



Thermal Performance of Analysis of Serpentine Channel Cold Plate for 18650 Cylindrical Lithium-Ion Battery

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Abstract: This research evaluates the thermal performance of a liquid cooling system with serpentine channel inlets for an 18650 cylindrical lithium-ion battery module. The study analyzed an eight-cell module with a baseline configuration and variations featuring two, three, and four serpentine curves using computational fluid dynamics simulations validated against previous experiments. A fixed mass flow rate of 0.0001 kg/s was applied. Results showed all configurations-maintained battery temperatures below 37.5°C, preventing thermal runaway. The Baseline configuration achieved the lowest maximum temperature of 37.447°C and the highest performance factor (J/F factor) of 0.053. The two serpentine curves offered the best temperature uniformity (1.114°C) and highest heat transfer coefficient. Although more serpentine curves reduced maximum temperature, they increased pressure drop, decreasing the J/F factor. The study concludes that the serpentine cold plate design effectively manages thermal containment, with the two-curve configuration providing the best balance of heat transfer and temperature stability.

Keywords: thermal; li-ion; battery, mini-channel; serpentine



SDGs Problem Solving

The study of serpentine cold plate liquid cooling for lithium-ion batteries directly contributes to SDGs Chapter #7. This study improves the thermal management of batteries, which makes EV batteries last longer, work better, and be safer. This helps make clean energy systems more reliable, lowers emissions, and supports the development of sustainable transportation.

Conflict of Interest Statement: The author(s) declares that the research was conducted in the absence of any commercial or financial relationship that could be construed as a potential conflict of interest.

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1. INTRODUCTION

Given the escalating global energy exigency and mounting environmental contamination, Electric Vehicles (EVs) represent a pivotal trajectory for the reorientation and advancement of the automotive sector, owing to their reduced effluent and superior operational efficacy. As the central element of the EV system (Li et al., 2024). Lithium-ion battery is dominantly used in EV due to their high energy density, extended cycle life, and low self-discharge rate (Mallick and Gayen, 2023).

The main problem with Lithium-ion battery is their temperature sensitivity, when low temperatures can impact a battery's performance, moreover high temperature accelerate the deterioration process and reduce the batteries life span (Lin et al., 2021). LIBs are working optimally between 25°C and 40°C, and with temperature uniformity less than 5°C (Hu et al., 2024). Therefore, it is necessary to develop a battery thermal management system (BTMS) that is both effective and efficient (H. Yang et al., 2023).

Battery Thermal Management System main cooling methods are categorized into active cooling system which is air cooling (Padalkar et al., 2024; Zhu et al., 2024), liquid cooling (Zhan et al., 2023; Chen et al., 2024) then passive cooling system which is phase change material (PCM) cooling (Y. Yang et al., 2023; Moaveni, Siavashi and Mousavi, 2024) and heat pipe cooling (Kleiner et al., 2022; Zhang et al., 2024). Among these methods, liquid cooling stands out as one of the most efficient solutions. Its exceptional thermal conductivity allows it to transfer heat rapidly and effectively, making it particularly advantageous in scenarios where managing larger heat loads is critical. This efficiency is especially valuable in applications where maintaining thermal uniformity and compact design is essential for optimal performance and safety (Patel and Rathod, 2020).

This comprehensive analysis of liquid cooling primarily focuses on the design and evaluation of cold plate configurations, which can generally be categorized into three types: traditional structures, biomimetic structures, and topology-optimized structures. Traditional structures stem from established engineering principles and utilize basic, uniform flow channel designs, including parallel, serpentine, and U-shaped channels, among others (Monika and Datta, 2022; Zuo et al., 2022). The arrangement of the channels and the placement of the inlet in parallel-flow cold plates are particularly emphasized. It is noted that positioning the inlet near the battery tab area and employing an appropriate number of channels can facilitate an optimal balance between temperature uniformity (ΔT) and pressure drop under specific operational conditions (Monika et al., 2021).

Prior research revealed that divergent-shaped channels in cold plates significantly enhances thermal management performance by both promoting heat dissipation downstream and reducing frictional resistance. Decreased the maximum temperature difference from 3.99°C to 3.19°C due to more uniform mass flow distribution (Kong et al., 2021). Nevertheless, the primary deficiency of this study lies in its observation that while increasing the inlet area sharply reduced the pressure drop, the key thermal metrics maximum temperature and temperature difference remained almost impervious to this alteration. Another study demonstrated nonuniform wavy minichannels significantly enhances the heat transfer characteristics, maintained an exceptionally uniform temperature, exhibiting a variation of less than 1.1°C across the tested velocity range (Khoshvaght-Aliabadi et al., 2023). However, as the modified channel designs necessitated substantially higher friction factors, increasing flow resistance by 25.3% to 93.6% compared to the conventional case.

