Analysis of electric vehicle battery cooling using fins

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Abstract: As the automotive industry progresses, electric vehicles (EV) grow with increasing demand throughout the globe. Nickel-metal hydride (NiMH) battery and lithium-ion (Li-ion) are widely utilized in EV due to their advantages such as impressive energy density, good power density, and low self-discharge. However, the batteries must be operated within their optimum range for safety and good thermal management to enable an extended lifespan, lower costs, and for improving safety. The need for a liquid cold plate (LCP) to be utilized in EV batteries is now highly reliable on the distribution of the specified temperature instead of only standard cooling systems. The main objective of this paper is to create a design of fin that can increase the rate of heat transfer in the electric vehicle battery. This project is about the analysis of Electric vehicle battery cooling using fins which includes the design of a fin and analysis of it using analysis software, Annoys. It was done to find its heat transfer rate and Nusselt number.

This has many applications in the field of electric vehicle manufacturing where these types of fins can help in maximum heat transfer thereby increasing the life of the vehicle and decreasing the possibilities of failures. In this paper, analysis has been carried out at different air velocities with different fin modeling as real fins. The geometry of the fins has a high impact on the heat transfer coefficient. The main goal is to find a suitable design of fin that can efficiently help in the cooling of the battery by increasing the rate of heat transfer.

Index Terms – **Fins, Honeycomb fin, Perforated Honeycomb fin.**

I. INTRODUCTION

Fin is the extended surface that's accustomed increase the speed of convective heat transfer. The fins are generally used on the surface where the heat transfer rate without the utilization of fins is insufficient to cool down or heat the body. As per the formula of convective heat transfer, the speed of heat transfer is directly proportional to the area exposed to the convective medium. Therefore the fins help to extend the area exposed to the circulating medium. Firstly, the heat is transferred from the body to the fins by means of conduction and then this heat from the fin is transferred away by convection.

For well over a century efforts have been made to produce more efficient methods for heat transfer. Most of these methods were aimed to fulfil the demands put forward by the automobile industry. When designing cooling systems they must be highly efficient and cost-effective. Many studies conducted by different researchers have shown the development over the years. Mostly used fins for heat transfer were rectangular fins. Many modifications were done to this model and studies were conducted. In the Battery module, thermal management paper by Jiaqi Fu, Xiaoming Xu and Renzheng Li they found that heat transfer fins inside a liquid cold plate can significantly decrease the highest temperature of the battery module and temperature difference among cells [1]. CFD analysis of finned tube heat exchangers by Mate Petrik, Gabor Szepesi and Karoly Jarmai has been done using modifications of the fin model at different velocities and temperatures to obtain an acceptable fin model for heat exchange purposes[4].In the paper "design and analysis of honeycomb structure cooling fin" by Maidin S and Azmi N F redesigned honeycomb structure cooling fin for high performance LED and analysis of thermal base on conduction and natural convection was conducted[7].

II. LITERATURE REVIEW

Electric vehicle battery

Normally Lithium-ion battery is used in electric vehicles for their working. In this work, we have taken Tata Nexon EV as the reference for the analysis. Tata Nexon EV has a permanent magnet synchronous AC motor whose power is 143 hp and produces a torque of 250 Nm. The battery is a high-energy density Lithium-ion battery pack with energy of 40.5 kWh. Currently used thermal management of batteries is done by a liquid cooling method. The dimension of the vehicle includes length * width * height (mm) is 3993 * 1811* 1616. The estimated charging time is about 6.5 to 15 hours using any 15A plug point or 7.2kW AC fast charger whereas 56 minutes using a 50kW DC fast charger [8].

Functions of cooling fin

Cooling fins depend on conduction to diffuse the heat away from what's being cooled. The fins are designed to extend the surface area with another liquid. Here the heat is transferred using convection, cooling the fins and warming the liquid. Cooling fins speed up the heat transfer as they create a way larger surface area with the liquid than would preferably be available.

