An Overview of the Engine Cooling System of Vehicle Radiators through MgO/Water Nanofluid

Annappa H Kotre
Lecturer, Department of Automobile Engineering, Government Polytechnic Bidar, Karnataka, India

***Abstract* - Using a novel coolant—a MgO/water nanofluid—this research intends to improve the thermal efficiency of a cross-flow automobile radiator. Due to their improved heat transfer capabilities, nanofluids have emerged as a possible alternative to water or ethylene glycol-based fluids, which are typically used in engine cooling systems. The specific heat capacity, density, thermal conductivity, and dynamic viscosity of a nanofluid of magnesium oxide and water are investigated in this study. A regulated flow rate ranging from 5 to 9 LPM was maintained throughout the trial. The findings showed that heat transfer performance was significantly improved, with an increase of 40% to 70% depending on the concentration of the nanofluid. The computational findings point to the possibility of using MgO/water nanofluid as an effective coolant in thermal management systems for automobiles.**

Keywords - Radiator, nanofluid, MgO particles, thermal conductivity, heat transfer rate.

1. INTRODUCTION

The fundamental purpose of this study is to enhance the thermal efficiency of car cooling systems, with the goal of ensuring that heat is dissipated into the environment in a more efficient and expedient manner. Nanofluids have developed as very effective heat transfer agents in recent decades owing to their higher thermal conductivity and the fact that they are extremely transparent. cooling qualities that are improved. Nanofluids, in contrast to traditional fluids such as water or ethylene glycol, display enhanced heat transfer properties, which makes them excellent for a variety of applications involving heat exchangers.

The radiator of a vehicle, which also serves as a cross-flow heat exchanger, is an essential component of the engine cooling system of an automobile. Through the process of dispersing excess heat, its major function is to control the temperature of the engine. For the purpose of this investigation, we make use of magnesium oxide (MgO) nanoparticles that have an average size of forty nanometers and are distributed in water to create a nanofluid cooling material. For the purpose of determining its thermal performance, this MgO/water nanofluid is being evaluated as a potential alternative for conventional coolants. Following the completion of the experimental investigation, computational modeling and validation are carried out with the help of CFD simulations in STAR-CCM+. This is done in order to evaluate the outlet temperature and the efficiency of heat dissipation.

A typical automobile with four cylinders and going at a speed of around fifty miles per hour produces approximately four thousand spark plugs ignite the gasoline in each cylinder, which results in controlled explosions occurring inside the engine at a rate of one per minute.

There is a significant amount of heat generated by these constant explosions, which, if not properly handled, might cause catastrophic damage to the engine in a matter of minutes by itself. When it comes to maintaining the correct temperature of the engine, the cooling system plays a crucial function. It helps to prevent the engine from overheating and also ensures that it does not run too cold, which might have a bad influence on fuel economy and lead to an increase in emissions. Liquid-cooled and air-cooled cooling systems are the two most common kinds of cooling systems used in automobile automobiles. In the past, air-cooled engines were used in automobiles such as the Volkswagen Beetle and the Chevrolet Corvair. These engines are also utilized in some motorbikes today. On the other hand, the vast majority of contemporary automobiles are powered by liquid-cooled systems, which are the subject of this research.

A number of essential components make up the cooling system. These components include coolant passages within the engine block and cylinder heads, a water pump that circulates the coolant, a thermostat that regulates the temperature of the coolant, a radiator that dissipates heat, a radiator cap that maintains the pressure in the system, and hoses that transport coolant between the engine, the radiator, and the heater core. As it moves through the engine's internal tubes, the coolant is able to take up heat from the engine. After that, it is transported to the radiator by means of hoses. During this stage, the fluid travels through thin tubes, where the air that is flowing in from the front grille of the car helps to enhance heat exchange, therefore cooling the fluid before it is recirculated back to the engine. The water pump ensures that the coolant is continuously circulated, which helps to maintain the system's performance and prevents any problems caused by thermal degradation.

The purpose of our study is to investigate the possibilities of incorporating a nanofluid composed of magnesium oxide and water into this system. This nanofluid has the ability to increase heat dissipation rates, decrease thermal resistance, and boost overall cooling efficiency in vehicle engines.

