Project ----Thermal Management of Li-ion Battery Pack

Efficient utilization of solar or wind energy is essential for reducing the global carbon dioxide emission and overcoming the depletion of fossil energy. Nevertheless, the solar or wind energy suffer from a significant drawback of intermittent power supply when the photovoltaic (PV) panel or wind turbine are used. Under these circumstances, electrical energy storage devices become indispensable for constructing zero carbon industrial zones. Li-ion battery pack is a relatively mature technique to store renewable electricity, and it has already been widely used in both vehicles or power station. Even though Li-ion battery pack has the advantage of high power and energy density, it still requires advanced cooling technologies to guarantee its operating temperature under safe range for avoiding self-heating ignition.

The water liquid flow with channels is a commonly used method to cool down Li-ion battery pack. In addition, phase change materials (PCMs) are also usually applied for thermal modulation of energy devices owing to its nearly constant temperature during solid-liquid phase change process. In this project, the water liquid cooling coupled with PCMs is required to be designed for thermal management of Li-ion battery pack.

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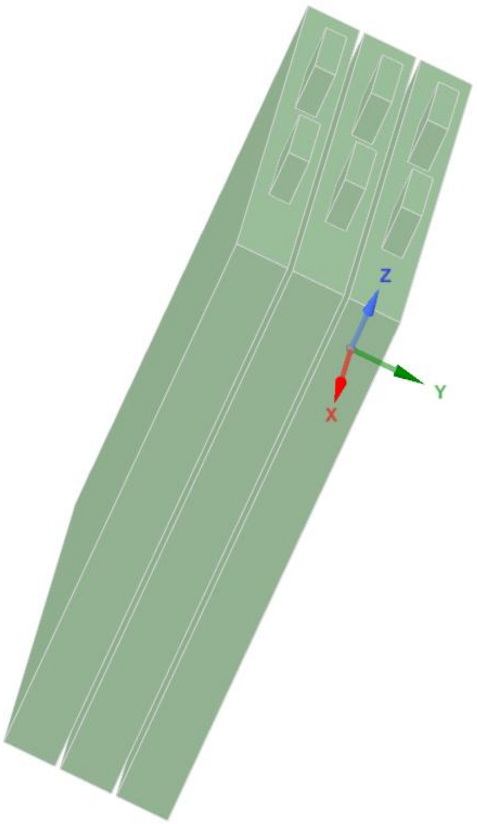
Known: The Li-ion battery pack unit is composed of **three batteries** as shown in the figure. **The configuration size of single Li-ion battery is assigned according to the tail ID number for each student in the last page.** The configuration size of ear electrode is about 4 mm*10 mm*10 mm. The out surface of Li-ion battery pack is exposed in the environment with a natural convective heat transfer coefficient of h=10 W/(m^2•K). The density, thermal conductivity, and specific heat of single Li-ion battery are ρ=2500 kg/m^3, λ=3 W /(m•K), and c_p=1000 J /(kg•K). The RT35 PCM is used with melting temperature of T_m = 35 ℃. In the PCM layer region, **the natural convection is driven by the buoyancy force with Boussinesq approximation.** The thermophysical properties of PCM is summarized below: density ρ_{PCM}=780 kg/m^3, thermal conductivity λ_{PCM} =0.2 W /(m•K), specific heat $c_{p\ PCM}$ =2000 J /(kg•K), dynamic viscosity μ=0.000365 Pa·s, thermal expansion coefficient β=0.0003085 K^{-1}, latent heat ΔH=255000 J/kg



The system (battery, water liquid, and PCM) initial temperature and environmental temperature are 25 °C!

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Known: The heat source term of single Li-ion battery is defined as follows:

$$\Phi_s = \frac{1}{V_s}\left(I^2 R + I T_b \frac{dE}{dT} \right) \quad \left(\mathrm{W/m^3}\right)$$

$$\frac{dE}{dT} = 0.22\ \mathrm{mV/K}$$

$$R(\Omega) = A - B*\mathrm{SOC} + C*\mathrm{SOC}^2 - D*\mathrm{SOC}^3 + E*\mathrm{SOC}^4 - F*\mathrm{SOC}^5$$

$$SOC(\%) = 1 - \frac{It}{Q}$$

Coefficient	*A*	*B*	*C*	*D*	*E*	*F*
Unit：Ω	0.00705	0.01853	0.05894	0.09151	0.06579	0.01707

V_S is the single battery volume, and T_b is the transient battery temperature. t is the transient operating time of battery, Q is the battery capacity 3.3 Ah. I is the discharging current given as：

Discharging rate	Current *I*	Total period
1 C	3.3 A	3600 s
2 C	6.6 A	1800 s
3 C	9.9 A	1200 s

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Find: Please design the configuration of water liquid cooling channel as well as the PCM layer between two single Li-ion batteries. The inlet water flow velocity should also be optimized to guarantee the maximum temperature of Li-ion battery pack is less than 40 ℃ with temperature uniformity of $\Delta T \leq 10$ ℃ under the help of thermal modulation using a PCM layer during 1 C, 2 C, and 3 C total discharging periods. Write down the governing equations and boundary conditions; Non-dimensionalizing all equations to get dimensionless governing parameters. Post-processing the results such as temperature field, velocity vectors, solid-liquid interface an so on.

For the tail number of student ID:0, 5

The single Li-ion battery configuration is 120 mm*60 mm* 10 mm

For the tail number of student ID:1, 6

The single Li-ion battery configuration is 115 mm*65 mm* 10 mm

For the tail number of student ID:2, 7

The single Li-ion battery configuration is 110 mm*70 mm* 10 mm

For the tail number of student ID:3, 8

The single Li-ion battery configuration is 105 mm*75 mm* 10 mm

For the tail number of student ID:4, 9

The single Li-ion battery configuration is 100 mm*80 mm* 10 mm