THERMAL INVESTIGATION OF METAL OXIDE BASED NANO COOLANT USED IN AUTOMOBILE RADIATORS FOR ENHANCING HEAT TRANSFER CHARACTERISTICS

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Abstract:

In the automotive industry, the demand for efficient engines has increased. There are many systems which affect the engine performance such as fuel ignition system, emission control system, cooling control system, etc. one of the parameters which affect the engine performance is that the rate of the radiator cooling system. Accessory of fins is one of the earlier approaches for cooling the systems. It provides greater area and increases the air convective heat transfer coefficient. The traditional approach of accelerating the cooling rate by using fins already reached their limit. There is a requirement for new thermal fluids to improve the heat transfer rate in the automotive car radiator. Advancement of Nanotechnology, Nanofluids seems to have the potential to replace the conventional coolants in the engine cooling system. The present work deals with synthesis and characterization of metal oxide nanoparticles which is to be dispersed in coolants used in automobile radiator. Sol-gel chemical process is used to synthesize and XRD and SEM is used to characterize the prepared metal oxide nanoparticles. Further, the heat transfer characteristics of water ethylene glycol based Titania and Zinc oxide based nanofluid was analyzed experimentally and compared with water ethylene glycol mixture. Three different concentrations of nanofluids were prepared by adding 0.1 vol. %, 0.2 vol. % and 0.3 vol. % of each Ti-Zn oxide nanoparticles into water ethylene glycol mixture. The experiments were conducted by varying the coolant flow rate between 8 lit/min to 14 lit/min for various coolant temperatures (70°C, 80°C, 90°C, and 100°C) to understand the effect of coolant flow rate on heat transfer.

Keywords: Sol-gel, X-Ray Diffraction (XRD), Field Emission Scanning Electron Microscope (FESEM).

1. INTRODUCTION

The conventional fluids such as ethylene glycol and water have been showing poor heat transfer performance due to low thermal conductivity values. Various studies have been performed to increase the coolants heat transfer rate. Suspension of metal oxide nano particles in a base fluid is one among them. Nanotechnology is the science and technology of minute things that are less than 100nm in size. In dimension scale, one nano-meter is actually equal to 10-9 meters. Nanofluids are potential fluids for heat transfer with enhanced heat transfer rate and thermophysical properties.

They have concluded that researches on nanofluids with various nanomaterials and base fluids shown that nanofluids having excellent thermal performance. They found base fluids characteristics, such as the ratio of water and ethylene glycol mixture, volume concentration, nanoparticle size, nanoparticle material and flow characteristics influenced the heat transfer characteristics of nanofluids [1]. Now the usage of nanofluids in the automobile applications such as lubricant, coolant, fuel additives, shock absorbed, and as a refrigerant has increased. The main aim of their project is to give awareness about the advantages of nanoparticles in the automobile industries. The project also delivers comprehensive data of nanofluid applications in the automobile industry [2]. Conducted experiment with water-based nanofluid in the automobile radiator and compared results with pure water. Preparation of the nanofluid was done by adding Al_2O_3 nanoparticles in between 0.1 vol% to 1 vol% into water. Liquid flow rate to radiator changed between 2 lit/min to 5 lit/min and the temperature maintained between 37°C to 49°C. The presence of Al_2O_3 particles in water made a significant increase in heat transfer, and the degree of heat transfer enhancement depends on the nanoparticles quantity used. Enhancement of 45% recorded at 1% volume concentration [3]. They were focused on ethylene glycol based copper nanofluids in an automotive cooling system. They have investigated on the enhancement of the heat transfer rate in the car radiator operated with nanofluid-based coolants. The rate of heat transfer and overall heat transfer coefficient in the cooling system increased with the usage of nanofluids based ethylene glycol compared to base fluid alone. An improvement of 3.8% in the heat transfer rate was achieved by adding 2% of copper nanoparticles in the base fluid at the Reynolds number of 5000 and 6000 for coolant and air respectively [4].

