PRODUCT APPLICATION NOTE

PCM based Li-ion battery thermal management

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Challenges involved with Lithium-ion batteries in EV's

Lithium-ion (Li-ion) batteries are widely used in Electric 2, 3 and 4-wheeler vehicles with varied power capacities ranging from 1 kWh – 5 kWh for 2-wheelers and more than 5 kWh for 3-wheelers. Since the electrochemistry of Li-Ion batteries is *temperature sensitive,* allowing batteries temperatures to go beyond the tolerance envelope can result in a multitude of issues such as;

1. Increase in reaction kinetics leading to uncontrolled exothermic reactions within the battery.
2. Moderate overcharging can lead to high temperatures ultimately causing short circuit.
3. Reduction in the life of the battery pack if allowed to be exposed constantly at high temperatures < 45 deg C during lifetime.

Battery Type	Charge temperature	Discharge temperature	Charge Advisory
Lead Acid	-20°C to 50°C (-4°F to 122°F)	-20°C to 50°C (-4°F to 122°F)	Charge at 0.3C or Less below freezing temperature. Lower V-threshold by 3mV/°C when hot.
NiCd, NiMH	0°C to 45°C (32°F to 113°F)	-20°C to 65°C (-4°F to 149°F)	Charge at 0.1C between -18°C and 0°C. Charge at 0.3C between 0°C and 5°C. Charge acceptance at 45°C is 70%. Charge acceptance at 60°C is 45%.
s **Li-ion**	0°C to 45°C (32°F to 113°F)	-20°C to 60°C (-4°F to 140°F)	Charging not possible at sub-zero temperatures

Key Benefits of passive thermal management through PCMs: -

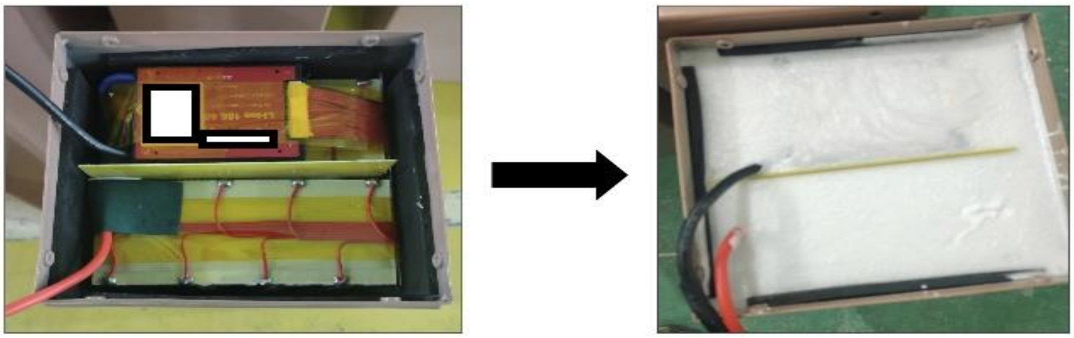
1. High latent heat capacity of PCM provides prolonged passive thermal management.
2. Prolonged temperature control within threshold limits during battery pack operation.
3. Electrically non-conductive with low dielectric constant.
4. High thermal conductivity enabling an optimum balance of heat absorption and dissipation.
5. Cost-effective compared to mechanical forced cooling or liquid cooling.

Value proposition for the Electric Vehicle and Battery pack manufacturers:-

1. **Improved range** – By increased useable capacity of the batteries by 25%.
2. **Enhanced safety** – Reduces the instance of a thermal runaway occurring by 4 times. Prolonged exposure to fire PCM-based battery pack delays the chain reaction by 40 minutes as compared to 5 to 10 minutes without PCMs.
3. **Faster charging** – Enables enhanced charging performance.
4. **Improved battery life –** Slows down degradation of the battery, improving the life by 75%.

Existing solution offered by PLUSS

Flood and Fill (F&F) technology – This is a low to moderate thermally conductive PCM with a liquid form-factor. This form-factor allows the battery back to be immersed inside liquid PCM. This process would require the outer casing of battery pack to be leak proof.



Before filling PCM *After filling PCM*

Fig 1: Battery pack – Before filling PCM and after filling PCM

Simulated temperature curves for 2-wheeler battery pack

During regular vehicle operations, drawing power from the battery pack results in gradual heating of the battery pack as shown.

