Systems & Control Transactions

Original Research Article
Peer Reviewed Conference Proceeding
ESCAPE 36 - European Symposium on Computer Aided Process Engineering
Sheffield, UK. 21-24 June 2026

PSE PRESS

A CFD Analysis of Dielectric Fluid Performance in Thermal Management of Li-ion Cells

Margarita G. Correa-Ibarra[a*], Jorge A. Alfaro-Ayala[a], Jose de J. Ramirez-Minguela[a], Zeferino Gamiño-Arroyo[a], and Agustin R. Uribe-Ramirez[a]

[a] University of Guanajuato, Department of Chemical Engineering, Mexico, Guanajuato, Guanajuato
* Corresponding Author: mg.correaibarra@ugto.mx.

ABSTRACT

The rapid electrification of the energy and transport sectors has increased the demand for efficient thermal management of Lithium-Ion Batteries (LIBs). LIBs operate optimally within a narrow temperature range (15–40 °C), effective Battery Thermal Management Systems (BTMS) are essential to prevent accelerated aging and performance degradation. Immersion cooling using dielectric fluids has emerged as a promising solution; however, a systematic comparison of their thermal and hydraulic performance remains limited. This study evaluates six dielectric fluids—Silicone Oil, Mineral Oil, Sunflower Oil, AmpCoolAC-100, E5-TM410, and Deionized Water—using Computational Fluid Dynamics (CFD) simulations of a lithium-ion battery pack composed of 32 fully immersed 18650 cells. The analysis focuses on key thermophysical properties, particularly the Prandtl number and thermal diffusivity, as criteria for coolant selection. The results demonstrate a strong correlation between cooling performance and the Prandtl number. Fluids with lower Prandtl numbers provide superior heat dissipation and lower hydraulic losses. Deionized water exhibited the best overall performance, maintaining maximum cell temperatures at 31.04 °C under a 2 LPM flow rate and achieving up to 31.33% better cooling than silicone oil. In contrast, high-viscosity oils showed poor thermal performance and significantly higher pressure drops. This work establishes the Prandtl number as a critical and reliable parameter for selecting dielectric fluids in immersion-based BTMS, highlighting deionized water as the most effective coolant among those evaluated.

Keywords: Battery Thermal Management., Computational Fluid Dynamics (CFD)., Dielectric Fluids., Prandtl Number., Immersion Cooling

INTRODUCTION

The urgent need for innovative solutions lowering the environmental impact of energy and transport sectors is leading to an unprecedentedly fast adoption rate of electrification [1]. Consequently, Lithium-Ion Batteries (LIBs) have been extensively adopted, whose choice is mainly driven by their high energy density (reaching 300 Wh/kg), efficiency (as high as 98%), lifetime (8-10 years) [2]. Lithium-ion batteries (LIBs) have established themselves as the primary energy storage technology for electric vehicles (EVs), grid-scale systems, and high-performance electronics due to their high power density, energy density, and extended cycle life. Despite these advantages, LIBs are highly sensitive to temperature, with their performance, safety, and reliability depending heavily on maintaining a narrow operational range, typically between 15°C and 40°C [3]. Operating outside these limits—specifically during high-current charging or rapid discharging—can result in accelerated aging, capacity degradation, and dangerous thermal runaway events [4].

To address these challenges, Battery Thermal Management Systems (BTMS) are employed to regulate peak temperatures and ensure uniform temperature distribution across individual cells and entire modules [3]. While conventional cooling strategies, such as forced air cooling and indirect liquid cooling, an emerging and highly effective alternative is direct liquid immersion cooling, where battery cells are submerged in an electrically non-conductive dielectric fluid [5].

While current literature has explored various categories of liquids—such as hydrofluoroethers, hydrocarbons, silicone oils, and esters—most studies focus on testing specific commercial products rather than establishing a systematic selection framework. For instance, research on deionized water (DELC-1) has shown temperature rise below 2.2 °C during 3C discharge with minimal parasitic power consumption [11]. Other studies highlight the "thermal buffer" created by low-boiling fluids like 3M Novec 7000, which utilizes latent heat to maintain cell temperatures near 34 °C even under aggressive 10C cycling [4].