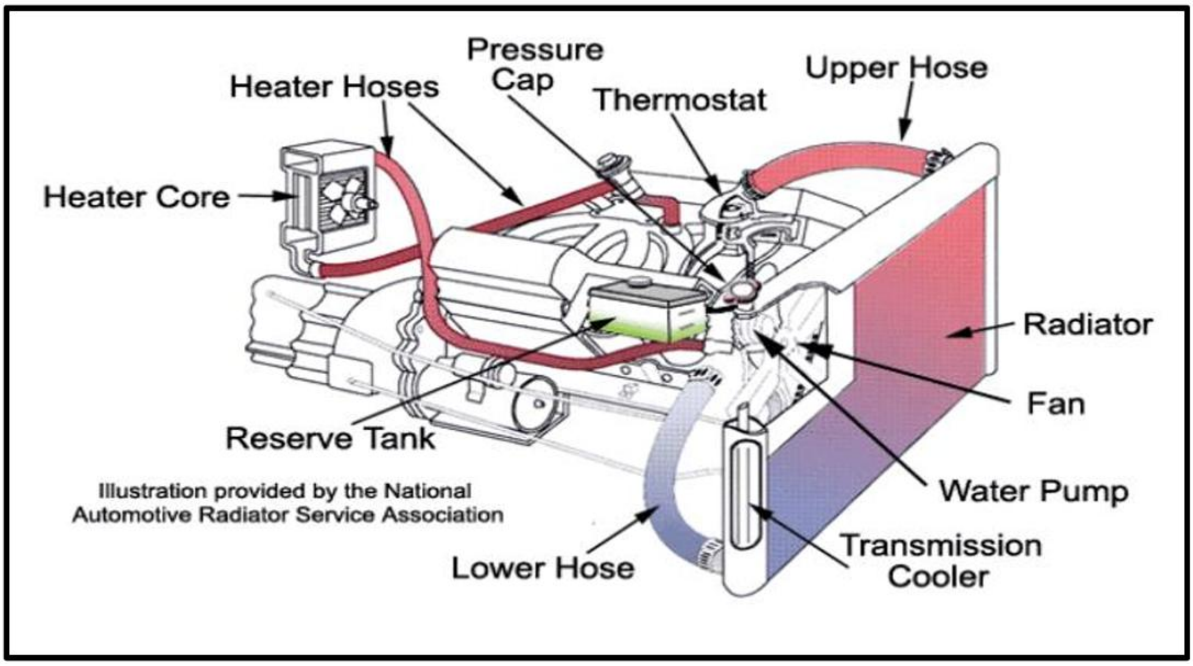

Fig 1.1: Engine cooling system component

The findings of this research have the potential to significantly contribute to the development of cooling systems that are more sophisticated and efficient for use in contemporary automobiles.

2. LITERATURE REVIEWS

The improvement of heat transmission was reported by Xie et al. [1] by the use of nanofluids consisting of Al2O3, ZnO, TiO2, and MgO, which were combined with a combination of water and ethylene glycol comprised of 55% and 45% respectively. Nanofluids composed of Al2O3, MgO, and ZnO shown a higher increase in heat transmission when compared to nanofluids composed of TiO2.

A radiator for an automobile was put through its paces by Peyghambarzadeh et al. [2] utilizing nanofluids based on Al2O3 and water. The volumetric concentrations were adjusted to fall anywhere between 0.1 and 1% of the total. At a volumetric concentration of 1%, it was observed that the greatest heat transfer increase was between 45 and 45 percent.

The experimental findings for CuO/water nanofluids that were evaluated in a vehicle radiator under a laminar flow regime were published by Naraki et al. [3]. Changes were made to the intake temperature, which ranged from 50 to 80 degrees Celsius, and the volumetric concentration was adjusted from 0 to 0.4%. Nanofluids with a volume of 0.4% were found to have an overall heat transfer coefficient that was 8% higher than that of water. In a vehicle radiator operating in a laminar flow regime, Hussein et al.[4] conducted experiments on water-based nanofluids containing TiO2 and SiO2.