Recent study introducing inclined ribs in serpentine channel cold plate is a highly efficacious technique for augmenting heat transfer, reducing 9.1% average temperature at the 2C-rate compare to the smooth channel (Jaffal *et al.*, 2023). But the most optimal design added friction factor by 151% compared to the smooth channel, representing a considerable energetic cost for the overall system. Another study demonstrating the efficacy of implementing heat conducting element with a variable contact area within serpentine liquid cooling channels to manage battery thermal profiles. The optimized design notably achieved a considerable 71.7% enhancement in temperature uniformity (ΔT) and 1.6% superior regulation of maximum temperature (T_{max}) compared to commercially viable serpentine channel design without HCEs (Shrinet, Akula and Kumar, 2024). A significant limitation stems from the primary focus on steady-state conditions for the extensive preliminary and multi-objective optimization analyses, which fails to fully capture the complex thermal behavior of lithium-ion batteries under realistic, dynamic operating profiles and variable heat generation that characterize actual usage scenarios.

A previous study shows unique zig-zag cold plate with four turns integrated with Phase Change Material. The zig-zag cold plate design fundamentally optimized heat transfer by inducing greater coolant turbulence compared to conventional serpentine cold plate, this configuration offering a 52,9% weight reduction compared to a conventional serpentine cold plate (Saxena *et al.*, 2025). However, although the system minimizes hotspot formation, the intermittent operation leads to generally maximum temperature (T_{max}) and temperature uniformity (ΔT). Comprehensive review of bio-inspired dendritic channels address the central drawback of conventional cold plate by offering dramatically reduced flow resistance while simultaneously enhancing temperature uniformity (ΔT). For instance, reducing 69.25% maximum temperature compared to conventional channels (Patimaporntap *et al.*, 2025). But a salient shortcoming recognized across the literature is the unresolved trade-off between enhanced heat transfer and increased pressure drop in many conventional mini/micro-channel designs, especially when employing augmentation techniques like wavy geometries or pin fins.

Current literature shows a significant gap in research on liquid-cooling systems with cold plates, particularly regarding pressure drops in Battery Thermal Management Systems (BTMS). This study aims to evaluate various inlet structure designs to enhance heat transfer efficiency and reduce pressure. Improving these aspects is essential for optimizing liquid-cooled systems, ensuring thermal uniformity and a compact design for peak operational efficiency and safety.

2. METHODOLOGY

2.1. Lithium-Ion Battery Model

This research delves into a specialized liquid cooling system crafted specifically for the cylindrical lithium-ion cell known as the 18650 types. With dimensions of 18 mm in diameter and 65 mm in height, this battery is compact yet powerful, boasting a nominal capacity of 1.3 Ah. The detailed dimensions of the battery model are visually represented in Figure 1, providing a clear understanding of its size and structure.

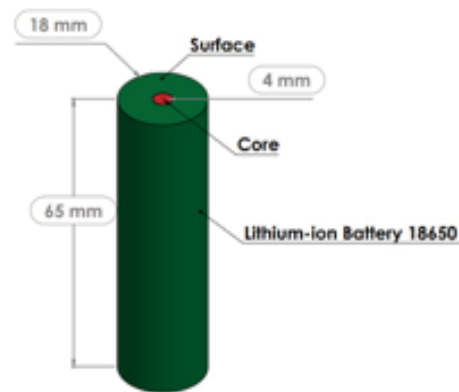


Figure 1. Lithium-ion 18650 battery model

2.2. Mini-Channel Cold Plate Models

Power battery packs typically feature a modular design, enabling straightforward replacement and maintenance. To form a compact module, the battery cells are arranged in a geometric layout consisting of two rows and a single column at the inlet and a serpentine model. This arrangement is then separated into two internal columns before being rejoined into a single column at the end of the cold plate. The cooling system incorporates a combination of a mini-channel cold plate and liquid cooling methods, as illustrated in Figure 2.

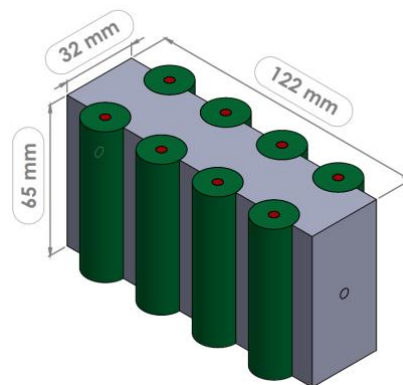


Figure 2. Liquid cooling system with mini-channel cold plate structure

The cold plate is made from aluminum, a material known for its lightweight nature and excellent thermal conductivity. This cold plate acts as an efficient medium for heat transfer. The thermal properties of the battery pack model are assumed to be uniform. The specific characteristics of the materials are outlined in Table 1.

Table 1. Material properties

Material	Aluminium	Battery	Water
ρ ($\text{kg} \cdot \text{m}^{-3}$)	2179	2534.26	998.2
c ($\text{J} \cdot \text{kg}^{-1} \cdot \text{K}^{-1}$)	871	15583	4128
k ($\text{W} \cdot \text{m}^{-1} \cdot \text{K}^{-1}$)	202.4	3.02	0.6
μ (Pa·s)	-	-	1.03×10^{-3}

2.3. Governing Equation

The study of coolant fluid flow in this work utilizes the Reynolds-Averaged Navier-Stokes (RANS) technique, particularly focusing on mini-channels. To ensure fluid mass conservation throughout the domain, the equations solved included Equation (1), the Mass Conservation (Continuity Equation), Equations (2) used to calculate momentum conservation (Julian *et al.*, 2022). Equation (3) used to determine the temperature in the fluid and solid domains (Jungbecker and Veit, 2012). The heat source for the solid domain is defined by Equation (4), which is based on experimental thermal response data commonly used for homogeneous heat situations. Furthermore, Equation (5) is used to account for heat transfer phenomena that are both in homogenous and transient (Adams, Yao and Fairweather, 2011).

