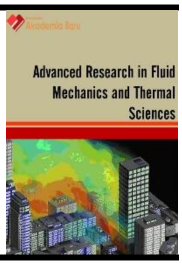
Journal of Advanced Research in Fluid Mechanics and Thermal Sciences 59, Issue 2 (2019) 330-337

Penerbit Akademia Baru

Journal of Advanced Research in Fluid Mechanics and Thermal Sciences

Journal homepage: www.akademiabaru.com/arfmts.html
ISSN: 2289-7879



A Review on Vehicle Radiator Using Various Coolants

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ARTICLE INFO

Article history:
Received 11 May 2019
Received in revised form 13 June 2019
Accepted 8 July 2019
Available online 20 July 2019

Keywords:
Nanocellulose, radiator, Propylene Glycol, Water, Ethylene Glycol

ABSTRACT

In a radiator, force convectional is the important thing that can be considered. The examples of convectional heat transfer fluids are nanofluid, water, glycerol, Ethylene Glycol and nanocellulose. These base fluids have been used widely in automotive radiators and these fluids recently have very low thermal conductivities. In advance, many researches have been done regarding to the study of enhancement of the convective heat transfer performance in nanoparticles. On the other hand, using nanofluids, due to the enhanced heat carrying capacity of the nanofluids; the pumping power required will also be reduced. All of these transfer fluids play an important role in many industrial sectors such as air-conditioning, transportation, microelectronics, power generation and chemical production.

1. Introduction

An engine coolant is a fluid which flows through the engine and prevents it from overheating by transferring the heat generated by the engine to other components that either make use of it or dissipate it [1,2]. A feature of an ideal coolant entails a low viscosity, high thermal capacity, has chemical inertness and is low-cost [3]. Further, it should neither cause nor promote corrosion of the cooling system. In addition, the most common coolant is water. Its high heat capacity and low cost makes it a suitable heat-transfer medium [4,5]. It is usually used with additives, like corrosion inhibitors and antifreeze. Antifreeze, a solution of a suitable organic chemical (most often ethylene glycol, diethylene glycol, or propylene glycol in water, is used when the water-based coolant has to withstand temperatures below 0 °C, or when its boiling point has to be raised [6,7].Furthermore, if this excess heat from engine is not removed, the engine temperature becomes too high which results in overheating and viscosity breakdown of the lubricating oil, metal weakening of the overheated

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engine parts, and stress between engine parts resulting in quicker wear, among the related moving components. In radiator, force convectional is the important thing that can be considered. The examples of convectional heat transfer fluids are nanofluid, water, glycerol, Ethylene Glycol and minerals oil [1]. These base fluids have been used widely in automotive radiators and these fluids recently have very low thermal conductivities. In advance, in the last decade, many researches have been done regarding to the study of enhancement of the convective heat transfer performance in nanoparticles [8,9]. All of these transfer fluids play an important role in many industrial sectors such as air-conditioning, transportation, microelectronics, power generation and chemical production [10,11]. Although different systems have been connected to upgrade their heat transfer abilities, their execution is regularly constrained by their low thermal conductivities which impede the execution improvement and smallness of heat exchanges [12]. According Naraki *et al.*, [13] the experimental under laminar flow in a car radiator shows that the overall heat transfer coefficient with nanoparticles absolutely more than the base fluid. There was experimentally studied from [5] for forced convection heat transfer of Fe_2O_3 and CuO nanofliuds in car radiator. As the result from the research, the overall heat transfer coefficient is increase but the inlet temperature of liquid is decrease [3].