This project aims to conduct a rigorous computational fluid dynamics (CFD) analysis of the thermal management of a lithium-ion battery pack. The study will focus on evaluating the cooling behavior of various dielectric fluids. The goal is to identify the best fluid that ensures the best cooling of the cells. Unlike other studies that analyze dielectric fluids without a robust foundation, this project adopts a strategic selection approach. It prioritizes comparative analysis of the thermophysical properties of different dielectric fluids to identify the most option for the thermal management of lithium-ion battery packs. This study is based on a previously reported cell pack geometry, which will allow us to validate existing simulation models or, alternatively, propose concrete improvements for cooling.

METHODOLOGY

Governing Equations

The numerical model of the battery pack cooling system is based on the fundamental principles of mass, momentum, and energy conservation, which are governed by the following equations. The fluid is considered to be an incompressible, Newtonian flow, and the thermal properties of the fluids are assumed to be constant.

The mass conservation equation, Eq. (1), describes how mass is conserved within the system.

$$\partial p/\partial t + \nabla \cdot (\rho v) = 0 \quad (1)$$

The momentum conservation equation, also known as the Navier-Stokes equation, Eq. (2), describes the motion of a fluid. It relates the forces acting on the fluid, such as pressure and viscosity, to changes in its velocity.

$$\rho(\partial v/\partial t + v \cdot \nabla v) = -\nabla P + \mu \nabla^2 v + \rho g \quad (2)$$

Finally, the energy conservation equation, Eq. (3) is utilized to model the thermal behavior of the system where S_T is heat generation of battery pack. This equation is crucial for understanding the heat transfer between the batteries and the dielectric fluid.

$$\rho Cp(\partial T/\partial t + v \cdot \nabla T) = -\nabla \cdot (k \nabla T) + S_T \quad (3)$$

Model-Geometry

The present study investigated the thermal performance of a Li-ion battery pack cooled by immersion in different dielectric fluids. A numerical model was developed and simulated using the commercial software ANSYS FLUENT. The model geometry, Figure 1, based on the work [6], consisted of a pack of 32 18650-type cells arranged with a 4 mm spacing in a total immersion cooling system. The manifold for the cooling system was designed with three inlets and three outlets, each featuring a diameter of 15 mm and a height of 25 mm.

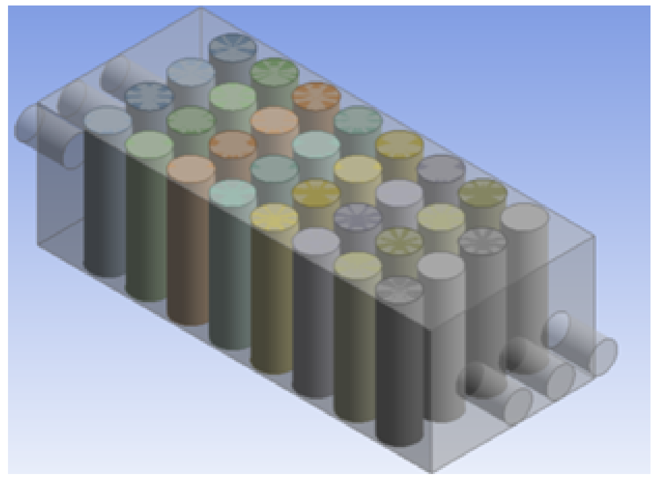

Figure 1. Geometry of pack Li-ion batteries analyzed.

Mesh Sensitivity Analysis

A mesh sensitivity analysis was conducted using the E5-TM410 dielectric fluid. The purpose of this analysis was to determine the best mesh density, balancing computational cost with solution accuracy. We focused on a range of mesh sizes between 1.55 mm and 3.75 mm, as this range consistently demonstrated stable and reliable behavior, thus justifying its selection for the rest of the study.

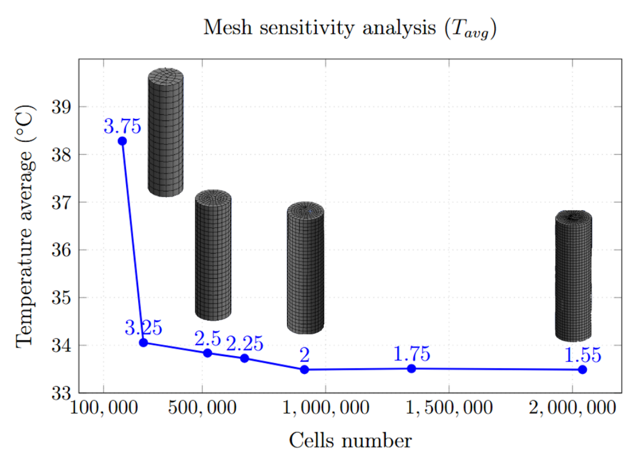

Figure 2. Mesh sensitivity analysis showing the battery temperature average as a function of mesh cell count.