2. METHODOLOGY

2.1. Synthesis of Nanoparticles

The sol-gel process contains the development of a colloid period (sol) and gelation of the sol to form a network in a non-stop liquefied phase (gel). The precursors for the synthesis of this colloid have commonly of a metallic component a rounded with the aid of number responsive ligands.The preliminary material is processed to shape a dissoluble oxide and varieties a sol in interaction with water or diluted acid. Deduction of the liquefied from the sol produces the gel, and the sol/gel change controls the element size and shape. Calcinations of the gel produce the oxide. Sol-gel process discusses the condensation and hydrolyzes of alkoxide-based precursors such as tetraethyl orthosilicate or TEOS. The reactions in the sol-gel y primarily grounded on the hydrolyze and condensation of metallic alkoxides M(OR)z defined as :

$$MOR + H_2O \rightarrow MOH + ROH \text{ (hydrolysis)}$$

$$MOH + ROM \rightarrow M\text{-}O\text{-}M + ROH \text{ (condensation)}$$

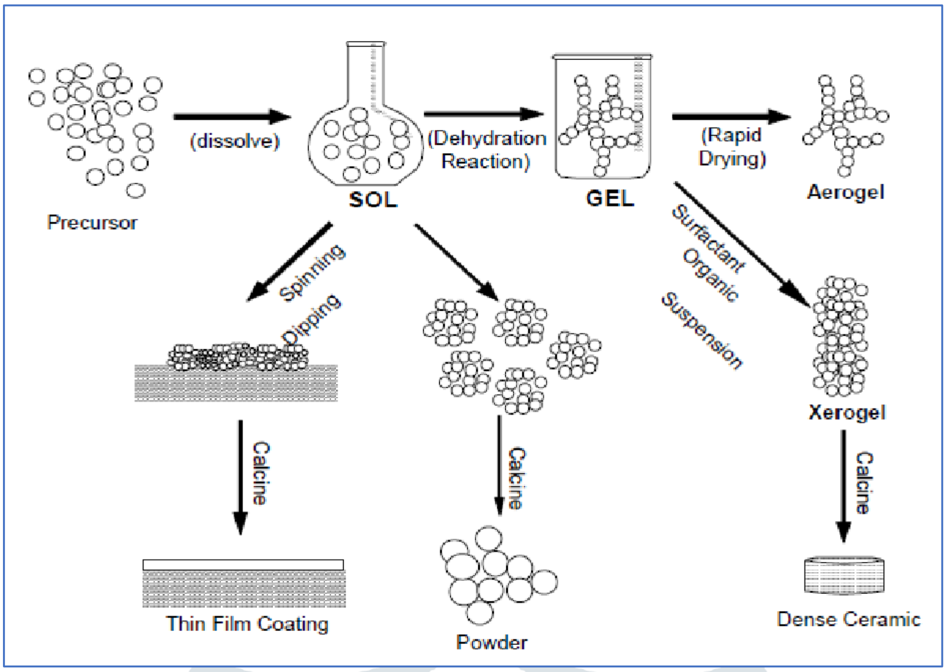

Figure 1: Schematic representation of sol-gel process

Prepared nanoparticles of titanium and zinc oxide are tested with the XRD technique. XRD results depict that the particles are perfect crystals. Field emission SEM gives elemental and topographical information at 10x to 300,000x magnification with virtually unlimited depth of field. FESEM results suggest that the particles are less than 100 nm and almost spherical in nature. The surfaces of the particles are rough and there were some protrusions on the particles.

2.2. Preparation of Nano Coolant

Firstly, ethylene glycol of 20% was mixed to the water, then the mixture is stirred at 1500 rpm at the temperature of 45 degrees on the hot plate magnetic stirrer for 25 minutes. Later, the mixture was kept undisturbed to check for separation of the mixture. Further using ultrasonicate the measured nanoparticles are dispersed in the coolant, ultrasonication is done for 10 minutes.

S. No	**ZnO**	**TiO_2**	**Quantity of coolant (lts.)**	**Weight of combined Nanoparticles (gms)**
1	-nix-	-nix -	2	-nix-
2	0.1	0.1	2	3.248
3	0.2	0.2	2	6.496
4	0.3	0.3	2	9.744

Table 1: Samples of Titania and Zinc Oxide

2.3. Experimental Setup:

These Nano based metal oxides were used in automobile radiators for enhancing the heat transfer rate as shown in the below photographic view figure 2.

Figure 2. Radiator setup and Hose pipe Connections

3. RESULTS AND DISCUSSIONS

3.1. FESEM Results

FESEM results depict that the particles synthesized are almost spherical; there was an agglomeration of nanoparticles. The particles of titania and zinc oxide are in the nano range, and the average particles of both are approximately 75 nm which is less than 100 nm.