One of the strategy to increase the heat transfer in car radiator is by using nanofluid because it is the new innovation that can be obtained by dispersing nanoparticles on the base fluids [3,14]. In the best condition, the heat transfer coefficient upgrade of around 55% contrasted with the base liquid was recorded [15,16]. Utilizing distinctive fin sorts and micro channels, various tube embeds, or harsh surfaces demonstrate a few efforts made for expand. Besides that, in their researchers found that expanding the fluid circulation rate can enhance the heat transfer execution while the fluid inlet temperature to the radiator has next to zero impact [8]. Nanofluid researched in the present work with low concentration improved the heat transfer rate up to 37% in examination with base liquid [17]. In additions, Nanoparticles, the added substances of nanofluid, play a critical part in changing the thermal transport properties of nanofluid additionally they change the liquid attributes since thermal conductivity of the particles is higher than standard liquids [18,19].

2. Radiator

A radiator is a heat exchanger which absorb heat from a hot coolant that passes through it and directs the collected heat to the air that blown in by the fan [9,20]. It is made of many tubes which are mounted in parallel arrangement where the coolant will flow from the inlet to the outlet. Heat is extracted from the tubes by the fins on the radiator surface and transfer it to the air that flows in through the radiator. The amount of heat extraction depends highly on the difference between temperature of the fluid that runs through the radiator and tubes [4]. Radiator is made up of three main portions such as inlet tank, core, and outlet tank. Core mainly consist of two sets of passage which are set of tubes and sets of fins [21]. Tubes will be the flow passage for the coolant while air will flow between the fins. Heat is transmitted to the fins by the tube that obtained it from the hot coolant [22]. Air that flows between the fins will eventually pickup and carries the heat away [23].

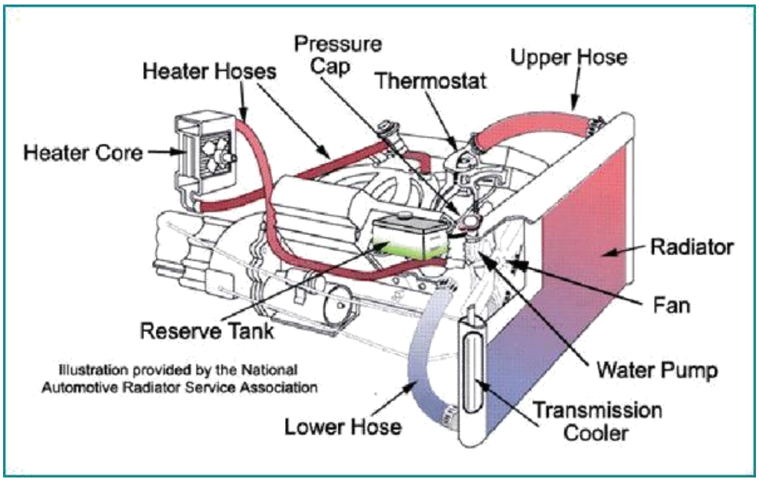

Fig. 1. Parts of cooling system in car [24]

2.1 Types of Radiator Coolant

Coolant can be defined as a fluid that prevents overheating of a device by flowing through it to gather excessive unwanted heat produced by the device. The collected heat will be transferred to another device that will exploit or disperse it. A coolant with high thermal capacity, low-cost, low viscosity and is chemically inert whereby it does not cause or promotes corrosion of the cooling system is considered as an ideal coolant [24]. Besides that, a coolant is normally chemically combined with a high boiling point liquid to form a compounded fluid. This compounded fluid function as an antifreeze agent against extremely cold conditions and as well as solves the problem of overheating during hot weather. A coolant with relatively high boiling temperature can cool faster as the engine gets hotter. During an operation of an internal combustion engine, about a third of heat energy produced are considered as unwanted heat that ends up in the cooling system. Besides that, it is observed that conventional fluids are unable to meet the increasing demand for cooling in high energy applications including automobile engines. In view of this, a new technique is needed to improve the existing cooling performance of heavy vehicle engines. An engine is prevented from getting damaged when the radiator coolant elevates the boiling point of the water which permits it to transmit more heat away from the engine [5].