$$\frac{\partial \rho}{\partial t} + \frac{\partial}{\partial x_i}(\rho u_i) = 0 \quad (1)$$

$$\rho_l \left[\frac{\partial \vec{v}}{\partial t} + (\vec{v} \cdot \nabla) \vec{v} \right] = -\nabla p + \mu \nabla^2 \vec{v} \quad (2)$$

$$\rho C_p \frac{\partial T}{\partial t} = \lambda_x \frac{\partial^2 T}{\partial x^2} + \lambda_y \frac{\partial^2 T}{\partial y^2} + \lambda_z \frac{\partial^2 T}{\partial z^2} + Q_{gen} \quad (3)$$

$$Q_{gen}(t) = \rho C_p \frac{\Delta T}{\Delta t} \quad (4)$$

$$Q_{gen(1-2)}(x, y, z, t) = Q_{gen(1-2)}(t) - \lambda \nabla^2 T_{(1-2)} \quad (5)$$

2.4. Mesh and Boundary Conditions

This study developed an unstructured tetrahedral mesh to simplify complex shapes, as illustrated in Figure 3a. The boundary conditions are depicted in Figure 3b, outlining a BTMS with three zones: the battery zone, cold plate zone, and liquid zone. Both the batteries and aluminum cold plate start at 35°C, while water enters the BTMS at 25°C. Convection boundary conditions, with a heat transfer coefficient of 5 W/m²·K, are applied to the battery's outer surface to model thermal interaction. Variations in the BTMS, presented in Table 2, include four configurations with different inlet structures: (a) baseline, (b) 2 serpentine curves, (c) 3 serpentine curves, and (d) 4 serpentine curves, all with a mass flow rate of 0.0001 kg/s. Heat generation is treated as a volumetric source in each battery cell, focusing on the radial gradient.

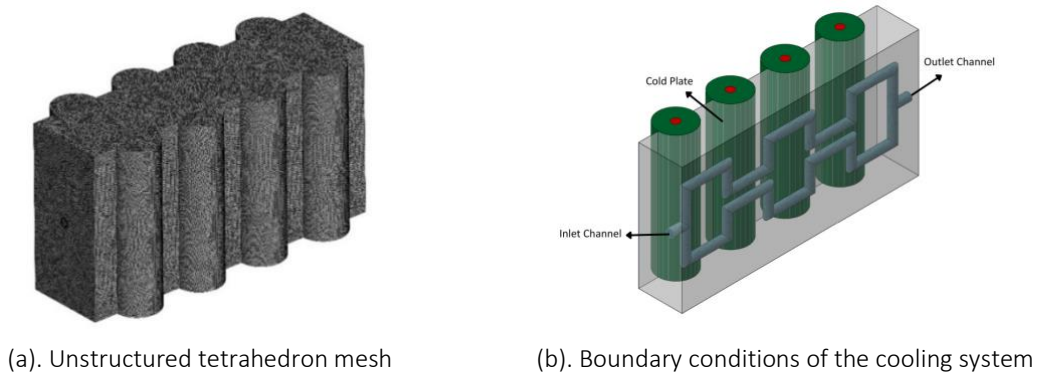


Figure 3. Mesh and boundary conditions

Table 2. Variation parameter

Diameter inlet (Ø)	Mass Flow Rate (kg/s)	Inlet Structure
4 mm	0.0001	Baseline
		2 serpentine curves
		3 serpentine curves
		4 serpentine curves

2.5. Non-dimensional Parameter

Prior research has focused on creating the J/F Factor, which accurately measures the efficiency and accuracy of representing interactions between heat transfer and friction factors within a system. Non-dimensional heat transfer defines as J factor, outlined in Equation. (6) by Ko et al. (Ko *et al.*, 2024). Then, Equation. (7) used to predict fluid flow pattern, Equation. (8) to indicating ratio of convective to conductive heat transfer across boundary (Adams, Yao and Fairweather, 2011). To quantifying the heat transfer rate to the surface are calculated by using Equation. (9), afterwards Equation. (10) used to calculate the rate of heat absorbed by the coolant. F factor as non-dimensional friction was evaluated using Equation. (11) by Ma et al., (Ma *et al.*, 2025). Then, the Equation. (12) calculating pressure drop of the cold plate, P_{in} defined inlet pressure, and P_{out} defined outlet pressure (Hussein, 2023).