Table 1. Thermal properties of dielectric fluids

Fluid	Viscosity (kg/m s)	Density (kg/m^3)	Cp (J/kg K)	K (W/m K)	Reference
Deionized water (DW)	0.0009982	998.2	4182	0.6	[7]
Sunflower (SF)	0.035672	910	1800	0.175	[8]
AmpCool AC-100 (AC)	0.00799646	811	2203.2	0.1373	[7]
E5-TM410 (E5)	0.015617	805	2100	0.14	[6]
Mineral oil (MO)	0.05152	920	1900	0.13	[7]

As shown in Figure 2, the maximum battery temperature approaches an asymptotic value beyond a cell count of approximately 700, 000, indicating a stable, mesh-independent solution. Based on these findings, a mesh size of 2.0 mm was selected for the full study, as it provided an optimal balance. The corresponding mesh, consisting of 914, 140 cells, yielded accurate results without the excessive computational burden of finer meshes. The error analysis further confirmed this choice, showing a maximum error of 14.3% for the coarsest mesh (3.75 mm). Notably, the error stabilized at zero for both the 2 mm and 1.55 mm meshes.

Dielectric Fluids Selection

To ensure a rigorous selection of dielectric fluids, we began by analyzing their thermophysical properties to determine their capacity for heat removal from the battery cells. We evaluated the properties of six fluids reported in different studies like their optimal fluids see Table 1, focusing initially on viscosity. The initial hypothesis was that a fluid with high viscosity would impede heat removal from the batteries, even with a powerful pumping system, which would also be costly. This preliminary analysis led us to conclude that a low viscosity is a critical requirement. A similar analysis was performed for density. Subsequently, we focused on two others crucial thermophysical properties: heat capacity (Cp) and thermal conductivity (k). For a fluid to be a coolant, it must possess high values for both Cp and k, as these properties directly influence its ability to exchange heat with another body.

The relationship between these properties was further explored through two dimensionless parameters: the Prandtl number (*Pr*), as defined in Eq. (4), and thermal diffusivity (α), shown in equation Eq. (5). The analysis revealed that high thermal diffusivity is desirable for effective cooling. Conversely, a low Prandtl number is also indicative of a coolant. This is because a fluid with both high diffusivity and low viscosity will have a low Prandtl number, which correlates with superior cooling performance.

$$Pr = \frac{\mu}{\alpha} \tag{4}$$

$$\alpha = \frac{k}{Cp\rho} \tag{5}$$

Table 2 shows the Prandtl number (Pr) and thermal diffusivity values for the previously selected dielectric fluids. These values reveal a clear hierarchy, with deionized water exhibiting the lowest Pr number (Pr ≈ 7), and silicone oil presenting the highest (Pr ≈ 8808). This significant difference in Pr suggests a wide range of potential cooling performance. Based on this trend, we simulated the six fluids to validate the hypothesis. If the Prandtl number serves as a reliable indicator of cooling performance, we expect the cooling efficiency of the fluids to follow the same order as their Pr ranking.

Table 2. Prandtl number ranking of dielectrics fluids.

Fluid	α (m^2/s)	Pr	Ranking
Deionized water	1.44×10^{-7}	6.96	1
AmpCool AC-100	7.68×10^{-8}	128.32	2
E5-TM410	8.28×10^{-8}	234.26	3
Sunflower	1.07×10^{-7}	366.91	4
Mineral oil	7.44×10^{-8}	752.98	5
Silicone oil	1.13×10^{-7}	8807.95	6

Boundary Conditions

The simulation was initialized under transient conditions with a time step of 720 seconds and was terminated once convergence was achieved. Heat generation was modeled using Eq. (6), within a numerical domain previously analyzed [6].

$$Q_b = 0.0013t^3 - 0.97t^2 + 143.12t + 293016 = 0 \tag{6}$$

The thermal properties of the batteries, presented in Table 3, were considered constant throughout the simulation. To accurately represent the thermal behavior of the cells, a thermal conductivity matrix was incorporated. This approach accounted for the anisotropic nature of the material by specifying thermal conductivity in the axial (k_{zz}=19.03), radial (k_{yy}=1.07), and tangential (k_{xx}=19.03) directions, effectively modeling the thermal conductivity tensor.

