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Experimental study of heat transfer enhancement using water/ethylene glycol based nanofluids as a new coolant for car radiators☆

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ABSTRACT

Traditionally forced convection heat transfer in a car radiator is performed to cool circulating fluid which consisted of water or a mixture of water and anti-freezing materials like ethylene glycol (EG). In this paper, the heat transfer performance of pure water and pure EG has been compared with their binary mixtures. Furthermore, different amounts of Al_2O_3 nanoparticle have been added into these base fluids and its effects on the heat transfer performance of the car radiator have been determined experimentally. Liquid flow rate has been changed in the range of 2–6 l per minute and the fluid inlet temperature has been changed for all the experiments. The results demonstrate that nanofluids clearly enhance heat transfer compared to their own base fluid. In the best conditions, the heat transfer enhancement of about 40% compared to the base fluids has been recorded.

1. Introduction

After the publication of our previous paper [1] about the application of water/Al_2O_3 nanofluids instead of pure water in the car radiator and recording the interesting heat transfer enhancement of about 45%, we want to investigate the application of nanoparticle in the mixture of water and anti-freeze materials (as the base fluid) which is conventionally used in the cars' radiators. It is common in the area of cold or hot weathers that some additives are added to the water in the automotive radiator which decrease freezing point and elevate boiling point of water. It keeps the radiator fluid from freezing when it is very cold and keeps the car from overheating on very hot days. Almost all of these additives are from glycol family specially ethylene glycol (EG). The major use of EG is as a medium for convective heat transfer in, for example car radiators, liquid cooled computers, chilled water air conditioning systems, and the like. Because water is a much better engine coolant, the mixture of water and EG has been used. The trouble with water is that it freezes or boils at extreme temperatures. Anti-freezing agents like EG can withstand much greater temperature extremes, so by adding it to water we can make a compromise. Most of the good cooling abilities of water are retained but the ability to withstand extreme temperatures comes from the anti-freeze. As can be seen in Fig. 1, a mixture of 60% EG and 40% water does not freeze to temperatures below −45 °C. EG disrupts hydrogen bonding when dissolved in water. Pure EG freezes at about −12 °C, but when intermixed with water, the freezing point of the mixture is depressed significantly. The minimum freezing point is observed when the EG percent in water is about 70%, as shown in Fig. 1. However, the boiling point for aqueous EG increases monotonically with increasing EG percentage. Thus, the use of EG not only declines the freezing point but also elevates the boiling point such that the operating range for the heat transfer fluid is broadened on both ends of the temperature scale [2].

It has been proved that conventional fluids, such as water and EG have poor convective heat transfer performance and therefore high compactness and effectiveness of heat transfer systems are necessary to achieve the required heat transfer. Among the efforts for enhancement of heat transfer the application of nanoparticle additives to liquids is more noticeable and currently a large number of investigations are devoted to this subject [3–8]. Nanofluids are formed by suspending metallic or non-metallic oxide nanoparticles (that are significantly smaller than 100 nm) in traditional heat transfer fluids. These so-called nanofluids display good thermal properties compared with fluids conventionally used for heat transfer and fluids containing particles on the micrometer scale. These fluids are a new window which has been opened recently and it was confirmed by several authors that these working fluids can enhance heat transfer performance [9,10].

In the car radiators, the coolant media is pumped through the flat tubes while the air is drawn over the fins by forced convection, thereby heat exchanges between the hot circulating fluid and air. The application of nanofluids in these finned tube radiators may result in several potential benefits including increased heating output for equal liquid flow. These performance impacts, in turn, may be translated into a reduction in total required heat transfer area. Superior heat transfer properties of nanofluids may also result in lower liquid flow

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