$$j = \frac{Nu}{Re \cdot Pr^{1/3}} \quad (6)$$

$$Re = \frac{\rho U D}{\mu} \quad (7)$$

$$Nu = \frac{h_w D}{\mu} \quad (8)$$

$$h_w = \frac{Q_t}{A_c [T_{bmax} - (T_{lin} + T_{lout})/2]} \quad (9)$$

$$Q = m \cdot C_p \cdot (T_{in} - T_{out}) \quad (10)$$

$$f = \frac{2 \Delta p D_c}{\rho U_{in}^2 L} \quad (11)$$

$$\Delta P = P_{in} - P_{out} \quad (12)$$

2.6. Mesh Independence Test

To account for mesh quality in relation to computing efficiency, the number of elements must also be further evaluated. Computes the error value in each mesh model using the Grid Convergence Index. To calculate the error value in each mesh model, the authors use Roache's approach (Roache, 1994). The number of elements in each mesh is constrained by a grid refinement ratio, as defined in Equation (13). Furthermore, to calculating error percentage from fine mesh to medium mesh using the Equation (15), then, from medium mesh to coarse mesh using the Equation (16). Equation (18) being used to verify the Grid Convergence Index a reliable estimator of the discretization error. Then, evaluating the result of final error value by using Equation (19).

Table 3 gives a summary of the results of the mesh independence test. After evaluating a coarse mesh of 1,251,866 elements and a medium mesh of 2,508,363 elements, the analysis Indicated a

GCI value below 5%, suggesting that the discretization is within an acceptable range. The fine mesh was selected as the ideal configuration for this study. Therefore, a total of 5,000,895 fine grid elements were used for all subsequent simulations.

$$r = \frac{h_2}{h_1} \quad (13)$$

$$\bar{p} = \frac{\ln\left(\frac{f_3-f_2}{f_2-f_1}\right)}{\ln(r)} \quad (14)$$

$$GCI_{fine} = \frac{F_s|\epsilon|}{(r^{\bar{p}}-1)} \quad (15)$$

$$GCI_{coarse} = \frac{F_s|\epsilon|r^{\bar{p}}}{(r^{\bar{p}}-1)} \quad (16)$$

$$\epsilon = \frac{f_{n+1}-f_n}{f_n} \quad (17)$$

$$\frac{GCI_{coarse}}{GCI_{fine}r^{\bar{p}}} \approx 1 \quad (18)$$

$$f_{r_{h=0}} = f_1 + \frac{(f_1-f_2)}{(r^{\bar{p}}-1)} \quad (19)$$

Table 3. Result of grid test

Mesh	Fine	Medium	Coarse
Difference of temperature	35.7158	35.7162	35.7230
$\bar{p}$		3.836607957	
r		2	
GCI_{fine}		0.000%	
GCI_{coarse}		0.018%	
$f_{rh} = 0$		35.7157	
$\frac{GCI_{coarse}}{GCI_{fine}r^{\bar{p}}}$		1	
Error	0.0001%	0.0014%	0.0204%

3. RESULTS AND DISCUSSION

3.1. Validation

The research begins with numerical validation based on confirmed experimental findings from earlier research by Wang et al., ([Wang et al., 2022](#)). The thermal behavior of the single lithium-ion battery (LIB) model, operating at an initial ambient temperature of 35°C and subjected to a 2C discharge rate, is clearly illustrated in [Figure 4](#). The maximum errors were 3.914% for the core and 3.474% for the surface, when compared to the experimental data. Furthermore, the temperature increase trend at each location matched the experimental conditions. The validated numerical model subsequently provides a reference for models without cooling.

3.2. Analysis

The investigation into the liquid cooling system's performance, detailed in [Figure 5](#), shows significant temperature reduction at a fixed mass flow rate of 0.0001 kg/s. The "No Cooling" scenario reveals

uncontrolled temperature escalation exceeding 52°C, jeopardizing battery integrity. In contrast, all cooling configurations keep the maximum temperature below 37°C after 1200 seconds.

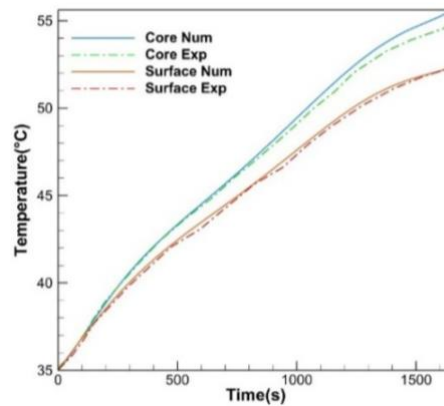


Figure 4. A comparison between numerical and experimental data on a single battery

The Baseline configuration shows the best initial temperature at 37.447 °C. Among the serpentine inlet structures, the 2 curves configuration peaks at 37.484°C but maintains battery temperature below 37°C by the end of discharge. Increasing the number of curves further reduces the maximum temperature, with 4 curves reaching 37.453°C, approaching the Baseline.

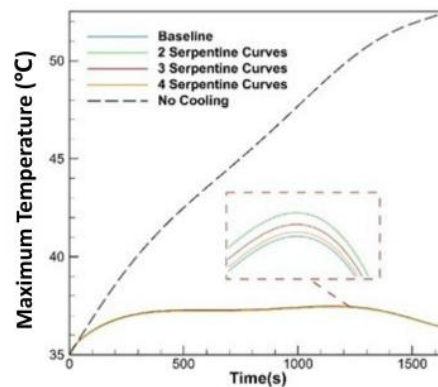


Figure 5. Maximum temperature for each configuration

This indicates that, while the Baseline is the optimal performer, increasing the serpentine curves is a viable and effective strategy for minimizing the maximum temperature reached during the initial thermal excursion, showcasing the robustness and potential for optimization in these complex channel geometries. Moreover, in comparison with a conventional serpentine channel by Saxena et al., (Saxena et al., 2025), which reached a maximum temperature of 36.9 °C, the present results demonstrate that serpentine-channel configurations are capable of effectively maintaining temperature between 25°C to 45°C.