Table 3. Properties of the Battery Pack Simulation

Thermal property	Value
Density (kg/m^3)	2055.1
Specific heat (J/kg K)	1129.95
Thermal conductivity (W/m K)	Anisotropic

Table 4. Boundary conditions of the fluids.

Boundary Conditions	Value
Inlet Temperature (°C)	25
Volumetric Flow Rates	2, 3, 4 and 5
Wall Slip Condition	Non-Slip

The boundary conditions for the fluids, as detailed in Table 4, were applied to the six fluids analyzed in this study. The investigation was conducted at four different volumetric flow rates (LPM) to evaluate the influence of fluid velocity on battery cooling. The thermophysical properties for each fluid are listed in Table 1.

RESULTS

Model Validation

As shown in Figure 3, the simulated maximum and average temperatures exhibit excellent agreement with the values reported in the reference article [6]. The maximum temperature data showed a maximum error of 2.25% at a flow rate of 5 LPM, while the minimum error was 0.49% at 3 LPM. Similarly, the average temperature data demonstrated a comparable trend, with a maximum error of 1.3% and a minimum error of 0.35%.

All percentage errors are well within the acceptable range for this type of analysis, these results successfully validate the numerical model against the published reference data.

Figure 4 presents the simulation results for the six dielectric fluids, clearly indicating deionized water delivered the best cooling performance. It maintained the maximum battery temperature within the optimal Li-ion operating range (15°C–40°C) across all volumetric flow rates, achieving a value of 30.04°C even at the lowest flow of 2 LPM. In contrast, silicone oil was the least effective, only maintaining a temperature within the safe range at the highest flow rate of 5 LPM (39.3°C).

As demonstrated, deionized water (DW) was the only coolant capable of maintaining the battery temperature within the desired operational range across all tested volumetric flow rates. In contrast, the other fluids—E5-TM410, AmpCoolAC-100, Sunflower oil, and mineral oil—only maintained temperatures within the acceptable range at higher volumetric flow rates of 4 and 5 LPM. Furthermore, even under these conditions, they operated at the upper thermal limit of the range, rendering them less reliable due to the heightened risk of temperature fluctuations exceeding the safe operational threshold.

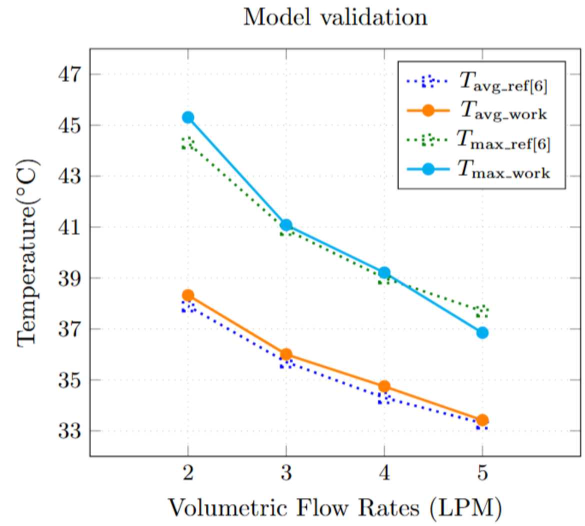

Figure 3. Thermal behavior of batteries using the E5-TM410 fluid for model validation.

Thermal Behavior of the Dielectric Fluids

At a reduced flow rate of 2 LPM, the performance difference among the coolants became more pronounced. Silicone oil exhibited the most significant thermal deviation, exceeding the maximum temperature limit by 17.7% (47.11°C), followed by mineral oil (14.66%, 45.86°C), sunflower oil (13.38%, 45.35°C), E5-TM410 (13.26%, 45.30°C), and AmpCoolAC-100 (11.76%, 44.71°C). Given that all tested fluids exceeded the safe operational threshold at this flow rate, it is deemed unsuitable for operation. In contrast, a flow rate of 5 LPM is recommended, as it maintained all fluids within the prescribed temperature range. Consequently, silicone oil was identified as the least effective coolant, maintaining the battery within the operational range only at the maximum flow rate of 5 LPM. These findings unequivocally designate silicone oil as unsuitable for this battery cooling application under most operational flow conditions.

