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DIRECT THERMAL MANAGEMENT FOR LITHIUM ION BATTERIES

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1. ABSTRACT

Fast charging of Lithium Ion Batteries in Electric Vehicles is important to reduce 'range anxiety' among motorists. However, fast charging generates considerable heat, which must be removed to avoid battery degradation at high temperatures. Direct thermal management, where the cells are in contact with a dielectric liquid to cool them, offers the potential for more efficient heat transfer. However, these fluids generally have less favourable physical properties compared to water. We present some a new experimental flow system to quantify the heat transfer performance of dielectric fluids and as part of a project to identify strategies for improvement.

2. INTRODUCTION

Electric vehicles (EVs) are important for the decarbonisation of road transport and use batteries, typically Lithium Ion Batteries (LIBs) to store energy. LIBs are best operated between about 10 and 45°C. At higher temperatures degradation of the cells occurs, leading to lower cell capacity and hence reduced vehicle range [1]. Very high temperatures can lead to thermal runaway and fire. Fast charging is highly desirable for motorists to shorten refuelling times. However, fast charging leads to high rates of ohmic heat generation, which can cause battery temperatures to rise above the optimum range [1]. LIBs are therefore cooled to avoid degradation to the cells. Today, most commercial EVs use water-glycol based coolants, which must be kept physically separate from the electrochemical cells to avoid short circuits. Direct thermal management of cells uses a dielectric fluid as the coolant, in contact with the cells and electrical terminals [1]. This offers a number of advantages in heat transfer efficacy and energy density of the battery pack, however, the thermal properties of these fluids are generally less favourable.

Here, we present a new experimental arrangement and some preliminary heat transfer results we have taken, and compare them to literature as we look towards strategies for heat transfer improvement.

3. METHODOLOGY

Two custom experimental rigs have been constructed to examine the heat transfer performance. The first, 'rig 1', uses hot water as the heating utility and is shown in figure 1. The flowrate of hot water is considerably higher

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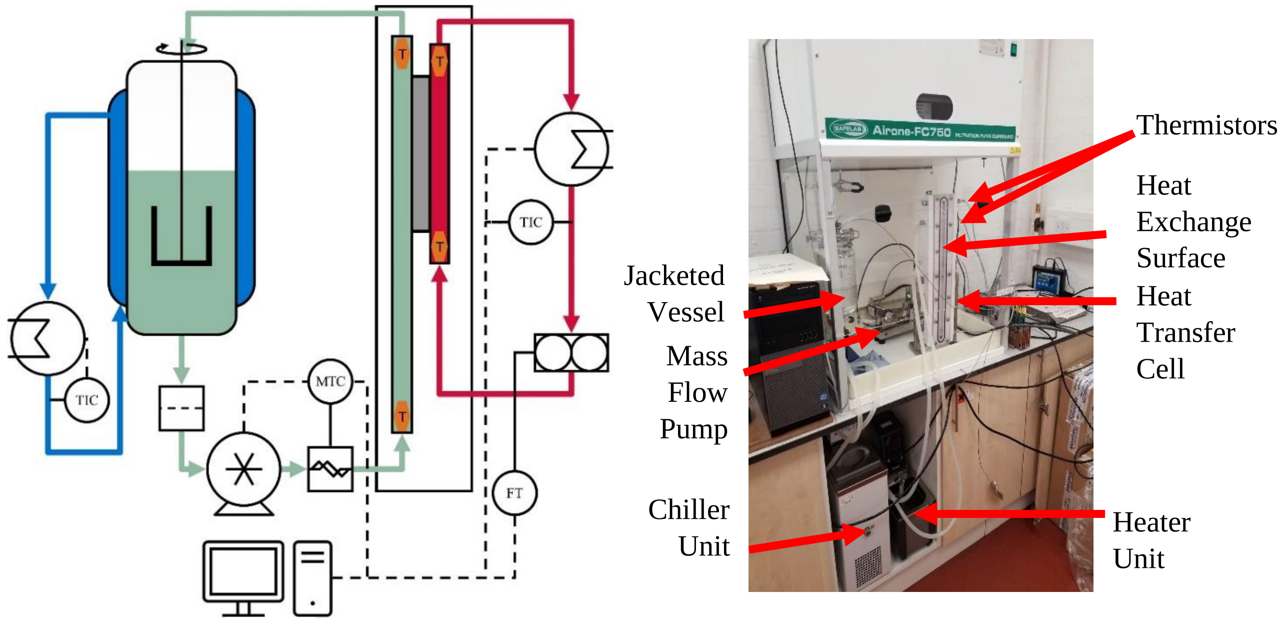
than that of the thermal management fluid (the process fluid) such that the wall temperature is approximately constant. Both flows are through a rectangular cross sectional duct. An aluminium plate between the hot and cold streams is the heat transfer surface and can be easily exchanged so that textured surfaced can be investigated on the cold side. The depth of flow on the process side can also be changed by the use of inserts to 1, 2 or 3 mm. The utility and process fluid channels are both 12 mm wide and the heat transfer plate length exposed to the fluid flow is 150 mm. The flow rate is set by use of a gear pump and Coriolis mass flow meter unit. Hence, a range of Reynolds numbers and hydraulic diameters can be investigated.