Figure 6 shown the temperature uniformity (ΔT) across all configurations shows strong performance in the liquid-cooling system. The 2 serpentine curves configuration achieves the best temperature uniformity, with a peak of 1.114°C in the first 100 seconds, dropping below 1°C for the rest of the discharge. The Baseline configuration peaks at 1.134°C, while the 3 and 4 serpentine curves reach 1.130°C and 1.138°C, respectively. This indicates that during the initial phase, increasing the number of curves slightly raises peak non-uniformity. Nevertheless, serpentine-channel designs overall

provide superior temperature uniformity when compared with divergent-shaped channels by Kong et al., (Kong et al., 2021), which have been reported to exhibit temperature non-uniformity ranging from 3.99 °C to 3.19 °C.

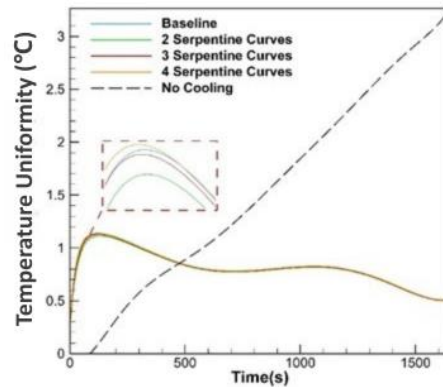


Figure 6. Temperature uniformity for each configuration

The advantage of using an inlet structure is evident in the "No Cooling" condition, where temperature uniformity decreases by over 3°C during the discharge cycle due to extreme temperature gradients, harming cell health and performance. The proposed liquid cooling system effectively reduces this temperature differential to below 1.14°C, significantly improving thermal uniformity. While the 2 serpentine curves configuration performed best for initial uniformity, serpentine designs overall succeed in maintaining better thermal uniformity throughout the battery module's operation.

Table 4. Pressure drops and heat transfer coefficient with each configuration

Inlet Structured	ΔP (Pa)	h_w (W m ⁻² K ⁻¹)
Baseline	0.195	153.530
2 serpentine curves	1.693	177.085
3 serpentine curves	1.886	154.954
4 serpentine curves	2.044	137.556

The analysis of pressure drops, and heat transfer presented in Table 4. shows a trade-off between pressure drop (ΔP) and the heat transfer coefficient (h_w) in various inlet structured configurations. The Baseline configuration has the lowest pressure drop at 0.195 and a moderate heat transfer coefficient of 153.530. In contrast, the addition of serpentine curves increases pressure drop significantly, rising to 1.693 for 2 curves and continuing to 2.044 for 4 curves, highlighting the relationship between flow path complexity and pumping power. The 2 serpentine curves configuration offers the best heat transfer performance, with a coefficient of 177.085, but further increases in serpentine curves result in decreased performance, dropping to 137.556 for 4 curves, indicating that excessive tortuosity can hinder heat dissipation efficiency. Consistent with prior findings, wavy mini-channel geometries have been reported to significantly enhance heat transfer performance (Khoshvaght-Aliabadi et al., 2023) geometrical modifications are also associated with markedly higher friction factors, resulting in flow resistance increases ranging from 25.3% to 93.6% relative to serpentine channel designs.

Figure 7 present the J/F factor that indicates the balance between heat transfer capability and fluid pumping power. A higher J/F value represents better thermal performance with reduced flow resistance. The Baseline configuration achieved the highest J/F value of 0.053, while serpentine configurations showed lower values, reflecting a worse balance between heat transfer and pressure drop. For instance, the 2 serpentine curves (2 SC) had a J/F of about 0.036, dropping to 0.028 for 3 SC, and further to 0.023 for 4 SC. This suggests that while serpentine paths may improve local heat transfer, the increased pressure drop in these more complex channels significantly lowers overall performance, as indicated by the Baseline structure's superior J/F value.

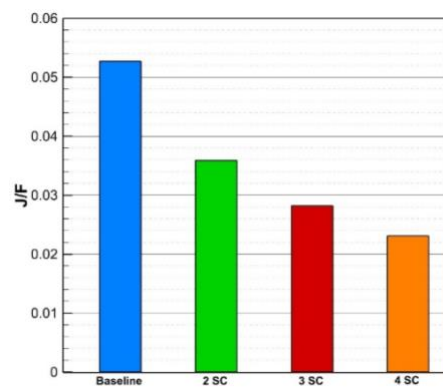


Figure 7. J/F factor difference for each configuration

The thermal contour plots in **Figure 8**, show temperature variations across the batteries for different cold plate designs. The Baseline configuration exhibits noticeable thermal stratification, with temperatures increasing from the inlet to outlet, particularly impacting the last two batteries where cooling is inconsistent. In comparison, the serpentine flow paths (2, 3, and 4 curves) demonstrate improved thermal management, reducing high-temperature areas in the rightmost batteries and promoting a more uniform temperature distribution in the central batteries.

