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Heat transfer Characteristic of Deep Eutectic Solvent

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1. Introduction

DES has been proposed as an alternative to ionic liquids. DES has the same overall solvent properties as IL. It has the same basic characteristics but overcomes the disadvantages of IL. DES is cheaper, easier to synthesize, less toxic and biodegradable than IL.

Prior to DES, IL was studied as a heat transfer fluid because of its stable nature in the heat. There is still little research on DES as a heat transfer liquid. IL has been studied in recent years to replace existing heat transfer fluids. Compared to conventional heat transfer fluids, IL has a wide temperature range, high heat capacity, high density, high thermal chemical stability, and low vapor pressure.

Conventional heat transfer liquids include silicon oil and diphenyloxide / biphenyl. This liquid has several disadvantages. Such as low density, high vapor pressure, low chemical stability, and low decomposition temperature. IL has been proposed and studied as a fluid to overcome these drawbacks. For example, it is reported that the sensible heat transfer of the ionic liquid is 2 to 3 times higher than the minimum heat transfer requirement. Another study on the heat transfer performance of 1-hexyl-3-methylimidazolium tetrafluoroborate in microfibers has shown that the initial decomposition is at 440.6 ° C which is the lowest decomposition temperature of silicon oil and diphenyloxide / biphenyl [1].

Therefore, the goal of this study is to measure heat transfer coefficient of DES as a heat transfer fluid.

2. Methods and Results

2.1 Preparation of DES

The salt-working ChCl and the glycerol acting as HBD are placed in a round-bottomed flask at a 1: 2 molar ratio. Set the temperature at 348.15K on the hotplate and stir at 600mRPM for 2 hours [2].

2.2 Experimental Setup

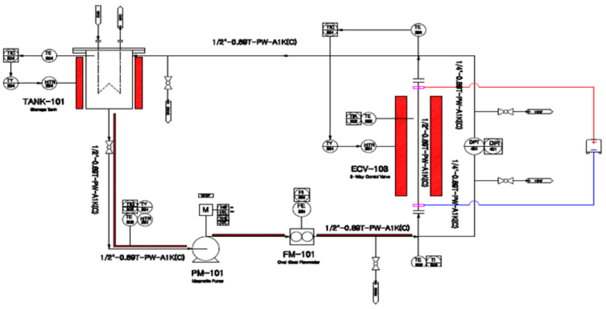

Fig. 1. Layout of the forced convective thermal loop

The above schematic shows the configuration of the experimental device. The experimental setup consists of tank and pump flow meter test section, DC power supplier, differential pressure gauge and control panel.

In the test section, a tube of stainless steel contains heater installed outside along its length of 0.5 m with inner diameter of 10.92 mm whereas outer diameter is 14.92 mm.

Besides that, the total length of the entry pipe line is approximately 0.9m which ensures turbulent flow condition in Newtonian flow at the entry of the section test. However, in non-newtonian fluid condition, it is not enough to ensure turbulent flow. At the test section, 1.0 HP pump is connected to collecting tank of 0.045m^3 capacity.

The function of this pump is to circulate the working fluid through test section. Test section is wrapped with ceramic insulation and two copper heaters; each with 814W rating.

On the other hands, the digital flow meter is connected between the pump and the inlet of the test section for measuring the flow rates. The digital flow meter can measure the flow rate in liter per minute (LPM) up to 30 LPM.

A chiller with capacity of 1.4 kW and a collecting tank each mounted on both ends of the test section.

At surface of the test section, five K-type thermocouples were installed. Two of them were installed with position at tank, line. The other three of the thermocouples was installed at the inlet and outlet of the test section to measure the temperature of working fluid.

Power supply of 814W will be set constantly to supply heat during the experiment. In the meanwhile, the chiller will be adjusted to obtain fluid bulk temperature of 60℃ .

Indirect heating can be done according to the outlet temperature setting in the test section, and direct heating can also be performed using the DC power supplier. In the case of indirect heating, the temperature of the solution in the test section is heated to the temperature to be tested. The heat transfer coefficient can be determined from the measured temperature difference and the given calorific value through direct heating using a DC power supplier.

2.3 Hydraulic Experiment

The differential pressure was measured at each temperature while increasing the flow rate. It was confirmed that the differential pressure value increases with increasing the flow rate.

Also, it was confirmed that the lower the temperature of the same Reynolds number, the larger the differential pressure value.

The rate of change of differential pressure according to Reynolds number increased with lower temperature.

When the performance factor of the differential pressure gauge and the pump is reflected, only the experimental value in the Larminar section can be obtained. Turbulent sections can also be measured if the performance of the pump and differential pressure gauge is further improved.