The fluid input temperature and volumetric concentration were both altered within a range of 60-80 degrees Celsius and 1-2% respectively. An increase in thermal conductivity of twenty percent was discovered by Lee et al. [5] after conducting an experiment in which they combined ethylene glycol and CuO nanoparticles with a size of thirty-five nanometers and a concentration of four percent by volume. In their experimental investigation, Yu et al.

[6] found that the thermal conductivity of nanofluid is strongly dependent on the volume concentrations of nanoparticles, and that it increases in a nonlinear manner with the increase in volume concentration. Furthermore, the enhanced thermal conductivity was found to be 26.5% at a concentration of 5.0vol.%. Nguyen et al. [7] conducted an experimental investigation to determine the effect of volume concentration and temperature on the dynamic viscosity of an Al_2O_3–water nanofluid. They discovered that the viscosity of the nanofluid significantly increases with the increase of particle volume concentrations, but it decreases with the increase in temperature. The viscosity of an Al_2O_3–water nanofluid that was created by mechanical blending with a particle size of 28 nm and a concentration of 5 vol.% was examined by Wang et al. [8]. The researchers found that the viscosity rose by 86% in comparison to the underlying fluid. In addition, they tested Al_2O_3/ethylene glycol nanofluid and discovered that it had a viscosity that was forty percent higher. Additionally, Das et al. [9] made the observation that the viscosity of the nanofluid rises in proportion to the increase in the particle volume concentration.

According to the results that Elias et al. [10] provided, the thermal conductivity, viscosity, specific heat, and density of Al_2O_3 nanofluids in water and ethylene glycol that were utilized as coolant in vehicle radiators were all investigated. The temperature of the coolant was maintained at 50 degrees Celsius, and the volume concentration was maintained at 1%. It was discovered that the density, thermal conductivity, and viscosity of the nanofluids all increased as the volumetric concentrations of the nanofluids increased, however the specific heat of the nanofluid decreased. In their research, Masuda and colleagues [11] investigated the thermophysical characteristics of nanofluids composed of Al_2O_3–water, SiO_2–water, and TiO_2–water. When determining the thermal conductivity of nanofluids, the transient hot-wire approach was taken into consideration. In their study, they found that the thermal conductivity of nanofluids increased by 32% when the concentration was 4.3% by volume. They came to the conclusion that the increase in relative thermal conductivity was not influenced in any way by temperature. The thermal conductivity of Al_2O_3 and CuO that were suspended in water was measured in an experiment that was carried out by Lee et al. [12]. In ethylene glycol and water respectively. Al_2O_3 and CuO had particle sizes of 23.6 nm and 38.4 nm, respectively, when measured in nanometers. The findings of their investigation revealed that nanofluids exhibited a greater thermal conductivity compared to the base fluid, and this difference was shown to rise as the concentration of the nanofluids rose.

3. THERMOSTAT AND RADIATOR: KEY COMPONENTS OF THE COOLING SYSTEM

Through its ability to regulate the flow of coolant between the engine and the radiator, the thermostat is an essential component in the process of ensuring that the engine is always functioning at its ideal temperature. The flow of coolant to the radiator is restricted when the temperature is too low, which guarantees that the coolant stays at a temperature that is higher than the one that has been specified beforehand. Instead, the coolant is routed via a bypass, which enables it to recirculate inside the engine until it reaches the required temperature.

The temperature. After reaching this threshold, the thermostat will activate a valve, which will then let the coolant to flow through the radiator in order to provide the desired cooling effect. In order to prevent the coolant from boiling, the whole cooling system is built to function under pressure. This greatly raises the boiling point of the fluid, which prevents the problem from occurring. Nevertheless, an excessive amount of pressure might result in damage to the system, which may include hose ruptures and leaks. To prevent this from happening, a radiator cap is used to control the pressure levels in the radiator. Once it reaches a certain limit, this cap is meant to discharge any extra pressure that has built up there. A simple discharge of surplus coolant into the road was the standard practice prior to the 1970s. The majority of contemporary automobiles, on the other hand, are equipped with a closed-loop system that allows the surplus fluid to be temporarily kept in a reserve tank and then subsequently returned to the cooling system after the engine had cooled down.