The distribution of temperature within the battery pack provides direct insight into the effectiveness of heat transfer between the dielectric fluids and the batteries. As previously analyzed, deionized water provides superior cooling performance compared to silicone oil. These findings are further supported by the thermal behavior observed at a flow rate of 5 LPM, as illustrated in Figure 5a-c. The results compare the temperature profiles of three dielectric fluids selected to represent the top, median, and bottom rankings of the proposed methodology.

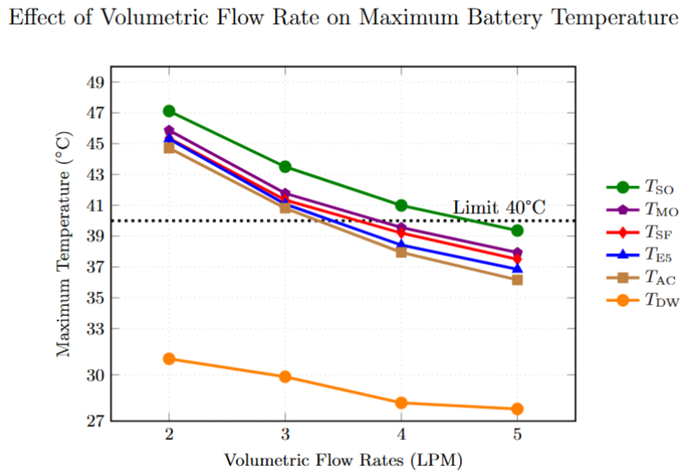

Figure 4. Relationship between the volumetric flow rate (LPM) and the maximum battery temperature for the different dielectric fluids.

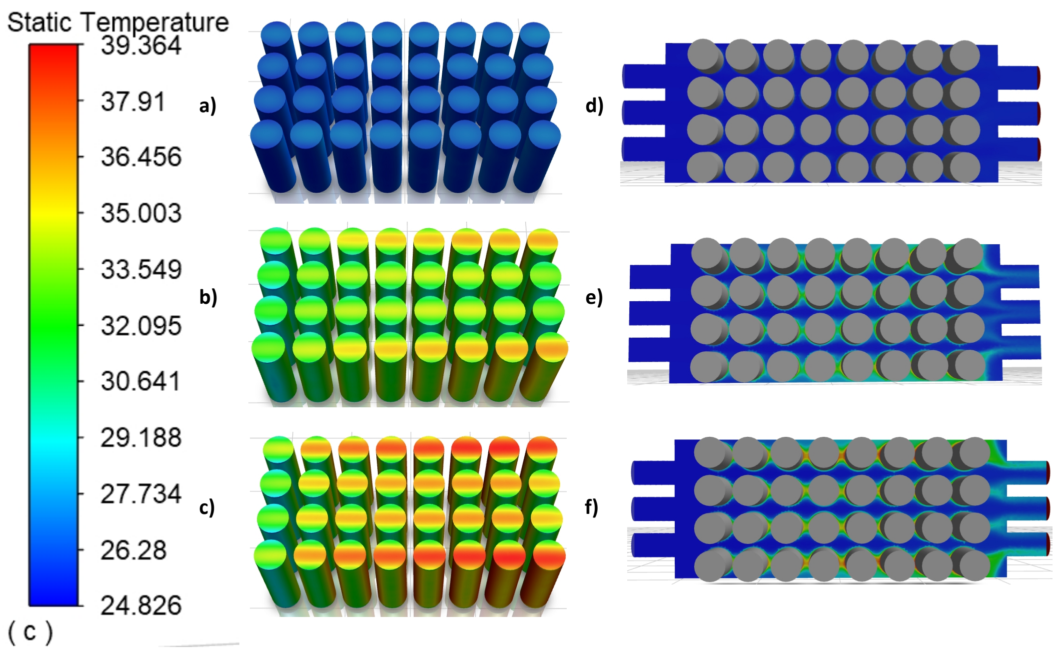

Figure 5. Comparison of the thermal distribution within the battery pack for three representative coolants selected through the proposed methodology: (a) deionized water (top-ranked), (b) E5-TM410 fluid (intermediate performance), and (c) silicone oil (lowest-ranked). Panels (a–c) show the temperature distribution across the battery cells, while panels (d–f) illustrate the corresponding temperature fields of the coolant flow within the pack for (d) deionized water, (e) E5-TM410, and (f) silicone oil.

