat Exchanger

Shell & Tube Heat Exchanger	
Manufacturing Details	Technical Teaching (D) Equipment, Bangalore
Inner Diameter of the pipe	15mm
Outer Diameter of the tube	16mm
Length of condenser	750mm
Number Of Tubes	24
Number of Passes	2

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Shell Diameter	0.5m
Material used	Cast iron
Rota meter	45cc/sec(maximum limit)

A. Experimental apparatus and Method

The most usually found in industrial applications: Tubular, Plate and Shell & Tube heat exchangers) and to understand the factors and parameters affecting the heat transfer rates. The goal of this experiment for co-current

- **a)** The heat lost to the surroundings.
- **b)** The overall efficiency.
- **c)** The temperature efficiency for the hot and cold fluids.
- **d)** The overall heat transfer coefficient U determined experimentally.
- **e)** The overall heat transfer coefficient U determined theoretically. Compare with the experimental one.

A schematic diagram of the experimental apparatus is shown in Figure 3.1 and Figure 3.2; it consists of a test section, hot water loop, and coldwater loop and data acquisition system. The test section is the horizontal concentric tube heat exchanger as shown in Figure 3.2 the test section and the connections of the piping system are designed such that parts can be changed or repaired easily.

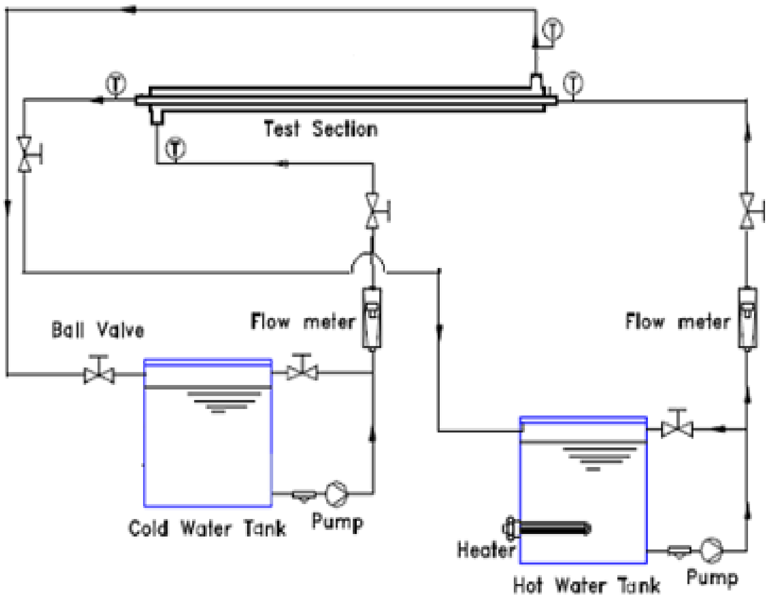

Fig.2: Schematic diagrams of experimental apparatus

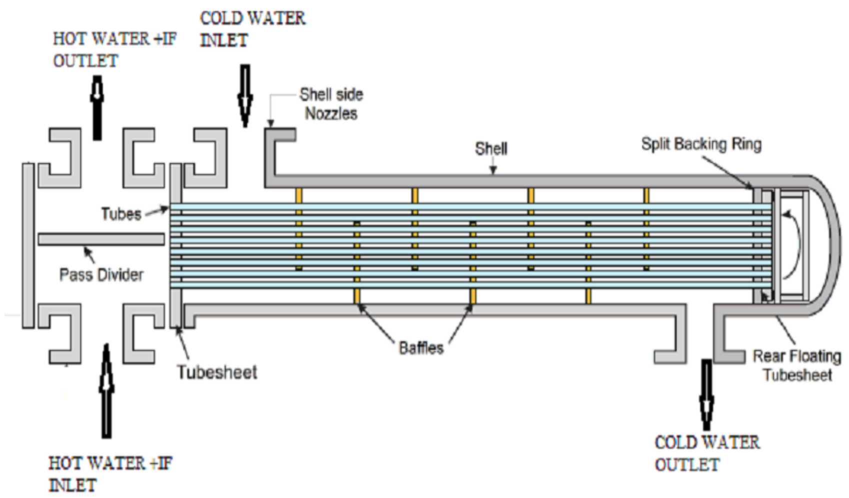

Fig.3: Cross section of shell and tube heat exchanger [7]

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Table III Observation table for parallel flow pure tap water (flow rate – 25 cc/sec)