3.1 Coolant Circulation Process

For the purpose of effectively controlling the temperature of the engine, the cooling system adheres to a certain route. The water pump is responsible for initiating the flow of coolant through the interior channels of the engine block. This coolant's primary function is to absorb heat that is produced by the combustion process. Following this, the coolant travels to the cylinder head, where it collects itself. The combustion chambers are a source of extra heat. The hot coolant goes through the top radiator line and into the radiator if the thermostat is open. Once inside the radiator, the coolant is cooled as it travels through a network of tiny tubes that are exposed to airflow. Following this, the fluid that has been cooled makes its way via the lower radiator pipe and finally returns to the water pump, therefore completing the cycle. It is important to carefully design the capacity of the cooling system depending on the kind of engine, its size, and the anticipated workload.

It is necessary to have a more robust cooling system that includes a bigger radiator and extra coolant routes in order to accommodate engines that are larger and more powerful, such as the V8 engines seen in heavy-duty cars. modest automobiles, on the other hand, which have four-cylinder engines that are modest in size, need less cooling capacity. In order to improve the effectiveness of the cooling system, bigger cars have radiators that are broader and higher, with a greater number of tubes. This allows for the maximum amount of airflow to come from the front grille.

3.2 Radiator Design and Function

Before the coolant is recirculated through the engine, the radiator, which is an essential part of the cooling system, is in charge of removing heat from the coolant. The core of the majority of contemporary radiators is composed of aluminum tubes that have been flattened, and the fins of the radiator are organized in a zigzag pattern between the tubes. Because of these fins, heat transfer is improved. In order to facilitate effective heat dissipation, increasing the surface area that is exposed to airflow is essential.

The core of the radiator is surrounded by certain tanks that assist in directing the flow of coolant. In modern radiators, these tanks are often composed of a durable plastic material, although in previous types, brass tanks with copper cores were employed. When compared to their conventional equivalents, modern radiators made of aluminum-plastic provide enhanced efficiency as well as cost-effectiveness. Gaskets are inserted between the aluminum core and the plastic components in designs that make use of plastic end tanks. This is done to avoid coolant leakage and to ensure that the cooling system is both sealed and effective.