2.1.1 Water

Water is a very functional fluid to be used as radiator coolant. It is cheap, possesses good heat-transferring qualities and readily available. It possesses high specific heat capacity which enables it to be an effective thermal transitions medium between engine materials and radiators. This allows water to avoid any thermal overloads resulting from excessive component temperature. Water is categorized as an ideal coolant because of its ability to absorb and release heat efficiently. Apart from that, water is a liquid with low viscosity where it can flow easily. Thus, this characteristic permits water to be used commonly as radiator coolant. However, water has a very low boiling point of 373 K. Since the temperature in a radiator can exceed 373K, this can cause water to vaporize. Loss of coolant can create gas pockets or voids in the water jackets that can cause localized hot spots and implosion. Since water freezes at 273K, this reduces its efficiency in circulating as a coolant in radiator [3]. Thus, water cannot be used as radiator coolant in countries with winter season as it will eventually freeze up and lead to difficulty of starting up the car or causing serious engine damage.

2.1.2 Ethylene Glycol

An organic compound (IUPAC name: ethane-1, 2-diol), Ethylene Glycol is widely used as an automotive antifreeze. It is colourless and odourless in its pure form but Ethylene Glycol is extremely dangerous and any ingestion can result in death. This is mainly due to its high toxic properties. Ethylene Glycol marketed as antifreeze and it can be used during summertime as well as during cold weather because of its higher boiling points [25]. The main drawback of these coolants is that they are very toxic and can be dangerous to humans, animals and the environment [26].

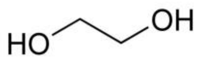

Fig. 2. Ethylene Glycol structure [27]

2.1.3 Propylene glycol

Propylene Glycol is considerably less toxic antifreeze compared to Ethylene Glycol. Propylene Glycol is utilized as antifreeze where the Ethylene Glycol usage would be inappropriate. Any exposure to heat and air causes Propylene Glycol to oxidize. This phenomenon leads to formation of lactic acid (28). Propylene Glycol is very corrosive; thus it need to be properly inhibited. In order, to prevent low pH attack on the system metals, Protodin is added to act as a buffer. Protodin helps to avert acid attack that causes corrosion by creating a protective skin inside the tank and pipelines. Propylene Glycol supports the formation of biological fouling that leads to increment of corrosion rate in a radiator system. Corrosion of the radiator system starts after the formation of bacterial slime. Thus, radiator system which applies Propylene Glycol should be maintained on a continuous basis. Regular monitoring should be done on inhibitor level, pH and colour. Nevertheless, routine check-up should be done on biological contamination. Colour changes of Propylene Glycol into red in colour can be used as an indication that it should be replaced (29). Propylene Glycol are much safer to use around children and animals, and easier to dispose of than the more toxic ethylene products.

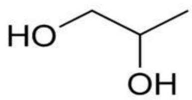

Fig. 3. Propylene Glycol structure [28]

2.1.4 Nanocellulose

Nanocellulose research is presently a field of focused scientific research as it possesses extensive potential application in biomechanics, foods, electronic, and automotive fields. Nanocellulose is a natural nanomaterial that seems to give a range of opportunities to obtain superior material properties for various end products [30]. Nanocellulose has at least one dimension within the nanometre size range. The properties of variety of conventional materials are altered after fused together nanocellulose [31]. This is mainly due to great surface area per weight which possess by nanocellulose compared to larger particles. This makes nanocellulose to be more reactive than certain molecules [32]. Nanocellulose has produced a high interest, particularly as a filler in biocomposites. Sustainability, abundance, mechanical properties such as large surface to volume ratio, high tensile strength and stiffness, high flexibility, and good electrical and thermal properties are some beneficial attributes of nanocellulose. Moreover, nanocellulose classified as safe to handle and to consume [33]. Previous studies regarding application of nanofluids with radiator coolant which are water and Ethylene Glycol in radiator will be referred as benchmark in the research. This is to strengthen the obtained result during experiment [34]. The focused study will be fully about the manipulative variables in project such as thermal conductivity, nanoparticles volume concentration, nanoparticles size, viscosity and friction and wear caused by nanofluids in an automotive radiator. With the development of nanostructured materials in the recent years, attempts were made to apply nanoparticles together with base fluids as radiator coolant to improve their cooling properties [35]. When some nanoparticles were added into the radiator coolant, the coolant properties can be effectively improved. Many research studies have been conducted to test thermo physical characteristics of nanofluid and the findings were recorded with respect to the engine performance [1,2,20].