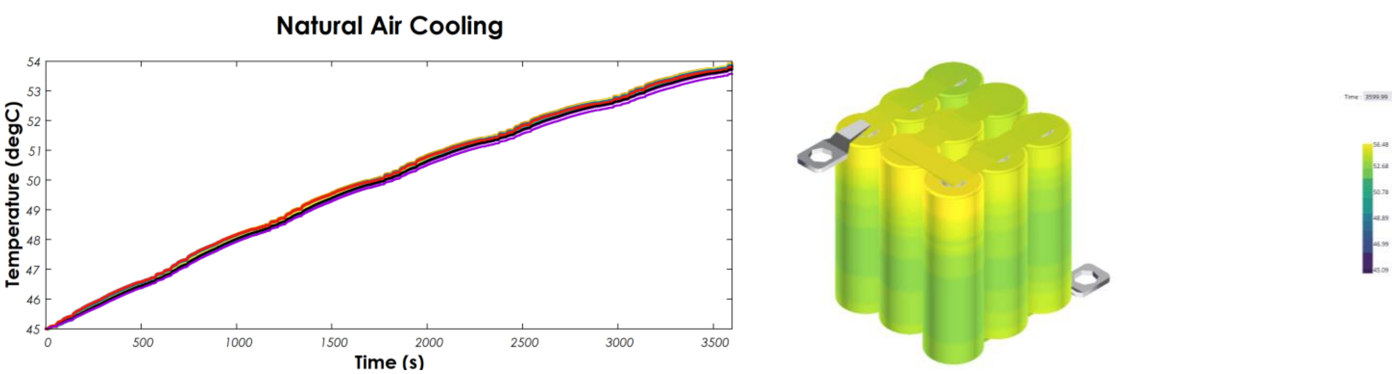
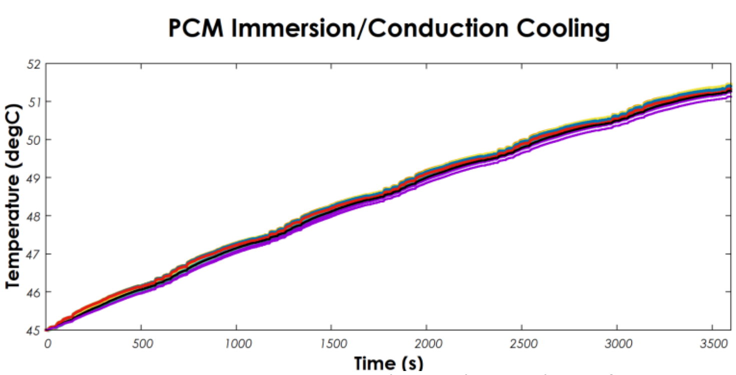


Fig 2: Simulation of battery pack without PCM

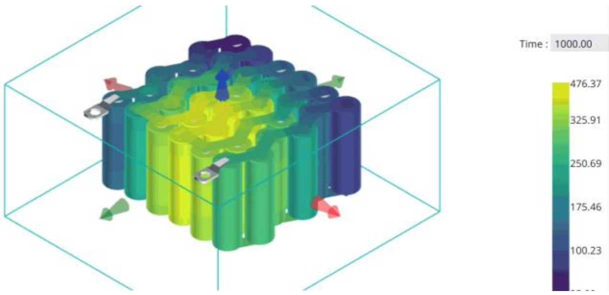


For a 9-cell battery pack (top right) filling the air gaps between the cells with PCM results in a delayed increase of temperature in the pack during regular vehicular operations. For every 50 g of PCM incorporation, temperature increase of 2ºC may be arrested for the shown design.

Fig 3: Simulation of battery pack with PCM of 10 kJ/kg

The maximum temperature of the battery pack reached 54 degrees C in 3500 seconds with natural air cooling whereas with PCM with latent capacity of 10 kJ/kg, the temperature is restricted to 51 degrees C within the same time. Hence, a much better performance is expected with PCM OM49 having latent heat of 224 kJ/kg.

When a cell in the pack undergoes **thermal runaway** (center cell in adjacent image, TR triggered by heating), the excess heat runs the risk of causing other cells to undergo thermal runaway (TR), creating an unsafe chain reaction. The presence of PCM OM49 successfully arrests any chance of thermal runaway whatsoever.



The temperature of the "trigger" cell initially rises due to heating with a 50 W heater. However, a delay in thermal runaway trigger is seen when PCM is employed (PCM pack takes thrice as long to initiated TR).

Fig 4: Thermal runaway simulation after triggering center cell

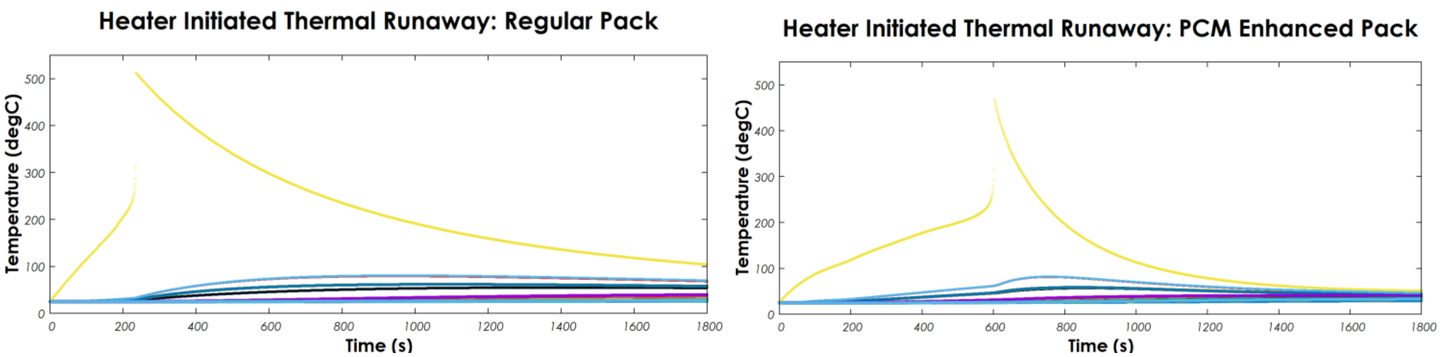


Fig 5: Cell temperature curves after triggering thermal runaway using OM49

The above figure 4 and figure 5 depict that the maximum cell temperature reached 500 degrees C within 210 seconds of triggering thermal runaway in a regular pack whereas this time gets delayed to 600 seconds after the use of PCM. In thermal runaway simulation, 100% of PCM's latent heat has been considered.