(a) (b)

Figure 1: (a) a schematic of rig 1. Cooling water to jacketed vessel in blue, thermal management fluid in green, hot utility in red and heat transfer plate in grey. Thermistors are shown as orange hexagons. (b) Photograph of rig 1.

The process side film heat transfer coefficient is isolated by using a utility side heat transfer coefficient from a CFD simulation carried out by a co-worker.

Rig 2 uses electrical heating to provide a constant flux boundary condition, similar to the boundary provided by pouch or prismatic cells in a battery pack. Additionally, heating is provided in a parallel plate configuration, as shown in figure 2.

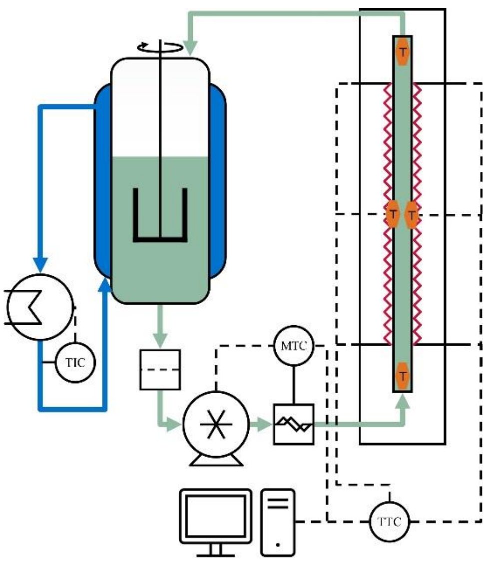


Figure 2: A schematic of rig 2. The Temperature Transmitter Controller, TTC, can operate in a temperature controlling or heat flux controlling mode.

4. RESULTS

Preliminary results for the use of water as a benchmark fluid in rig 1 are presented here. Literature data for the same geometry are hard to find, but Lyczkowski *et al.* [2] presented computational work for the same geometry but using gases and presented results as local Nusselt number, Nu, against reciprocal of the Graetz number, Gz. Their results have been presented here as the length averaged Nusselt number, figure 3. Our data, also shown in figure 3, may show convergence to the expected fully developed Nusselt result of 4.79 [3], but we do not have sufficient range of Gz to be certain yet. As expected at higher Gz, Nu is higher, but our data deviates from the fully developed result at lower Gz. This may be due Lyczkowski *et al.* modelling gases and our experiments using liquids. We aim to investigate a wider range of Graetz numbers and aspect ratios to test this hyopthesis.

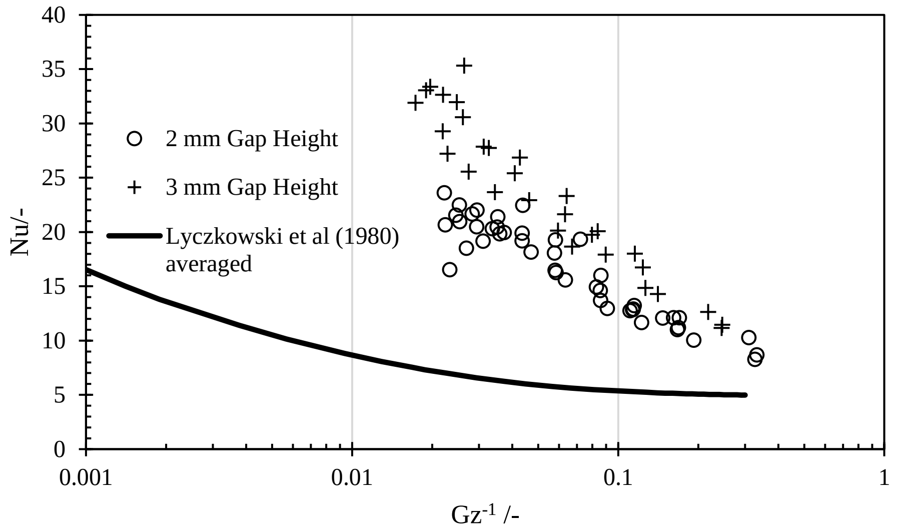


Figure 3: The measured Nusselt numbers plotted against the inverse Graetz number based on the length of the heat transfer plate for a 2 mm and 3 mm gap height. Comparison with the literature is shown.

5. CONCLUSIONS

Improving direct liquid thermal management fluids offers the potential to increase charging rates and decrease LIB degradation during charging and discharging. Initial results from custom built rigs show behaviour qualitatively similar to that expected. We aim to investigate the use of surface texture, roughness and flow patterns to optimise heat transfer.

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