Notably, the highest battery temperature was recorded when using silicone oil, confirming its lower performance relative to the other candidates. A closer inspection of an individual cell reveals evident anisotropic thermal diffusion. This phenomenon is a direct consequence of the simulated thermal conductivity varying with direction (radial, axial, and tangential).

The overall temperature distribution across the battery pack is non-uniform. Higher temperatures are consistently observed in the downstream and peripheral cells in the six fluids. Achieving a uniform temperature is critical for prolonging the cycle life of each cell. Thermal non-uniformity can lead to the premature degradation and eventual failure of individual cells, which necessitates the costly replacement of the entire battery pack.

To mitigate this issue, the implementation of a system that promotes a more uniform thermal distribution is essential. A potential solution is the use of turbulence promoters, which can disrupt the boundary layer and enhance heat transfer throughout the pack of batteries.

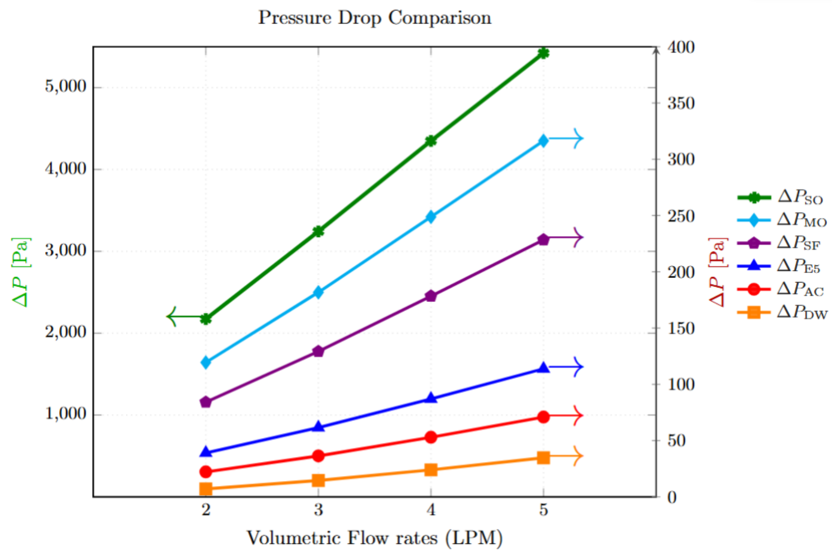

Figure 6. Pressure Drop comparison: Silicone Oil (left axis) vs. Others fluids (right axis).

These promoters could help transition the flow from a laminar to a turbulent regime, improving cooling efficiency at the implemented volumetric flow rates. The implementation of turbulence promoters is deemed necessary for this simulation. Promoters enhance fluid velocity and disrupt the boundary layer, which facilitates more effective heat removal from the batteries. This is crucial because, without them, the fluid's capacity to absorb heat diminishes as it flows through the pack, leading to higher temperatures in the downstream and peripheral cells.

This behavior is corroborated by the fluid temperature distribution shown in Figure 5d-f. The figure indicates that fluid temperature is significantly higher in the downstream cells compared to the inlet. This can be attributed to the fluid's initial momentum and impact with the first row of batteries, which promotes local turbulence and more effective cooling. As the fluid progresses, its momentum is dissipated and its heat absorption capacity diminishes, resulting in a less efficient heat exchange with the subsequent cells.

Further evidence for this behavior is provided by the fluid outlet temperatures at a flow rate of 5 LPM, the higher outlet temperatures observed in the more viscous fluids, such as silicone oil (26.34°C), mineral oil (26.01°C) and sunflower (26.02°C), particularly at low volumetric flow rates, indicate a less efficient heat exchange. This suggests that the longer residence time of these fluids in the battery pack allows for a greater increase in temperature as they absorb heat, which is less effective for overall thermal management.

The pressure drop across the battery pack, detailed in Figure 6, exhibits a direct correlation with fluid viscosity. As expected, the highly viscous silicone oil (μ= 0.96 kg/m·s) produced the most significant pressure drop, measuring 5422.29 Pa at 5 LPM—a value approximately 156 times greater than that of deionized water. Mineral oil (μ= 0.05 kg/ms), the second most viscous fluid, followed with a pressure drop of 331.42 Pa, which is about 9.12 times that of water. This substantial difference underscores the profound impact of even incremental viscosity increases on hydraulic resistance. The remaining fluids exhibited progressively lower pressure drops: sunflower oil at 228.4 Pa (6.58x DW), E5-TM410 at 113.83 Pa (3.2x DW), and AmpCoolAC-100 at 70.9 Pa (2.04x DW).

