Effects of Thermal Stratification and Heat Transfer Augmentation using Hybrid Nanofluids.

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"PAPER FOR THE YOUNG SCIENTIST AWARD"

1. INTRODUCTION & OBJECTIVE

This extensive study explores the field of managing the battery temperature of electric vehicles (EVs) in great detail, with a primary focus on ethylene glycol solution for liquid cooling system optimization. Conventionally, the battery pack is cooled by running a mixture of water and ethylene glycol, although this approach is insufficient. The major reason of Lithium -ion battery failures is overheating, however physical damage to the battery can result in thermal hazardous issues. Also, one of the numerous issues affecting Lithium-ion batteries is stratification, which reduces the battery capacity. This article is innovative in the implication that the consequence of thermal stratification and liquid cooling system of Lithium-ion batteries in EVs with ND-AG/EG hybrid nano coolant. Moreover, Numerical analysis is made in terms of thermal stratification, mixed convection and non-Darcy porous medium. We can observe this new physical development in mathematical formulation of non-linear PDE. Utilizing the suitable dimensionless parameters the governing equations are converted into non-dimensional ordinary differential equations and solve numerically using MATLAB. The numerical findings are explored graphically. Validation of the numerical approach, for few cases the present study and previous in literature have proportionality. The current findings exhibit that the ND-Ag/EG hybrid nanofluids at dissimilar temperatures of EG, EG at 25ºC shows the enormous heat transfer in the lithium plated liquid cooling system.

In the modern world, the most essential requirement of life is transportation, yet the conventional combustion engine is progressively becoming outdated. Petrol-diesel vehicles are highly polluting and causes global warming. Due to the rapid growth of population, Industries, and reduction in natural sources of fossil fuels. We need to switch over electrical vehicles. Electrical vehicles (EVs) are significantly more environmentally friendly and emit no exhaust emissions. Also an electrical vehicle has substantially lower cost consumption than the petrol-diesel. Chen et al. [1] reviewed that the usage of EVs has been steadily rising with the use of Lithium-ion batteries. Khan et al. [2] analyzed in terms of battery performance and safety, modern electric cars (EVs) still fall short of customer expectations, even in spite of notable advancements in the battery thermal management systems. Their study resulted that the creation of thin and heat resistant battery cells can benefit from the recently released BTMS. Jung et al. [3] Investigated how to improve the properties of heat transmission and battery thermal management by employing laser-induced graphene (LIG). Direct laser irradiation is used to apply LIG to a LiFePO4 battery's polyimide. Their study offers insightful information about how high-performance batteries that are subjected to harsh environments to regulate heat.

One of the numerous issues affecting the safety, life cycle, and efficiency of lithium-ion batteries is a phenomenon known as stratification. The uneven distribution of lithium-ions in the battery cell's electrolyte is due to the effect of stratification. Murthy et al. [4] analyzed the magnetic influence of a non-Darcy porous media saturated with thermally stratified nanofluid under convective boundary conditions. Their findings resulted when the thermophoresis parameter is increased, the non-dimensional heat transfer rate decreases and the velocity, temperature, nanoparticle mass transfer rate, and volume fraction distributions all increase. Hemalatha and Kameswaran. [5] studied the shape effects of nanoparticle in a non-Darcy porous medium in a vertical plate. Madhavi et al. [6] they investigated how mixed convective heat transfer from a vertical plate in a non-Darcy porous media is affected by thermal stratification with variable permeability and melting.

Plate specification based on the literature

Colling plate thickness	2-3 mm
Cooling wall thickness	0.60- 1.20 mm
Coolant inlet temperature	298.15-303.15 K

2. RESULTS & HIGHLIGHTS OF IMPORTANT POINTS

Improving the nanoparticle volume fraction, the effects of stratification is reduced. This results in a reduction of uneven distribution within the Lithium-ion batteries. It helps to prevent the reduction in battery capacity and degraded life cycle, short circuit, and waste heat scenario.

The current findings exhibit that the (ND-Ag/EG) provides the superior heat source in the presence of stratification. As a result of enhanced mixed convection, there is a reduction in stratification, which shows improved heat transfer.

W:EG(0:100) at 25ºCand W:EG(60:40,40:60) at 20ºC are compared to show the improved heat transfer. Various temperatures of EG are also analysed to find the heat transfer performance of ND-Ag/EG. W:EG(0:100) at 25ºC shows the enormous heat transfer rate in Lithium plated liquid cooling system. However, the requirement to keep the battery temperature at a constant 25ºC poses a significant barrier to technology's general implementation, these findings and combination of ND-Ag/EG will be useful for the upcoming technology.

Highlights

- Increasing the nanoparticle volume fraction reduces the temperature, which helps to improve the heat transfer performance of the battery.
- Improving the mixed convection parameter reduces the effects of stratification, which promotes to improve the battery capacity.
- Heat source and sink of the battery is also obtained graphically, It results is decreasing temperature profile even at temperature variations.
- Temperature is varied to analyse the battery capacity, Even at increased temperature the heat transfer performance is more by the use of ND-Ag/EG hybrid nanofluid.

- Different temperatures of ethylene glycol are analysed and Also different ratios of water and ethylene glycol are also considered, the our finding resulted that EG shows enhancing heat transfer rate than the mixture of water and ethylene glycol combination.
- Although at four different temperatures, EG at 25ºC are fixed to reduce the stratification effects and improve the heat transfer, because the inlet temperature is specified in the existing literature.
- Nanodiamond nanoparticle has very high thermal conductivity metal which helps to control the heat generation and silver nanoparticle is reacting as a antioxidants which protect the engine from waste heat scenario.

REFERENCES

[1] W. Chen, J. Liang, Z. Yang, G. Li, "*A review of lithium-ion battery for electric vehicle applications and beyond*,'' Energy Procedia 158 (2019) 4363-4368.

[2] S.A. Khan, C. Eze, K. Dong, A.R. Shahid, M.S. Patil, S. Ahmad, I. Hussain, J. Zhano, "*Design of a new optimized u-shaped lightweight machine learning approach*," International Communications in Heat and Mass Transfer 136 (2022) 106209.

[3] E. Jung, D. Kong, M. Kang, J. Park, J.-H. Kim, J. Jeong, J.B. In, K.-Y. Oh, H. Lee, "*Enhanced Immersion Cooling using Laser-induced graphene for Li-ion battery thermal management*," International Communications in Heat and Mass Transfer 155 (2024) 107558.

[4] P.V.S.N. Murthy, Ch. Ram Reddy, A.J. Chamkha, A.M. Rashad, "*Magnetic effect on thermally stratified nanofluid saturated non-Darcy porous medium under convective boundary condition*," International Communications in Heat and Mass Transfer 47 (2013) 41-48.

[5] R. Hemalatha and Peri. K. Kameswaran, "*Impact of nanoparticle shapes on non-Darcy porous medium*,'' International Communications in Heat and Mass Transfer 130 (2022) 10577.

[6] M. V. D. N. S. Madhavi, Peri K. Kameswaran and K. Hemalatha, "Effects of Thermal Stratification and Variable Permeability on Melting over a Vertical Plate," Numerical Heat Transfer and Fluid Flow, Lecture Notes in Mechanical Engineering.