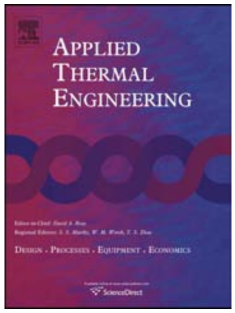
Accepted Manuscript



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PII: S1359-4311(13)00857-0

DOI: 10.1016/j.applthermaleng.2013.11.053

Reference: ATE 5198

To appear in: *Applied Thermal Engineering*

Received Date: 27 September 2013

Revised Date: 7 November 2013

Accepted Date: 25 November 2013

Please cite this article as: N. Javani, I. Dincer , G.F. Naterer, B.S. Yilbas, Analysis and Optimization of a Thermal Management System with Phase Change Material for Hybrid Electric Vehicles, *Applied Thermal Engineering* (2014), doi: 10.1016/j.applthermaleng.2013.11.053.

Analysis and Optimization of a Thermal Management System with Phase Change Material for Hybrid Electric Vehicles

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Abstract

In the present study, energy and exergy analyses are conducted to investigate a new cooling system of hybrid electric vehicles (HEVs). A latent heat thermal energy storage system is integrated with an active refrigeration cycle where n-octadecane is selected as the phase change material (PCM). The liquid cooling system flows through the chiller following a conventional vapor compression cooling cycle. The latent heat shell and the tube heat exchanger operate in parallel with the chiller and a fraction of coolant enters the heat exchanger and, therefore, decreases the heat load of the chiller, leading to a lower work required by the compressor. The exergy destruction rate and the exergy efficiency of each component in a hybrid thermal management system (TMS) are calculated. In addition, the effects of parameters such as the fraction of coolant entering the heat storage system (PCM mass fraction), evaporator temperature, and compressor pressure ratio on the system performance are investigated. The findings of the exergy analysis reveal that the overall exergy efficiency of the system with PCM presence is 31%, having the largest exergy destruction rate of 0.4 kW and the heat exchangers have lower exergy efficiency as compared to other components. In addition, the results of the parametric study show that an increase in PCM mass fraction results in an increase in exergy efficiency of the system. An environmental impact assessment is also conducted and the results show that an increase in exergy efficiency of the cooling system reduces greenhouse gasses and also increases the sustainability of the system. Moreover, a multi-objective optimization using the genetic algorithm is performed by incorporating two objective functions, namely exergy efficiency to be maximized and total cost rate of the system to be minimized. A Pareto frontier is obtained and a single desirable optimal solution is selected based on LINMAP decision-making process. The results show that the maximum exergy efficiency of the system is 34.5% while the minimum total cost rate is 1.38 $/hr.

Keywords: Exergy efficiency, Hybrid electric vehicle, Optimization, Phase change material, Thermal management system.