SR.NO.	TIME(min)	Th1	Th2	Tc1	Tc2	ΔT_1	ΔT_2	LMTD
1.	0	60.3	39.2	37.6	25.3	35.0	1.6	17.94
2.	5	60.5	38.9	37.5	25.3	35.2	1.4	17.89
3.	10	60.6	39.0	37.6	25.8	34.8	1.4	17.58
4.	15	60.3	39.0	37.6	25.6	34.7	1.2	17.64

SR.NO.	TIME(min)	Th1	Th2	Tc1	Tc2	ΔT_1	ΔT_2	LMTD
1.	0	60.1	38.6	35.1	24.7	35.4	2.5	18.91
2.	5	60.3	39.1	36.9	24.6	35.7	2.2	18.59
3.	10	60.3	39.2	37.9	24.8	35.5	2.1	18.11
4.	15	60.3	39.4	37.2	24.9	35.4	2.2	18.47

Table IV: Observation table for parallel flow pure tap water (flow rate – 35 cc/sec)

SR.NO	TIME	Th1	Th2	Tc1	Tc2	ΔT_1	ΔT_2	LMTD
1.	0	60.3	38.8	37.1	22.7	37.6	1.7	19.43
2.	5	60.7	38.7	37.1	22.6	38.1	1.1	19.61
3.	10	60.4	37.3	36.9	22.9	37.5	1.0	18.58
4.	15	60.5	38.1	37.0	23.0	37.5	1.1	18.99

Table V : Observation table for parallel flow pure tap water + ionic solution 1gm (flow rate – 25 cc/sec)

SR.NO	TIME	Th1	Th2	Tc1	Tc2	ΔT_1	ΔT_2	LMTD
1.	0	60.7	37.2	34.2	22.6	38.1	1.9	19.96
2.	5	60.5	37.7	34.7	23.3	37.2	2.0	19.55
3.	10	60.3	38.3	34.9	22.9	37.4	2.4	19.98
4.	15	60.4	39.0	35.7	22.7	37.7	2.3	20.21

Table VI: Observation table for parallel flow pure tap water + ionic solution 1gm (flow rate – 35 cc/sec
Table VII Observation table for parallel flow pure tap water + ionic solution 2gm (flow rate – 25 cc/sec)

SR.NO	TIME	Th1	Th2	Tc1	Tc2	ΔT_1	ΔT_2	LMTD
1.	0	60.3	38.8	37.1	22.7	37.6	1.6	19.43
2.	5	60.9	38.9	37.1	22.6	38.5	1.8	19.81
3.	10	60.5	37.5	36.9	22.9	38.5	1.4	18.74
4.	15	60.5	38.1	37.0	23.0	37.5	1.2	18.99

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SR.NO	TIME	Th1	Th2	Tc1	Tc2	ΔT_1	ΔT_2	LMTD
1.	0	60.3	37.2	34.2	22.6	38.1	1.9	19.80
2.	5	60.5	37.7	34.7	22.5	37.2	2.0	20.03
3.	10	60.4	38.3	34.9	22.5	37.4	2.4	20.26
4.	15	60.6	39.0	35.7	23.0	37.7	2.7	20.12

Table VIII Observation table for parallel flow pure tap water + ionic solution 2gm (flow rate – 35 cc/sec

Where,

Th1 – Temperature of hot side inlet. ^{0}C
Th2 – Temperature of hot side exit. ^{0}C

Tc1 – Temperature of cold side inlet. ^{0}C
Tc2 – Temperature of cold side exit. ^{0}C
ΔT_1 - (Th1 - Tc2) Temperature difference between hot and cold fluid ^{0}C
ΔT_2–(Th2 - Tc1) Temperature difference between hot and cold fluid ^{0}C
LMTD – Logarithmic mean temperature difference. ^{0}C

IV. CALCULATION

Following calculation are the sample calculations, from above table chose value for finding out LMTD, overall heat transfer coefficient (U) in the time duration five minutes.

Logarithmic Mean Temperature Difference ΔT_{LMTD} in ^{0}C

$$\Delta T_{LMTD} = \frac{\Delta T_1 - \Delta T_2}{\ln\left[\frac{\Delta T_1}{\Delta T_2}\right]} \qquad (1)$$

Parallel Flow (Pure Tap water) for 1gm flow rate 25cc/sec

a) $\Delta T_1 = T_{h1} - T_{c2}$ ^{o}C (2)
b) $\Delta T_2 = T_{h2} - T_{C1}$ ^{o}C (3)
$\Delta T_1 = 60.3 - 37.6 = 22.7$ ^{0}C
$\Delta T2 = 39.2 - 25.3 = 13.9$ ^{0}C
$\Delta T_{LMTD} = 22.7 - 13.9 / \ln(22.7/13.9)$
$= 17.94$
Avg. LMTD = (17.94+17.89+17.58+17.64)/ (4) =17.76 ^{0}C
$Q = m^* Cp^* \Delta Tc$ (4)
$= 25 *10^{-3} *4.18* 12.07$
$= 1.2618$ KW
U = Q / A* LMTD (5)
Where,
A= Cross sectional area m^2
= 0.4508 m^2
$U = 1.2618 *10^3 / 0.4508 * 17.94$
= 156.02 W/ m^2 K