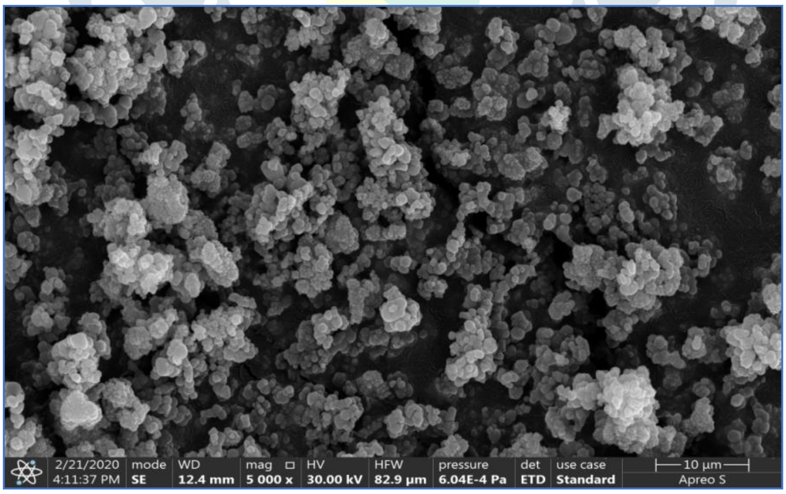

Figure 3. FESEM Result of Titanium Nanoparticles

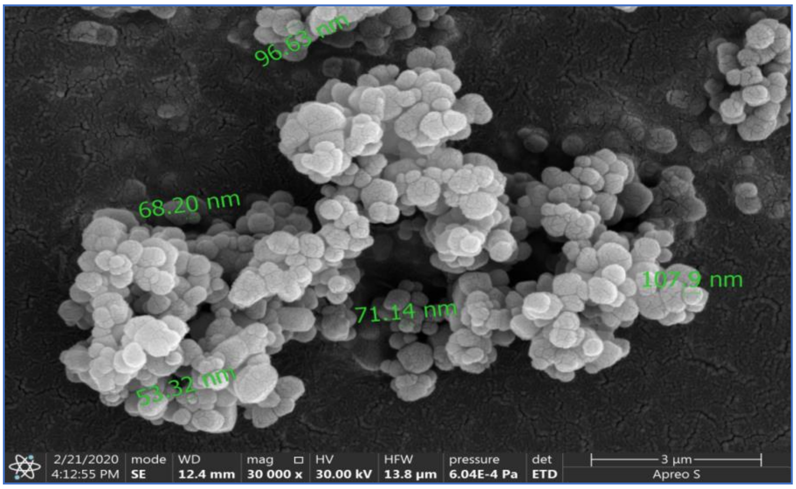

Figure 4. Surface Morphology of Zinc Oxide Nanoparticles

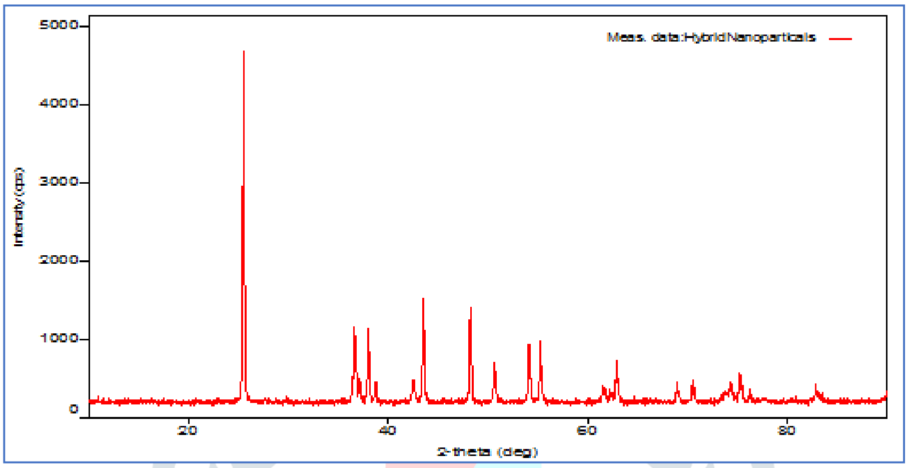

Figure 5. XRD of combined Titania and Zinc oxide hybrid Nanoparticles

The XRD results of combined Titania and Zinc oxide nanoparticles reveal that the particles are highly crystalline; it is because of high-intensity peaks induced with a minimum band gap of peaks.