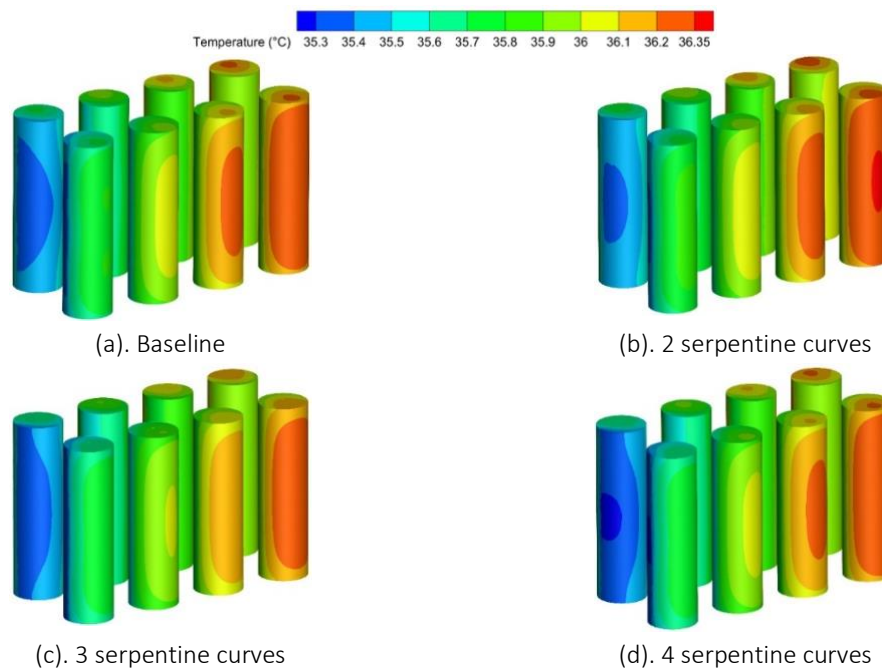


Figure 8. A comparison of thermal contours within the battery module for various inlet structure

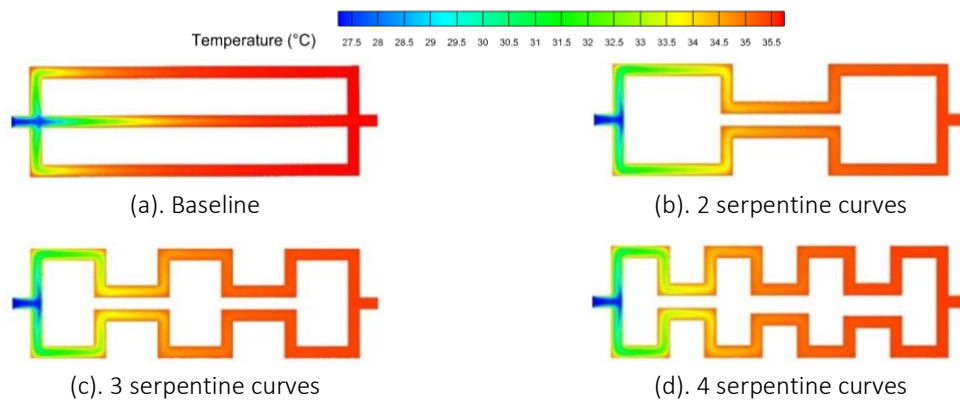


Figure 9. A comparison of thermal contours on mini channel for various inlet structure

Figure 9, illustrates fluid temperature distribution within mini channels for four flow configurations. The Baseline design, with its straight channels, shows a steep temperature rise, peaking at the outlet. Conversely, the 2 serpentine curves design introduces multiple direction changes that enhance convective mixing, resulting in a more gradual temperature increase. This trend continues with the 3 and 4 serpentine curves, where the latter effectively spreads the heat load, even if the final outlet temperature remains high.

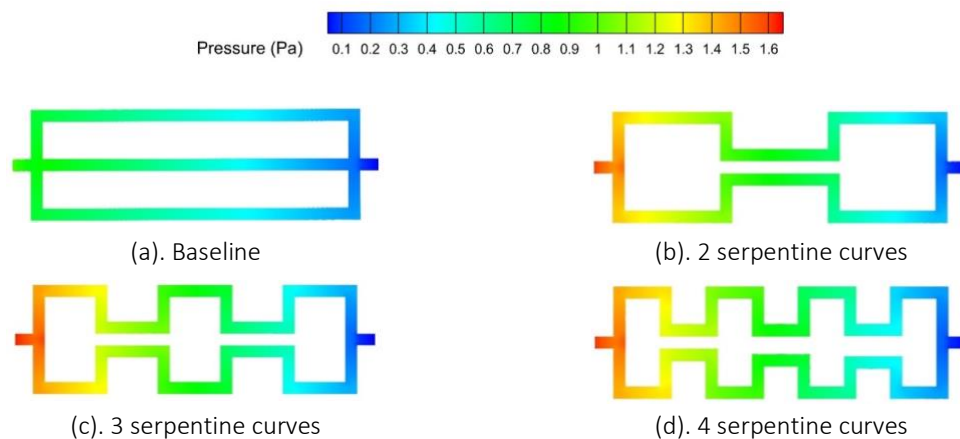


Figure 10. A comparison of pressure contours within the battery module for various inlet structure

Pressure contour plots in Figure 10, reveal that the Baseline configuration has the lowest pressure drop due to its simple flow path. In contrast, serpentine curves significantly raise pressure drops. The 2 serpentine curves design shows higher pressure regions at the inlet and turns, indicating increased pumping power needs. As curves increase to 3 and 4, high-pressure zones expand, demonstrating that pressure drop increases with flow complexity.