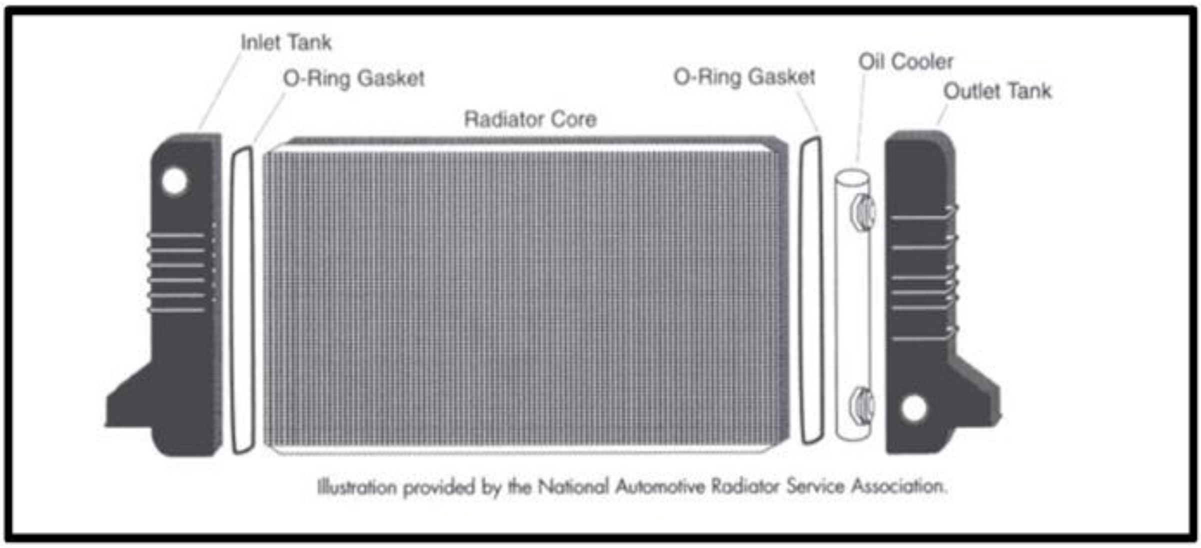

Fig 1.2: The Radiator

3.3 Radiator Fans: Function and Importance

Electric fans are often situated below the radiator and placed in close proximity to the engine in the majority of cars. This is done to ensure that the vehicle is adequately cooled. These fans are protected by a casing that is encased around them, which not only avoids inadvertent contact but also improves the effectiveness of the airflow. Their major purpose is to ensure that airflow is maintained. During periods in which the car is either parked or traveling at a slow pace via the radiator. If these fans were not there, the temperature of the engine may quickly increase while it was idling or when it was moving in a stop-and-go traffic pattern.

When the engine was running, older cooling systems depended on a fan that was mechanically powered and mounted to the front of the water pump. This fan would spin constantly as long as the engine was running. Due to the fact that this particular sort of fan was belt-driven, its speed rose as the engine revolutions per minute (RPM) increased. In situations when the engine temperature increased due to heavy traffic, drivers of earlier cars would occasionally rev the engine while it was sitting in neutral in order to speed up the fan, which would result in more cooling. On the other hand, revving the engine in contemporary automobiles that are fitted with electric fans would not have the same impact and may possibly produce more heat if there is not enough cooling.

The computer system that is internal to the car is responsible for controlling the electric radiator fans. A temperature sensor is constantly monitoring the amounts of heat produced by the engine and transmitting this information to the computer. When the temperature reaches a certain level, the computer triggers a relay to turn on the fan. This increases the amount of airflow that passes through the radiator, which helps to prevent the radiator from overheating. This automatic system guarantees optimal cooling, which optimizes both the performance of the engine and the efficiency with which it saves gasoline.

Fig 1.3: Radiator Fans

3.4 Pressure Cap and Reserve Tank: Managing Coolant Expansion

Coolant is able to absorb heat and expand while the engine continues to operate. Because the cooling system is hermetically sealed, the expansion will inevitably result in a rise in the pressure inside the system. Increasing the pressure inside the system also raises the boiling point of the coolant, which enables it to work at greater temperatures. This is a design element that was purposefully included in the system without reducing to vapor. The use of a coolant that is based on ethylene glycol further amplifies this action, making it possible for the cooling fluid to safely resist temperatures that are higher than 250 degrees Fahrenheit (121 degrees Celsius). When it comes to controlling this pressure, the pressure cap is a very important component. When the pressure reaches a particular level, it is meant to discharge any surplus coolant into the reserve tank. This prevents any possible damage to the hoses and other components that may be present. After the engine has cooled down, the coolant that is stored in the reserve tank is pulled back into the system. This ensures that the coolant level remains constant and that the engine continues to function at its lowest possible level.

Fig 1.4: Pressure Cap

3.5 Radiator Pressure Cap: Function and Importance

One of the most important components that plays a role in maintaining the proper pressure inside the cooling system is the radiator pressure cap. This device, which was designed to serve as a safety mechanism, keeps the pressure of the system within a certain limit. The cap is equipped with a spring-loaded valve that is precisely calibrated to open in the event that the internal pressure occurs to be higher than this threshold.

At a level of pounds per square inch (PSI) that has been set in advance, release any surplus pressure. In severe circumstances, such as when the cooling system is not operating properly or when there is stop-and-go traffic on very hot days, the pressure may build up to a point where it exceeds the limit that has been established for the cap. When this occurs, a little quantity of coolant is discharged in order to protect the system from any possible harm that might occur. This extra coolant is collected in a separate expansion tank, which is normally not pressured, so that it does not end up being wasted.