Sample type	**ZnO**	**TiO_2**	**Overall weight % of nano particles**	**Quantity of coolant (lts)**	**Weight of combined nanoparticles (gms)**	**pH value**	**Viscosity (Cp)**	**Thermal conductivity (W/m K)**
Sample 1	Nil	Nil	Nil	2	Nil	7	17.3	1.21
Sample 2	0.1	0.1	0.2	2	3.248	7	18.5	1.33
Sample 3	0.2	0.2	0.4	2	6.496	7	19.2	1.78
Sample 4	0.3	0.3	0.6	2	9.744	7	19.8	1.81

Table 2: Samples of Titania and Zinc Oxide Properties

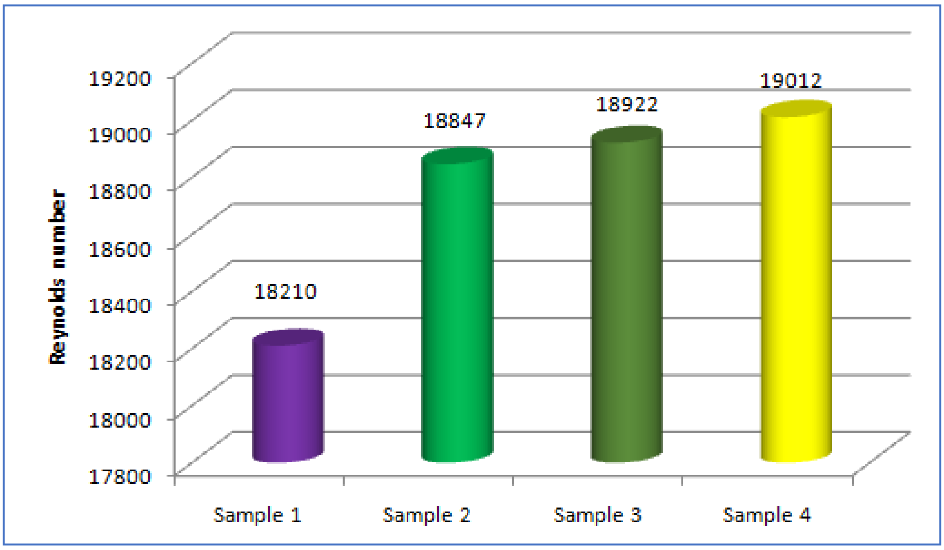

Figure 6. Reynolds number of the samples

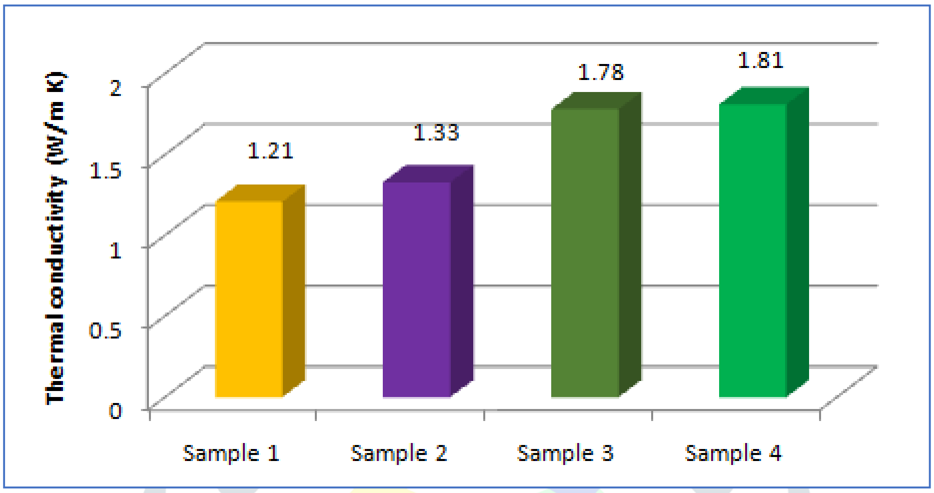

Figure 7. Thermal Conductivity values of the samples

Thermal conductivity of samples was tested using thermal conductivity analyzer. The graph depicts that the pure coolant thermal conductivity was 1.21 W/m k, with hybrid Titania and Zinc oxide nanoparticles inclusions in the coolant thermal conductivity was enhanced by 1.49% than pure coolant.