4. CONCLUSION

The investigation into the thermal and hydraulic characteristics of serpentine channel cold plate designs demonstrates the effectiveness of liquid cooling for 18650 lithium-ion battery modules. All configurations kept battery temperatures within the optimal range, unlike the uncooled scenario, which led to thermal escalation. The Baseline configuration achieved the best overall thermal-hydraulic performance with the highest J/F factor of 0.053 and a maximum temperature of 37.447°C,

due to a minimal pressure drop of 0.195 Pa. The 2 serpentine curves design excelled in temperature uniformity and heat transfer coefficient but had a higher-pressure drop of 1.693 Pa. Increasing serpentine curves improved maximum temperature suppression but decreased the overall J/F factor due to increased pressure drop. The 2 Serpentine Curve configuration is ideal for temperature uniformity, while the Baseline is the most energy efficient. The study concludes that while serpentine channels effectively control temperature, the optimal design must balance thermal benefits with hydraulic resistance.

REFERENCES

- Adams, J.F.W., Yao, J. and Fairweather, M. (2011) 'Reynolds Number Effects on Particle Dispersion and Deposition in Turbulent Square Duct Flows', *Computer Aided Chemical Engineering*. Elsevier, pp. 1683–1687. Available at: <https://doi.org/10.1016/B978-0-444-54298-4.50115-X>.
- Chen, C. et al. (2024) 'Numerical investigation on thermal management performance of soft packing Li-ion batteries with oblique multi-channel cold plates', *Renewable Energy*, 234, p. 121250. Available at: <https://doi.org/10.1016/j.renene.2024.121250>.
- Hu, X. et al. (2024) 'Advancements in the safety of Lithium-Ion Battery: The Trigger, consequence and mitigation method of thermal runaway', *Chemical Engineering Journal*, 481, p. 148450. Available at: <https://doi.org/10.1016/j.cej.2023.148450>.
- Hussein, A. (2023) 'Chapter 2 - Flow Assurance', in A. Hussein (ed.) *Essentials of Flow Assurance Solids in Oil and Gas Operations*. Gulf Professional Publishing, pp. 53–103. Available at: <https://doi.org/10.1016/B978-0-323-99118-6.00015-0>.
- Jaffal, H.M. et al. (2023) 'Performance enhancement of a novel serpentine channel cooled plate used for cooling of Li-ion battery module', *International Journal of Thermal Sciences*, 184, p. 107955. Available at: <https://doi.org/10.1016/j.ijthermalsci.2022.107955>.
- Julian, J. et al. (2022) 'Computational Fluid Dynamics Analysis Based on The Fluid Flow Separation Point on The Upper Side of The NACA 0015 Airfoil With The Coefficient of Friction', *Media Mesin: Majalah Teknik Mesin*, 23(2), pp. 70–82. Available at: <https://doi.org/10.23917/mesin.v23i2.18217>.
- Jungbecker, P. and Veit, D. (2012) '5 - Computational fluid dynamics (CFD) and its application to textile technology', in D. Veit (ed.) *Simulation in Textile Technology*. Woodhead Publishing, pp. 142–178e. Available at: <https://doi.org/10.1533/9780857097088.142>.
- Khoshvaght-Aliabadi, M. et al. (2023) 'Structural modifications of sinusoidal wavy minichannels cold plates applied in liquid cooling of lithium-ion batteries', *Journal of Energy Storage*, 57, p. 106208. Available at: <https://doi.org/10.1016/j.est.2022.106208>.
- Kleiner, J. et al. (2022) 'Experimental study of cell integrated heat pipe cooling with a lithium-ion cell emulator', *Journal of Energy Storage*, 56, p. 105808. Available at: <https://doi.org/10.1016/j.est.2022.105808>.
- Ko, Y.M. et al. (2024) 'A critical review on Colburn j-factor and f-factor and energy performance analysis for finned tube heat exchangers', *Energy*, 287, p. 129609. Available at: <https://doi.org/10.1016/j.energy.2023.129609>.
- Kong, W. et al. (2021) 'Enhancement of lithium-ion battery thermal management with the divergent-shaped channel cold plate', *Journal of Energy Storage*, 42, p. 103027. Available at: <https://doi.org/10.1016/j.est.2021.103027>.
- Li, H. et al. (2024) 'Performance enhancement of a battery thermal management system using novel liquid cold plates with micro-channel featuring pin fins', *Energy*, 301, p. 131731. Available at: <https://doi.org/10.1016/j.energy.2024.131731>.

