Modeling and Performance Analysis of Alternative Heat Exchangers for Heavy Vehicles

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Modeling and Performance Analysis of Alternative Heat Exchangers for Heavy Vehicles Wamei Lin Doctoral Thesis on the topic of Modeling and Performance Analysis of Alternative Heat Exchangers for Heavy Vehicles Popular Science Description: Low fuel consumption, and reduced exhaust emissions, as well as improved performance and durability become much more important than before for the vehicle industry. These requirements lead to a number of additional equipment installed in the vehicles. All these efforts increase the operating temperature in the engine compartment and reduce the available free space in the vehicle. In order to keep the engine working at its optimal condition, a huge amount of heat has to be removed from the engine to the surrounding air. In modern heavy vehicles, this heat is so huge that a conventional heat exchanger (HEX) cannot handle it easily. In addition, more and more electric powertrains are introduced to heavy vehicles. Because of the increased demand in cooling power, a larger heat exchanger size with a huge cooling surface area is required for the vehicle cooling system. However, the space in such vehicles is limited. It is impossible to increase the size of the conventional HEX to dissipate the required amount of heat from the vehicle. All these factors imply a need for a revolution of the HEX design in vehicles. Based on literature review, there are two ideas available for developing an alternative heat exchanger for heavy vehicles: 1) Changing the position of heat exchangers: Moving the HEX from the front of the vehicles to the roof of the driver compartment, which might increase the possibility to increase the size of the HEX. Based on the air flowing direction and the engine coolant direction, a countercurrent flow HEX is introduced at the roof position instead of a cross flow HEX. 2) Introducing new materials: Using graphite foam as a thermal material for HEXs in vehicles. Nowadays aluminum HEXs are very common in the vehicle industry. Due to the increasing cooling power and the space limitation in vehicles, a highly compact HEX is required. Graphite foam has even higher thermal conductivity, large specific surface area, and low density. These characteristics imply that graphite foam is a potentially good thermal material for HEXs (instead of the conventional aluminum HEX). However, due to its porous structure, the flow resistance of graphite foam is very high. In order to find an appropriate fin configuration with good performance in the HEX, a computational method is applied to simulate the performance of the HEX with different fin configurations. The numerical model is verified by experimental results from literature. The analysis of the results shows: 1) The overall size and weight of a countercurrent flow HEX can be reduced compared to the cross flow HEX because of the high power density and high compactness factor achieved by the countercurrent flow HEX. 2) Because of the high thermal conductivity and low density of the graphite foam, the graphite foam wavy corrugated fin provides higher power density and higher compactness factor than an aluminum louver fin. A graphite foam fin with two-side dimples exhibits higher coefficient of performance (COP) than an aluminum louver fin, and it becomes very efficient in energy saving. Thus, the graphite foam has a very high potential as an alternative material for heat exchanger applications. The countercurrent flow HEXs made from graphite foam can be designed to be much lighter and smaller than the convectional cross flow aluminum HEXs. A light and compact HEX is not only good for the thermal management of the vehicle, but also it reduces the weight of the vehicle which has an effect on the fuel consumption and overall cost. The present work is based on a research project "Development of new cooling systems for heavy vehicles - for reduced fuel consumption and lower carbon dioxide emission", which has been financially supported partly by the Swedish Energy Agency (STEM).

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