This behavior is a direct consequence of increased internal fluid friction and flow resistance at higher viscosities and volumetric flow rates. A high-pressure drop is a critical design drawback, as it necessitates a more powerful pumping system, thereby increasing the auxiliary energy consumption and reducing the net energy available for vehicle propulsion. While a turbulent flow regime—potentially enhanced by turbulence promoters—is desirable for improved cooling performance, its implementation would further exacerbate the pressure drop. Therefore, a strategic balance must be struck. It is suggested that turbulence promoters are most effectively deployed with low-viscosity fluids. This approach would enhance heat transfer while maintaining the associated pressure drop at a manageable level, avoiding the excessive energy costs incurred with high-viscosity coolants like silicone oil.

Hypothesis Validation

The simulation results validate the initial hypothesis that the Prandtl number (Pr) is a good parameter for selecting effective dielectric cooling fluids. As illustrated in Figure 4, the cooling performance of the fluids exhibits a strong inverse correlation with their Prandtl number. Deionized water, possessing the lowest Pr, delivered the best cooling performance, followed in descending order of performance by AmpCoolAC-100, E5-TM410, Sunflower oil, mineral oil, and finally, silicone oil with the highest Pr. This trend is further corroborated by the data in Figure 7. At a flow rate of 5 LPM, silicone oil (Pr ≈ 8807.95) reached a maximum battery temperature of 39.3°C, approaching the upper safe operating limit, whereas deionized water (Pr ≈ 6.96) maintained temperatures well within the optimal range.

This analysis confirms that the Prandtl number effectively integrates the influence of key thermophysical properties, as it is defined as the ratio of momentum diffusivity (kinematic viscosity, μ) to thermal diffusivity (α), where α is itself a function of thermal conductivity (k), density (ρ), and specific heat (Cp). While high thermal conductivity and specific heat capacity are crucial for effective heat transfer, they are insufficient if not considered in conjunction with viscosity. Fluids with favorable k and Cp values but high viscosity will exhibit a high Prandtl number, which significantly impedes heat transfer by restricting fluid flow. This underscores the necessity of a balanced thermophysical profile, where high thermal diffusivity (enabling rapid heat propagation) is coupled with low viscosity (ensuring efficient flow) for superior thermal management.

Furthermore, a quantitative analysis was conducted to compare the cooling system of each dielectric fluid against the top-performing coolant, deionized water. This comparison was based on the average battery temperatures recorded at a flow rate of 5 LPM. The results demonstrate that deionized water provides superior cooling, outperforming silicone oil by 31.33%, mineral oil by 28.75%, sunflower oil by 25.45%, E5-TM410 by 24.73%, and AmpCoolAC-100 by 22.42%.

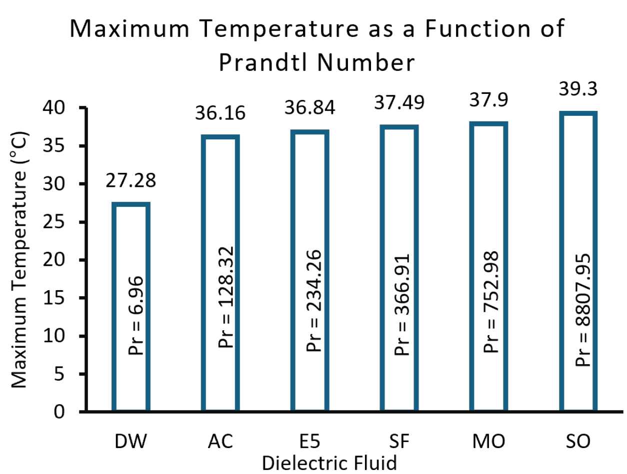

Figure 7. Comparison of Coolants: Maximum Temperature as a Function of Prandtl Number

Finally, the simulation results robustly support the hypothesis that a low Prandtl number and high thermal diffusivity are optimal for battery cooling. Deionized water is unequivocally the superior coolant among those tested, as it simultaneously excels in minimizing the maximum battery temperature, ensuring thermal uniformity, and operating with the highest hydraulic efficiency.

CONCLUSION

The analysis of the battery pack's thermal management through immersion in different dielectric fluids has conclusively validated the hypothesis that the thermophysical properties of the fluids, particularly the Prandtl number (Pr), are decisive for cooling. The simulation results confirmed that deionized water, with the lowest Prandtl number, provided the most superior cooling performance, maintaining maximum battery temperatures within the safe operational range of 20-40°C and outperforming silicone oil by 31.33%.