- Lin, J. et al. (2021) 'A review on recent progress, challenges and perspective of battery thermal management system', *International Journal of Heat and Mass Transfer*, 167, p. 120834. Available at: <https://doi.org/10.1016/j.ijheatmasstransfer.2020.120834>.
- Ma, K. et al. (2025) 'Numerical simulation of battery thermal management based on ring microchannel cold plate', *International Journal of Thermal Sciences*, 210, p. 109563. Available at: <https://doi.org/10.1016/j.ijthermalsci.2024.109563>.
- Mallick, S. and Gayen, D. (2023) 'Thermal behaviour and thermal runaway propagation in lithium-ion battery systems – A critical review', *Journal of Energy Storage*, 62, p. 106894. Available at: <https://doi.org/10.1016/j.est.2023.106894>.
- Moaveni, A., Siavashi, M. and Mousavi, S. (2024) 'Passive and hybrid battery thermal management system by cooling flow control, employing nano-PCM, fins, and metal foam', *Energy*, 288, p. 129809. Available at: <https://doi.org/10.1016/j.energy.2023.129809>.
- Monika, K. et al. (2021) 'An improved mini-channel based liquid cooling strategy of prismatic LiFePO₄ batteries for electric or hybrid vehicles', *Journal of Energy Storage*, 35, p. 102301. Available at: <https://doi.org/10.1016/j.est.2021.102301>.
- Monika, K. and Datta, S.P. (2022) 'Comparative assessment among several channel designs with constant volume for cooling of pouch-type battery module', *Energy Conversion and Management*, 251, p. 114936. Available at: <https://doi.org/10.1016/j.enconman.2021.114936>.
- Padalkar, A.B. et al. (2024) 'Effects of circumferential fin on cooling performance improvement of forced air-cooled battery pack', *Applied Thermal Engineering*, 238, p. 122013. Available at: <https://doi.org/10.1016/j.applthermaleng.2023.122013>.
- Patel, J.R. and Rathod, M.K. (2020) 'Recent developments in the passive and hybrid thermal management techniques of lithium-ion batteries', *Journal of Power Sources*, 480, p. 228820. Available at: <https://doi.org/10.1016/j.jpowsour.2020.228820>.
- Patimaporntap, N. et al. (2025) 'Thermal management for electric vehicle batteries using mini/micro-channels: A critical review of strategies, challenges, and future prospects', *International Journal of Heat and Mass Transfer*, 252, p. 127355. Available at: <https://doi.org/10.1016/j.ijheatmasstransfer.2025.127355>.
- Roache, P.J. (1994) 'Perspective: A Method for Uniform Reporting of Grid Refinement Studies', *Journal of Fluids Engineering*, 116(3), pp. 405–413. Available at: <https://doi.org/10.1115/1.2910291>.
- Saxena, V. et al. (2025) 'Enhanced thermal management system for Li-ion batteries using phase change material and liquid cooling under realistic driving cycles', *Energy*, 318, p. 134759. Available at: <https://doi.org/10.1016/j.energy.2025.134759>.
- Shrinet, E.S., Akula, R. and Kumar, L. (2024) 'Improvement in serpentine channel based battery thermal management system geometry using variable contact area and its multi-objective design optimization', *Journal of Energy Storage*, 96, p. 112726. Available at: <https://doi.org/10.1016/j.est.2024.112726>.
- Wang, N. et al. (2022) 'An online temperature estimation for cylindrical lithium-ion batteries based on simplified distribution electrical-thermal model', *Journal of Energy Storage*, 55, p. 105326. Available at: <https://doi.org/10.1016/j.est.2022.105326>.
- Yang, H. et al. (2023) 'A compact and lightweight hybrid liquid cooling system coupling with Z-type cold plates and PCM composite for battery thermal management', *Energy*, 263, p. 126026. Available at: <https://doi.org/10.1016/j.energy.2022.126026>.
- Yang, Y. et al. (2023) 'Towards a safer lithium-ion batteries: A critical review on cause, characteristics, warning and disposal strategy for thermal runaway', *Advances in Applied Energy*, 11, p. 100146. Available at: <https://doi.org/10.1016/j.adapen.2023.100146>.
- Zhan, S. et al. (2023) 'Effect of inlet and outlet positions on heat dissipation performance of lithium-ion battery cold plates: An analysis based on topology optimization', *International Journal of Heat and Mass Transfer*, 215, p. 124436. Available at: <https://doi.org/10.1016/j.ijheatmasstransfer.2023.124436>.
-

- Zhang, W. et al. (2024) 'Investigation on the thermal behavior of thermal management system for battery pack with heat pipe based on multiphysics coupling model', *Energy*, 308, p. 133053. Available at: <https://doi.org/10.1016/j.energy.2024.133053>.
- Zhu, X. et al. (2024) 'Optimization design of lithium battery management system based on Z-F composite air cooling structure', *Journal of Energy Storage*, 102, p. 114068. Available at: <https://doi.org/10.1016/j.est.2024.114068>.
- Zuo, W. et al. (2022) 'Performance comparison between single S-channel and double S-channel cold plate for thermal management of a prismatic LiFePO₄ battery', *Renewable Energy*, 192, pp. 46–57. Available at: <https://doi.org/10.1016/j.renene.2022.04.116>.