Fin design consideration

The conventional cooling fin is preferred by most manufacturers as it is more reliable and can reduce the surrounding heat. Moreover no regular maintenance is needed and no noise will be produced when using the cooling fins. In order to have a good cooling function, certain factors need to be highlighted in designing the cooling fin. Firstly, the surface area of the cooling should be focused. An effective cooling fin should have a wide surface area to flow the heat from the surrounding.

Other than that, the material that is being used should also have good heat conductivity and the design should not be too large or too heavy. Therefore, it is advisable to optimize the structure of the cooling fin. The design will be considered optimum when the fins require minimum cost of manufacture and are light in weight.

Material for honeycomb fin

Material selection plays a critical role in producing cooling fin for top performance. The goals of material selection include improving device performance, thermal regulation, and manufacturing yield, further as reducing thermal stresses, size requirements, weight, and cost. Aluminum and copper are favorable thermal management materials utilized within the assembling of cooling fins. The reason of applying those materials in cooling fin production is because the high thermal conductivity and reasonably low coefficient of thermal expansion properties exhibited by both materials. As for prime performance, low density material is preferable so as to scale back the weight.

III. METHODOLOGY

3D design modelling

The modelling of honeycomb structure is done using Solidworks software 2013 version. Two models are created.In Model-1 a hexagon of dimension 10mm is created and is extruded up to 30mm along with it, a base of 5mm is also created.Model-2 is a modification of Model-1 with perforations on it. To show the fluid part a rectangular section is created with dimensions 176.56mm * 178.88mm and is extruded up to 50mm.

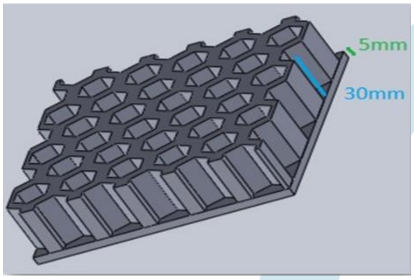

Fig.1. Honeycomb fin

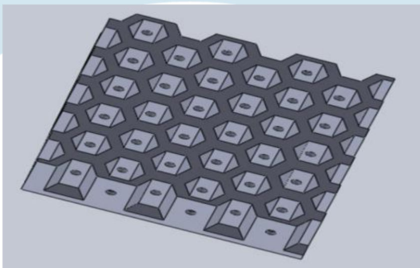

Fig.2. Perforated honeycomb fin

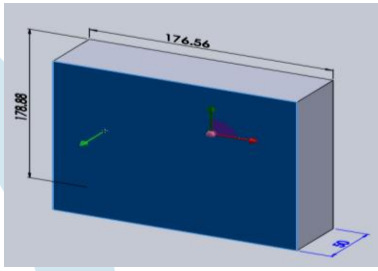

Fig.3. Fluid part

Assembling

The basic honeycomb structure and perforated honeycomb structure are assembled with the fluid part using Solidworks software and further analysis is done.

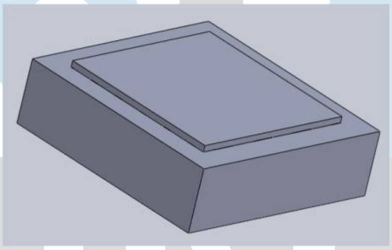

Fig.4.Assembled image

Analysis

Ansys Fluent is used for analysis as it generates accurate and reliable fluid simulation results. The geometry of the model is setup by naming the air inlet, air outlet and heating surface of the models. The Boolean operation used for this is, subtract and then meshing is done. Cartesian meshing is done to the models. The reason for choosing Cartesian meshing is because it makes handling complex and moving geometry much easier and accurate by cutting the cells rather than stretching and compressing the cells to fit. The resolution of the mesh is independent of its geometry. Cartesian meshing provides more grid refinements and increases accuracy of results. Mesh independence test of the models have to be conducted for finding the accurate value of meshing. It is done by running a few simulations with different mesh resolution and checking if the result changes with further refinement of the mesh. After mesh independence test the orthogonal mesh value is obtained as 0.32 for model-1 and 0.42 for model-2.After meshing of the models simulation is run. For that K-epsilon model is selected because this model is commonly used in computational fluid dynamics to simulate mean flow characteristics under certain conditions. After referencing journals the material of the fin is chosen as Aluminium and following boundary conditions are applied. The given velocities are 8m/s, 10m/s and 12m/s. The given temperatures given are 300K,320K and 350K.Then the initialisation of the solution is done before running it and the number of iterations given are 100 to obtain more accurate results and then calculations are run to obtain results.