3.6 Coolant Recovery and Reserve Tank System

A secondary valve is included into the radiator cap of a closed cooling system. This valve enables coolant to be sucked back into the radiator after the engine has cooled down. As the temperature drops, the coolant lowers in volume, which results in the formation of a partial vacuum. As a result of this vacuum effect, the coolant that was previously stored in the reserve tank. With the radiator, making certain that the system maintains the appropriate amount of coolant at all times without allowing air pockets to develop. This procedure works in a manner that is similar to lifting the plunger of a syringe, which enables fluid to return in a smooth manner. Generally speaking, the reserve tank is a container made of transparent plastic that has clearly indicated indications for coolant levels. These indicators are labeled as Full-Hot and Full-Cold. On the occasion that the engine achieves its typical working temperature, the coolant level ought to coincide with the indicator that indicates that it is fully hot. After the car has been switched off and the engine has cooled down to its full temperature, the fluid should settle at the point that indicates that it is fully cold. When these levels are monitored on a regular basis, it helps to ensure that the cooling system performs well and avoids either overheating or the loss of coolant.

Fig 1.5: Coolant Tank

3.7 Water Pump: Circulating Coolant for Efficient Engine Cooling

When the engine is operating, the water pump is an essential component of the cooling system because it ensures that the coolant is continuously circulated throughout the system. The majority of the time, it is located at the front of the engine and functions in conjunction with the movement of the engine. One or more of the following mechanisms is responsible for driving the pump:

In addition to providing power to the alternator and the power steering pump, a fan belt may also provide power to other components.

The alternator, the power steering pump, and the air conditioning compressor are all items that are driven by a serpentine belt, which is responsible for driving several accessories.

In addition to being the engine that powers the water pump, a timing belt is also responsible for controlling the movement of one or more camshafts are used. The impeller of a water pump is enclosed inside a housing, which is often constructed of cast iron or aluminum. This housing is component of the construction of a water pump. The impeller is attached to a rotating shaft, and a pulley is linked to the shaft from the outside via which rotation is enabled. Coolant leakage from the pump housing may be prevented by a seal, which in turn ensures that the pump operates efficiently.

During the rotation of the impeller, centrifugal force is used to pull coolant from the lower radiator hose and thrust it under pressure into the engine block. This process is carried out by the impeller. This procedure guarantees that the coolant is circulated effectively, so ensuring that the engine is kept at the ideal temperature throughout time. In order to avoid leaks at the location where the water pump is attached, a gasket is positioned between the water pump and the engine block.

3.8 Thermostat Valve: Regulating Coolant Flow and Temperature

The thermostat is a temperature-sensitive valve that is responsible for controlling the flow of coolant dependent on the temperature of the engine. The valve will open to enable coolant to flow through the radiator for the purpose of cooling if the coolant has reached a temperature that is high enough. On the other hand, if the coolant is still cold, the thermostat will continue to be closed, which will indicate that the Coolant is sent back to the engine via a bypass system, which is responsible for its return. This bypass guarantees that there is continuous circulation, which prevents localized overheating and enables the engine to achieve the appropriate temperature more rapidly.

Through the prevention of premature cooling, the thermostat assists in the acceleration of the engine's warming process. This is particularly advantageous in cold weather conditions, as it allows the heater of the car to generate warm air at a quicker rate. Beginning in the 1970s, thermostats have been engineered to keep coolant temperatures between 192 and 195 degrees Fahrenheit. Earlier devices, on the other hand, normally worked at temperatures around 180 degrees Fahrenheit. It has been shown via research that increasing the temperature of the engine may enhance the efficiency of fuel combustion, lower pollutants, and limit the accumulation of moisture inside the engine, all of which contribute to better lifespan and performance.

In the center of the thermostat is a chamber made of copper that is hermetically sealed and contains wax as well as a metal pellet. When the coolant reaches the temperature that has been determined, the wax expands, which causes a piston to move against a spring. This, in turn, causes the valve to open, which enables coolant to circulate.

The thermostat is often located inside a water outlet that is located at the top front of the engine. This water outlet also has a place where the upper radiator hose may be attached to the thermostat. It is normally fastened to the engine by means of two bolts and a gasket, which may be constructed from heavy-duty paper, a rubber O-ring, or a specialist silicone sealant. This is done in order to guarantee that the connection is not susceptible to leaks.