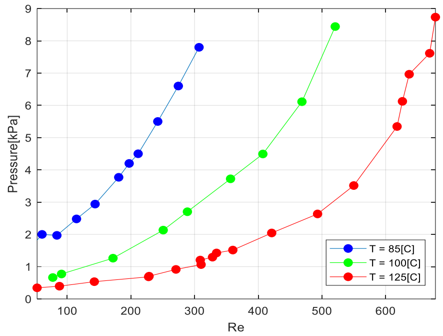

Fig. 2. Pressure drop

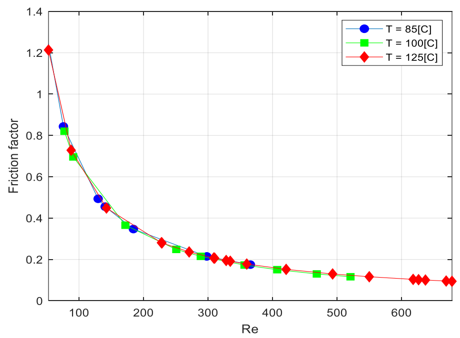

Fig.3. Friction factor in log scale

$$\Delta P = \frac{1}{2} f \frac{L}{D} \rho v^2 + \rho g H$$

$$f_{laminar} = \frac{64}{Re}$$

The differential pressure value according to the flow velocity can be expressed as a friction coefficient value according to the Reynolds number.

When comparing the differential pressure values according to the Reynolds number, there was a noticeable difference in the differential pressure value and the rate of change depending on the fluid temperature. The lower the temperature, the larger the differential pressure value and the greater the rate of change.

However, no significant difference was found when comparing the friction coefficient values according to Reynolds number.

2.4 Forced convective heat transfer coefficient calculation, h

When the heat transfer coefficient was measured while lowering the flow rate, the value of the heat transfer coefficient according to the Reynolds number gradually increased.

Nusstle number was used to calculate the error for the heat transfer coefficient. The Nusstle number reflecting the heat transfer coefficient obtained from the experimental data was regarded as the experimental value and the Nusstle number value obtained through the Mill's correlation equation was regarded as the theoretical value.

In this case, it is confirmed that the error value is within 20% in the range of Reynolds number 600 or less, which is the measured range.

$$\mathrm{h}[\mathrm{W}/m^2\mathrm{k}] = \frac{Q}{T_S - T_{i/o}}$$

$$\mathrm{Nu}_{ex} = \frac{hD}{k}$$

$$Nu_{cal} = 3.66 + \frac{0.065RePr\frac{D}{L}}{0.004(RePr\frac{D}{L})^{2/3}}$$

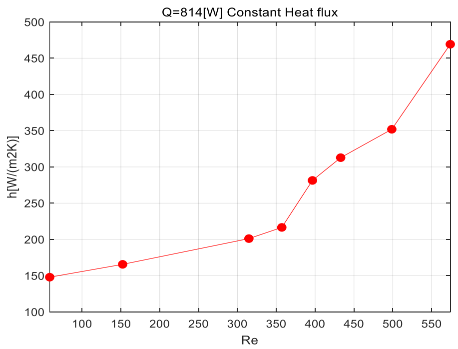

Fig.4. Heat transfer coefficient

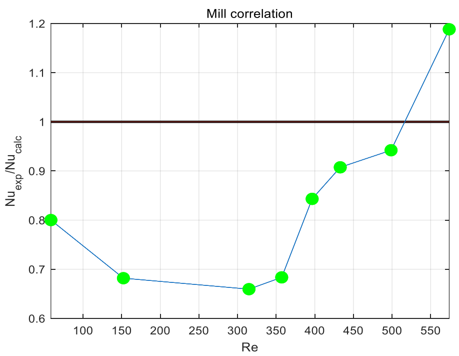

Fig.5. Error measured by Nu

3. Conclusions

In order to express the heat transfer characteristics of a new kind of fluid called DES, it is necessary to design an appropriate system. To design the system, the physicochemical properties of the liquid should be monitored as the temperature changes. As a result, density and viscosity were lowered as the temperature increased, like other ordinary liquids.

The temperature range for the heat transfer experiment of the fluid was set, and the range of density and viscosity was determined through experiments and papers. Based on this, the minimum maximum velocity of the fluid can be deduced. The flow rate of the fluid is essential information for designing the pump in the heat transfer experiment device.

Through the designed system, it was possible to numerically measure the hydraulic characteristics and the heat transfer characteristics of the liquid.

In the experiment, DES was decomposed and error value occurred. Therefore, it is better to refill the solution or lower the heating rate [3].

If the performance of the pump and differential pressure gauge is improved, it is possible to study turbulent flow. Future work will study the heat transfer characteristics for turbulent and compare it with other conventional HTFs currently in use.

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