3. Radiator Performance and Effectiveness

Continuous improvement in automotive industries seeks for the demand of high competence engines. A high competence engine must have a better fuel economy which matches its high performance. The performance of a vehicle is optimized as the size and capacity of an engine is increased. However, the size of the radiator increases together with the capacity of the engine. Fin addition has been one of the approach to elevate the cooling speed of the radiator. This method results to better enhancement of air convective heat transfer as it offers larger heat transfer area [36]. Furthermore, there is a lot of research regarding to the radiator in term of performance characteristics and effectiveness. One of the effort to increase the effectiveness of radiator is by adding nanocellulose in radiator coolant. The percentage of nanocelluose plays an important role to make sure that the amount of heat transfer can be increased by increasing the percentage of nanopcellulose. The nanocelluose is used in this experiment as the nanoparticles. Radiator was modelled using One-Dimensional simulation software to predict the performance characteristics and effectiveness of the radiator with addition of nanoparticles. Besides that, method of using micro channels and fins to extend the cooling rate of a radiator ended up being a traditional technology which already reached to its maximum limit. Moreover, Ethylene Glycol and water which referred as heat transfer fluids that currently used in car radiator exhibit very low thermal conductivity. This problem leads to research for latest and pioneering heat transfer fluids that will eventually improve the heat transfer rate in an automotive car radiator [37].

Currently computational modelling methodology offers reduction in time, repeatable analysis, and capable of running various operating conditions simultaneously, compared to the experiment approach. There is no database of nanoparticles available for one dimensional simulation in the simulation in the simulation software. The nanoparticles properties that is nanocellulose need to be studied and defined in the simulation software library before running the simulation. In additions, the thermal conductivity and viscosity correlation are depending on the volume concentration, temperature and the base fluid thermal conductivity. Nanofluid dispersed in high thermal conductivity base fluid will have higher enhancement in thermal conductivity. Whereas for viscosity, the nanofluids with higher viscosity base fluid will exhibits higher viscosity correlation. The enhancement ratio can predict the behaviour of nanofluids over the temperature. The optimum value of enhancement ratio is 5 where the enhancement ratio in region lower than 5 will aid the nanofluids heat transfer.

4. Conclusions

One of the strategy to increase the heat transfer in car radiator is by using nanofluid because it is the new innovation that can be obtained by dispersing nanoparticles on the base fluid. Nanofluid with low concentration improved the heat transfer rate up to 37% in examination with base liquid. Normally, maximum heat transfer enhancement and maximum must be to pumping power occurs at the highest volume concentration of the nanoparticles, simultaneously. Then, using nanofluids, due to the enhanced heat carrying capacity of the nanofluids, the pumping power required will also be reduced. In additions, Nanoparticles, the added substances of nanofluid, play a critical part in changing the thermal transport properties of nanofluid additionally they change the liquid attributes since thermal conductivity of the particles is higher than standard liquids [38,39]. Normally, maximum heat transfer enhancement and maximum must be to pumping power occurs at the highest volume concentration of the nanoparticles, simultaneously. Then, using nanofluids, due to the enhanced heat carrying capacity of the nanofluids, the pumping power required will also be reduced.

Acknowledgement
Authors would like to extend their gratitude to Ministry of Higher Education Malaysia and Universiti Malaysia Pahang (UMP) with grant number RDU180399 and RDU19115.

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