Fig 1.6: Thermostat Valve

There are some individuals who are under the incorrect impression that if they take away the thermostat, they would be able to fix the difficult-to-find issues that are associated with overheating. This is such a far cry from the reality of the situation. In the event that the thermostat is removed, the coolant will be able to circulate throughout the system without being regulated. The coolant has the potential to travel in any direction. At such a rapid rate that it will not be adequately cooled as it rushes past the radiator, which means that the engine may operate at temperatures that are even higher than they were before under certain circumstances. On occasion, the engine will never reach the temperature at which it is designed to operate.

4. RESULTS

The synthesis of MgO/water nanofluid begins with the acquisition of high-purity (99%) MgO nanoparticles, characterized by a particle size of 40 nm. The nanoparticles are white and possess a density of 3.58 g/cm³. To achieve optimal dispersion of MgO particles in water, the pH level is meticulously regulated to facilitate full dissolving of nanoparticles and inhibit agglomeration. The nanofluid is formulated at a 2% mass concentration (m/v), indicating that 2 grams of MgO is dissolved in 100 ml of water. The preparation method includes heating and constant agitation to get a homogeneous mixture. The solution is allowed to sediment for 48 hours post-stirring to improve stability. Various volume fractions of the synthesized MgO nanofluid are used as coolant, and their thermal and physical characteristics are examined to evaluate performance enhancements in the automotive radiator cooling system.

5. CONCLUSIONS

The purpose of this study is to enhance the thermal efficiency of a cross-flow automotive radiator by using a new coolant, which is a nanofluid composed of magnesium oxide and water. Nanofluids have emerged as a potential alternative to fluids based on water or ethylene glycol, which are normally used in engine cooling systems. With their enhanced heat transfer capabilities, nanofluids have emerged as a potential alternative. The purpose of this work is to evaluate the specific heat capacity, density, thermal conductivity, and dynamic viscosity of a nanofluid consisting of magnesium oxide and water. The results of the study demonstrated that the performance of heat transfer was greatly enhanced, with an increase ranging from forty percent to seventy percent depending on the concentration of the nanofluid. The results of the computer analysis indicate that it is possible to use a nanofluid composed of magnesium oxide and water as an efficient coolant in thermal management systems for vehicles.

REFERENCE

[1] D. E. Maddox and I. Mudawwar, "Single and two-phase convective heat transfer from smooth and enhanced microelectronic heat sources in a rectangular channel," Am. Soc. Mech. Eng. Heat Transf. Div. HTD, vol. 96, no. November 1989, pp. 533–541, 1988.

[2] S. U. S. Choi, "Enhancing thermal conductivity of fluids with nanoparticles," Am. Soc. Mech. Eng. Fluids Eng. Div. FED, vol. 231, no. March, pp. 99–105, 1995.

[3] G. Saxena and P. Soni, "Nano Coolants for Automotive Applications : A Review," vol. 20, no. February, pp. 8–22, 2018.

[4] X. Q. Wang and A. S. Mujumdar, "A review on nanofluids - Part I: Theoretical and numerical investigations," Brazilian J. Chem. Eng., vol. 25, no. 4, pp. 613–630, 2008.

[5] M. Kole and T. K. Dey, "Thermal conductivity and viscosity of Al2O3 nanofluid based on car engine coolant," J. Phys. D. Appl. Phys., vol. 43, no. 31, 2010.

[6] J. Sarkar, P. Ghosh, and A. Adil, "A review on hybrid nanofluids: Recent research, development and applications," Renew. Sustain. Energy Rev., vol. 43, pp. 164–177, 2015.

[7] J. Lee and I. Mudawar, "Assessment of the effectiveness of nanofluids for single-phase and two phase heat transfer in micro-channels," Int. J. Heat Mass Transf., vol. 50, no. 3–4, pp. 452–463, 2007.

[8] W. Yu and H. Xie, "A review on nanofluids: Preparation, stability mechanisms, and applications," J. Nanomater., vol. 2012, 2012.