Parallel Flow (Pure Tap water + ionic solution) for 1gm flow rate 25cc/sec

a) $\Delta T_1 = T_{h1} - T_{c2}$ ^{o}C
b) $\Delta T_2 = T_{h2} - T_{C1}$ ^{o}C
$\Delta T_1 = 60.36 - 37.1 = 23.2$ ^{0}C

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$\Delta T2$ = 38.8 – 22.7 = 16.1 ^{0}C

ΔT_{LMTD} = 23.2 – 16.1 / ln (23.2/16.1)

= 19.43 ^{0}C

Avg. LMTD = (19.43+19.61+18.58+18.99)/4= 19.15 ^{0}C

Q = m* Cp* ΔTc

= 25 *10^{-3} *4.18* 14.23

= 1.4870 KW

U = Q / A* LMTD

Where,

A= Cross sectional area m^2

= 0.4508 m^2

U = 1.1808*10^3 / 0.4508 * 19.43

= 169.76 W/ m^2 K

Average Maximum LMTD for pure water parallel flow =18.52 ^{0}c

Average Maximum LMTD for 2gm ionic fluid for parallel flow=20.05^{0}c

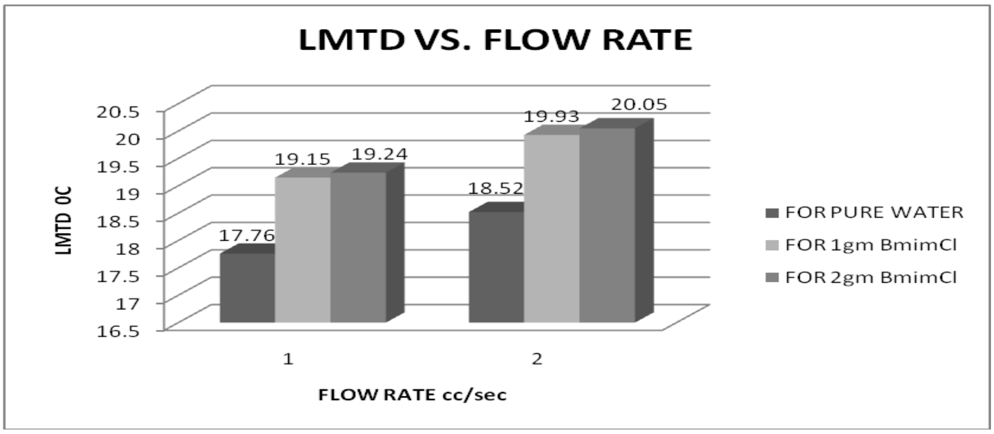
Therefore,

% Rise in LMTD for pure water parallel flow with respective ionic fluid parallel flow

= (20.05-18.52) *100/ 20.05 = 7.63%

Table IX: Comparison between flow rate & LMTD

SR.NO	FLOW RATE (cc/sec)	LMTD FOR PARALLEL FLOW(^{0}C)		
		FOR PURE WATER	FOR 1gm BmimCl	FOR 2gm BmimCl
1.	25	17.76	19.15	19.24
2.	35	18.52	19.93	20.05



Graph I

V. CONCLUSION

The heat transfer characteristics of the ionic fluid (1-Butyl 3-Methyl imidazolium chloride) presented. Thus working fluids other than water can also introduced great change while used in shell & tube heat exchanger. Clearly ionic liquids remain relatively costly compared with conventional organic solvents or water, but this must be set against the fact that they are generally used in much smaller quantities, and are likely to be reused in most applications. Use of (BmimCl) as a clean fluid has a significant effect on the enhancement of heat transfer. The experiment were quite satisfying for the output in terms of

% Rise in LMTD for pure water parallel flow with respective ionic fluid parallel flow7.63%.

An overview of few important aspects of ionanofluids together with experimental findings on their thermal conductivity and heat capacity are presented in this paper. Results showed that ionanofluids exhibit superior thermo physical properties compared to base ionic liquids. Thus it is conclude that ionic fluid (1-Butyl 3-Methyl imidazolium chloride) is very promising alternative fluid to increase the heat transfer rate especially shell & tube heat exchanger.

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