Analyse the results

The obtained results gives information about surface heat transfer coefficient and Nusselt number of both models and a graph is plotted using Nusselt number and velocity for both models and a conclusion is reached. Comparison between existing cooling fin and proposed designs are done.

IV. Results and discussions

Obtained Nusselt numbers shows effective convection through the model. Surface heat transfer rate is maximum at 350K.The figure shows the temperature boundary layer of model-1.In Model-2 the obtained Nusselt numbers shows more effective convection than in model-1 and also the surface heat transfer coefficient is higher at 350K .Since there are perforations rate of heat transfer is much higher as shown in the figure.

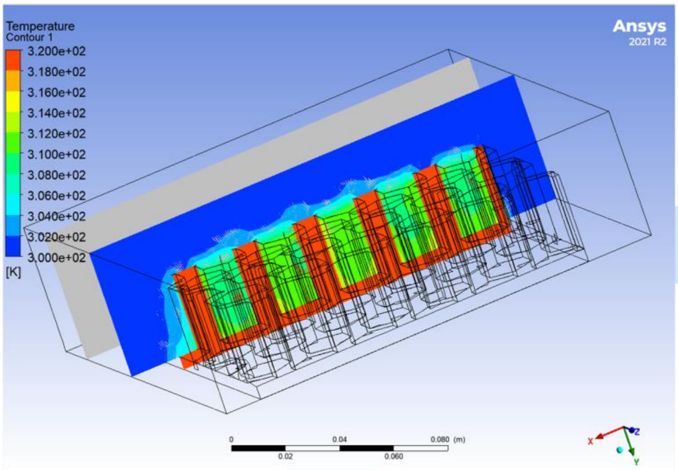

Fig.5. Analysis result of Model-1

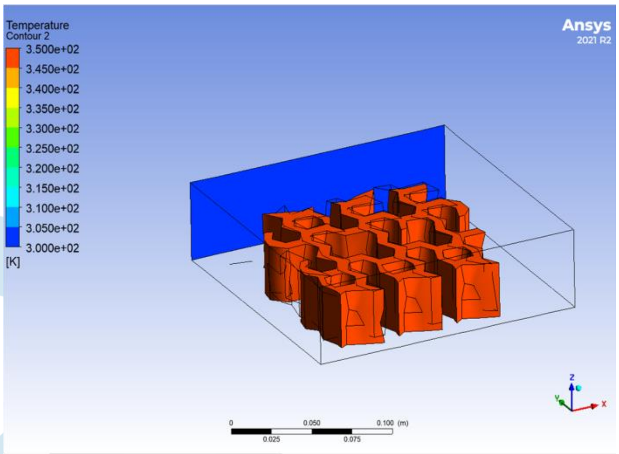

Fig.6. Analysis result of Model-2

Result Comparison

Nusselt number of Model-1 and Model-2

The value of Nusselt number is greater for Model-2.Greater the Nusselt number more effective convection occurs.