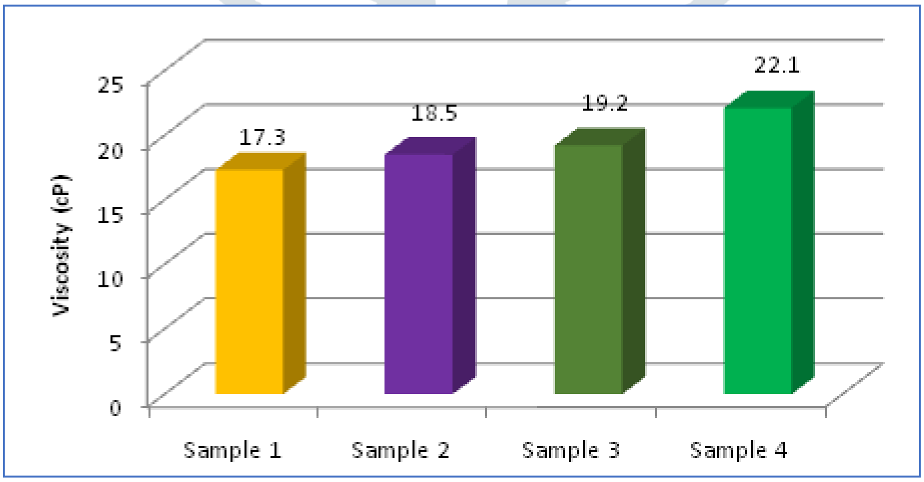

Figure 8. Viscosity values of the samples

The flow of coolant inside the radiator hose pipes and pipe lines of radiator is an important factor. The base coolant viscosity was 17.3 cP, with nanoparticles inclusion in the coolant viscosity was also increased, for sample 4 the viscosity was increased appreciably.

For the experimentation, sample 4 was selected, and the investigation was done using radiator cooling. Sample 4 was used to find the heat transfer rate and outlet temperature of the water.

Mass flow rate (l/min)	Heat transfer rate (W)
8	86
10	89.2
12	93.4
14	97.7

Table 3: Heat transfer rate values with respect to Mass flow rate

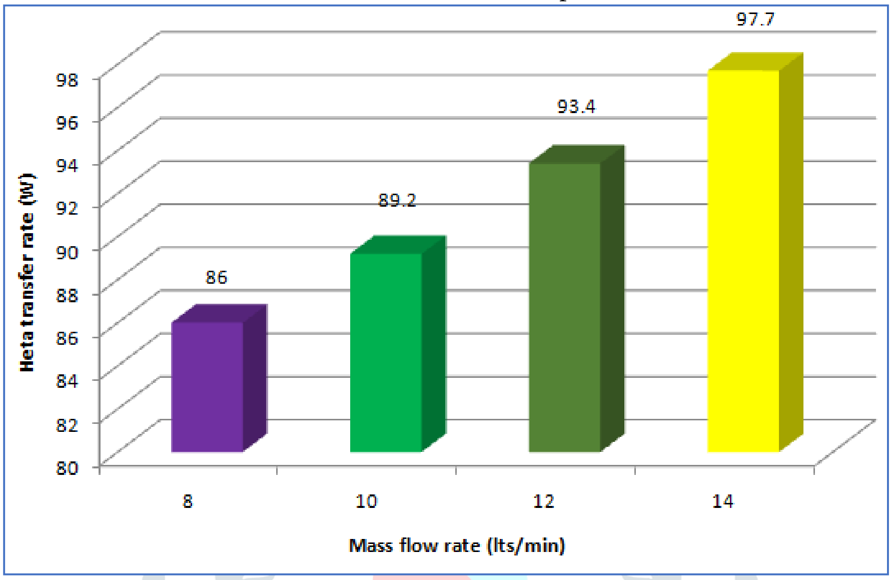

Figure 9. Heat transfer rate vs mass flow rate

The heat transfer rate was increased simultaneously with the increased mass flow. At low mass flow rate, there was a slow dispersion of nanoparticles with respect to the coolant. Whereas on the other hand, with increased mass flow rate, there was effective dispersion and movement of nanoparticles along with coolant.