Furthermore, the analysis of pressure drop revealed a key disadvantage of the more viscous fluids. The high pressure drop observed in silicone oil implies a greater energy demand for the pumping system, which compromises the vehicle's overall energy efficiency. In contrast, deionized water achieved exceptional cooling with minimal pressure drop, positioning it as the most promising option for a high-performance and energy-efficient thermal management system.

The uniform thermal management of battery packs is critical for maintaining their performance and lifespan. In a further work, a key area for improvement lies in achieving a more uniform temperature distribution across the battery cells. We propose the implementation of turbulence promoters, cooling fins integrated into the battery cells, or a combined arrangement of both within the cooling channels. These promoters are designed to alter the fluid's flow patterns, transitioning from a laminar to a more turbulent regime. This change in flow behavior enhances the convective heat transfer coefficient, leading to a more effective heat exchange and, ultimately, a more uniform and efficient cooling of the batteries.

ACKNOWLEDGEMENTS

This work was supported by *Secretaría de Ciencia, Humanidades, Tecnología e Innovación* (SECIHTI) through the graduate scholarship awarded to author Correa [No. CVU: 2082437]. The authors express the support to the Sistema Nacional de Investigadoras e Investigadores (SECIHTI). The author also express their gratitude to Dr. Fernando Israel Gómez Castro for his technical guidance and for encouraging the presentation of this work at this international venue.

AUTHOR IDENTIFIERS

Author ORCIDs:
Correa Ibarra MG: 0009-0003-6487-0718

Alfaro Ayala JA: 0000-0003-3081-282X
Ramirez Minguela JJ: 0000-0003-1921-5864
Gamiño Arroyo Z: 0000-0002-6228-8586
Uribe Ramirez AR: 0000-0002-3768-5301

REFERENCES

1. Muratori M, Mai T. The shape of electrified transportation. Environ. Res. Lett. 16:011003 (2020). https://doi.org/10.1088/1748-9326/abcb38
2. Wen J, Zhao D, Zhang C. An overview of electricity powered vehicles: lithium-ion battery energy storage density and energy conversion efficiency. Renewable Energy 162:1629-1648 (2020). https://doi.org/10.1016/j.renene.2020.09.055
3. Venkateswarlu B, chavan S, Joo SW, Metwally ASM. Numerical study on cooling enhancement in lithium-ion battery modules using hybrid nanoliquids in flow channels. International Journal of Hydrogen Energy 112:231-242 (2025). https://doi.org/10.1016/j.ijhydene.2025.02.399
4. Giammichele L, D'Alessandro V, Falone M, Ricci R. Preliminary analysis of a novel battery thermal management system based on a low boiling dielectric fluid. IOP Conf. Ser.: Earth Environ. Sci. 1106:012017 (2022). https://doi.org/10.1088/1755-1315/1106/1/012017
5. Nitin M. *CFD Simulation of Thermal Management System (Immersion Cooling) of Lithium Ion Batteries in EVs* (2021). https://doi.org/10.13140/RG.2.2.19948.69767
6. Han JW, Garud KS, Kang EH, Lee MY. Numerical study on heat transfer characteristics of dielectric fluid immersion cooling with fin structures for lithium-ion batteries. Symmetry 15:92 (2022). https://doi.org/10.3390/sym15010092
7. Jithin KV, Rajesh PK. Numerical analysis of single-phase liquid immersion cooling for lithium-ion battery thermal management using different dielectric fluids. International Journal of Heat and Mass Transfer 188:122608 (2022). https://doi.org/10.1016/j.ijheatmasstransfer.2022.122608
8. Gutierrez CM, Fernandez AO, Renedo Estebanez CJ, Salas CO, Maina R. Understanding the ageing performance of alternative dielectric fluids. IEEE Access 11:9656-9671 (2023). https://doi.org/10.1109/access.2023.3239895
9. Roe C, Feng X, White G, Li R, Wang H, Rui X, Li C, Zhang F, Null V, Parkes M, Patel Y, Wang Y, Wang H, Ouyang M, Offer G, Wu B. Immersion cooling for lithium-ion batteries – a review. Journal of Power Sources 525:231094 (2022). https://doi.org/10.1016/j.jpowsour.2022.231094