Velocity(m/s)	Nusselt numbers	
	Model-1	Model-2
8	0.0259	0.00252
10	450	0.068
12	510	610

Table 1. Nusselt number of Model-1 and Model-2

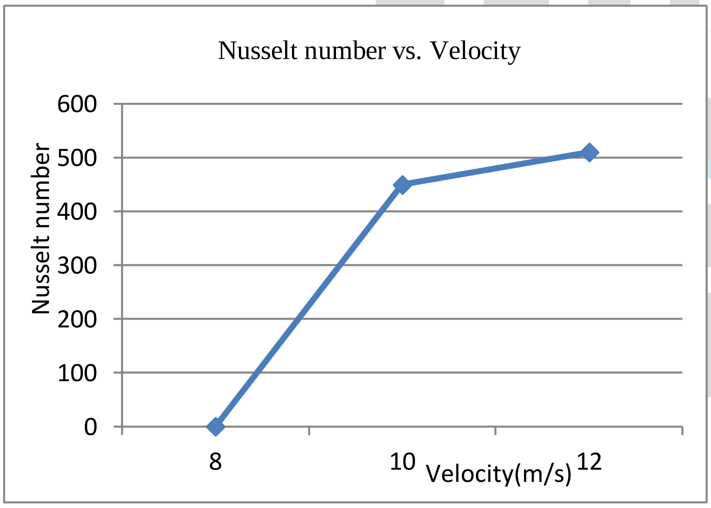

Fig.7.Nusselt number vs. velocity of Model-1

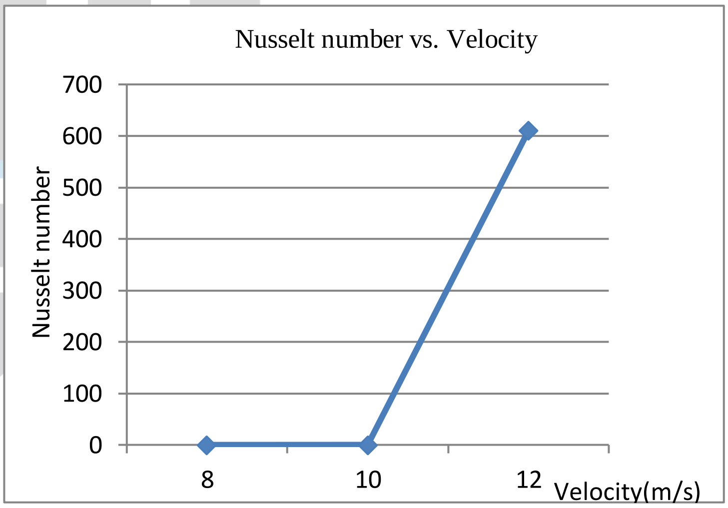

Fig.8.Nusselt number vs. velocity of Model-2

As Nusselt number increases heat transfer coefficient also increases. In Model-1 heat transfer coefficient is high at 350K which indicates that Nusselt number is also more at 350K. In Model-2 also the heat transfer coefficient is high at 350K and the value of Nusselt number is more than that of Model-1 which shows that more effective convection occurs through Model-2.

Comparison with the existing fin model

PROPERTIES	EXISTING FIN	MODEL-1	MODEL-2
Shape	Rectangular, Triangular	Honeycomb	Honeycomb with perforations
Number of fins	31	30	30
Nusselt number	3-14	0.0249-510	0.0025-610
Mass	High	Low	Lower
Type of design	Solid	Hollow	Hollow
Material usage	High	Low	Low

Table 2.Comparison of Model-1 and Model-2 with existing fin design.

V. CONCLUSION

In conclusion, this study has successfully achieved the objective which is to design a honeycomb structure cooling fin for high performance of battery of electric vehicle. In this work we found the difference between the existing cooling fin design and the proposed honeycomb structure cooling fin design. Both proposed cooling fins undergone analysis and simulation is done. After the simulation process results were compared. The proposed designs have low mass and maximum material utilization compared to the existing design. This study showed that honeycomb structure cooling fin have the potential to increase the working life and performance of electric vehicle battery. Further study should be conducted in the application of honeycomb structure cooling fin.

VI. FUTURE SCOPES

Several modifications can be done to the proposed design to increase its applications. The surface area of proposed design can be increased to increase the efficiency. Heat flux can be calculated and can be compared with the existing fin design. Design modifications can be done in the proposed design and further study can be conducted by changing the material

VII. ACKNOWLEDGMENT

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