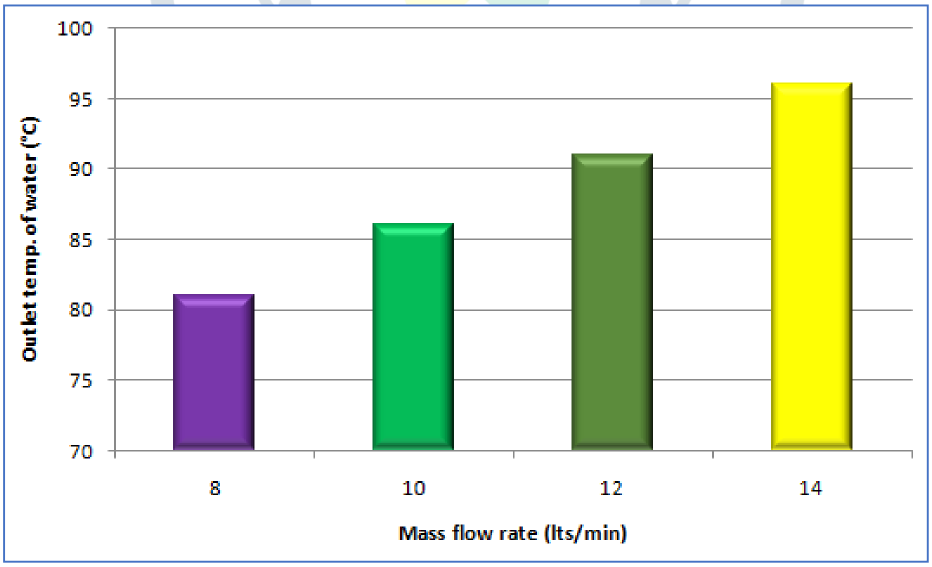

Figure. 10. Outlet temperature of water vs Mass flow rate

Sample 4 was used in the cooling system, and the results depict that with respect to the increased mass flow rate of nano-based coolant, there was increased outlet temperature of the coolant. The above result stated that the heat transfer rate increased by absorbing a tremendous amount of heat from the engine temperature maintaining optimum.

4. CONCLUSIONS

- The XRD results depict that the particles of both Titanium and Zinc are highly crystalline.
- The FESEM results suggest that the particles are less than 100 nm and almost spherical. The surfaces of the particles are rough; there were some protrusions on the particles. These protrusions will help for increased heat transfer rate.
- Sample 4 is having more thermal conductivity and viscosity; hence it is selected for the experimentation.
- Sample 4 which is 0.6 wt. % containing an equivalent amount of ZnO and TiO2 nanoparticles.
- The nanoparticles were not agglomerated and accumulated and in-fact effectively been dispersed and circulate along with coolant.
- The heat transfer rate increased, and the outlet temperature was reduced with increased mass flow rate.

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REFERENCES

1. W.H. Azmi, K. Abdul Hamid, N.A. Usri, RizalmanMamat, and K.V. Sharma. “Heat transfer augmentation of ethylene glycol: water nanofluids and applications - a review”, International Communications in Heat and Mass Transfer 75, 13–23, 2016.
2. S. Senthilraja, M. Karthikeyan and R. Gangadevi, “Nanofluid applications in future automobiles: comprehensive review of existing data”, Nano-Micro Letter, Volume 2, 306-310, 2010.
3. S.M. Peyghambarzadeh, S.H. Hashemabadi, M. SeifiJamnani, S.M. Hoseini, “Improving the cooling performance of automobile radiator with Al2O3 /water nanofluid”, Applied Thermal Engineering 31, 1833–1838, 2011.
4. K.Y. Leong, R. Saidur, S.N. Kazi, and A.H. Mamunc, “Performance investigation of an automotive car radiator operated with nanofluid based coolants”, Applied Thermal Engineering 30, 2685-2692, 2010.
5. DevireddySandhya, Mekala Chandra Sekhara Reddy, and VeeredhiVasudevaRao, “Improving the cooling performance of automobile radiator with ethylene glycol water based TiO2nanofluids”, International Communications in Heat and Mass Transfer 78,121–126, 2016.
6. KotiJeevith, M. Vivek, S. Thirumalini, “Study of heat transfer characteristics of Al2O3/water-Propylene glycol nanofluid as a coolant in an automobile radiator”, International Journal of Applied Engineering Research, Volume 10, pp 36204-36208, 2015.
7. K.P. VasudevanNambeesan, M. Vivek, S. Thirumaliniet. al., “Experimental study of heat transfer enhancement in automobile radiator using Al2O3/water-ethylene glycol nanofluid coolant”, International Journal of Automotive and Mechanical Engineering, Volume 12, pp. 2857-2865, 2015.