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Numerical Investigation of Total Heat Transfer Rate & Exergy Analysis of Automobile Radiator by Using Nanofluid as Coolant

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Abstract: ***The automobile sector is one of the fastest developing and growing industries not only in India but on the world level. The Indian automobile industry is one of the largest in the world. Sales of automobile are increasing rapidly every year. The sales of automobile are increased by about 14% in the year of 2017. The overall Commercial Vehicles segment grew by 19.94 percent in April-March 2018 as compared to the same period last year i.e. 2017. Further, above data shows that automobile sector is one of the vast area for research work for the comfort of passengers there are plenty of research area available in the field of automobile like suspension system, steering system, break system, engine design and many more. Engine of any vehicle is considered as heart of the whole automobile. Further, engine can only work well when it's cooling system done proper cooling of engine. Overheating and overcooling will consequences savior damage to engine. So, proper cooling of engine is very essential research area of any automobile sector. Engine cooling comprises several parts like radiator, pump etc. cooling of engine is done by coolants which flows in to the radiator tubes. Coolants take heat from engine and reject it to atmospheric air while passing through radiator tube. Coolants is a mixture of water and ant freezing agent mostly ethylene glycol. Water is one of the most effective coolants due to its thermo physical properties. But when we mix ant freezing agent in water its cooling capacity gets decrease. Now to increase its cooling capacity we have to make bigger radiator which further increase the weight of the automobile which decrease engine performance. So, there is a need of new technology for coolants which increase the cooling capacity without increase the size of radiator. The new technological coolant called "Nano Fluids" which is nothing but a mixture of Nano sized particles in the mixture of water and ant freezing agent. Due to its good thermo physical properties Nano fluids will produce better cooling as compared to conventional coolants. Present study uses 60% of water and 40% of ethylene glycol as base fluid with three Nano particles like Al2O3,CuO and MgO. The radiator used is cross flow heat exchanger with unmixed fluid which id TBD-232 type diesel engine. For the calculation of total heat transfer rate and second law efficiency a computer program in C++ language has been made. The present study shows that, the total heat transfer rate of the radiator has been found higher, when nano-fluids were used as coolants rather than of base fluids only. An increment of 15% to 18% was seeing in the total heat transfer rate of the radiator using nano-particles in the base fluid. Nano fluid based on MgO, Al2O3 and CuO, having total heat transfer rate grater then 18%,17%, and 15% respectively of base fluid coolant only. MgO based nano fluids shows highest total heat transfer rate as compared to other nano fluids. The second law efficiency of the radiator has been found higher, when nano-fluids were used as coolants rather than of base fluids only. An increment of 19% to 21.5% was seeing in the second law efficiency of the radiator using nano-particles in the base fluid. Nano fluid based on MgO, Al2O3 and CuO, having second law efficiency grater then 21.42%, 20.95%, and 19.75% respectively of base fluid coolant only. MgO based nano fluids shows highest second law efficiency as compared to other nano fluids.***

Keywords: Exergy, Nanofluid, Hear Transfer Rate

1. Introduction

Heat transfer has been a great challenge for the automobile to achieve better performance and efficiency. Convection heat transfer plays an important role in automobile cooling systems. Throughout the automotive component heat must be added, removed or moved from one process to another. Radiator is a main part of an engine. Radiators are heat exchangers used for cooling internal combustion engine and also used in aircraft, locomotives, etc. Normally it is used as a cooling system in an engine. Most of liquid cooling system consists of components like radiator, water pump, electric cooling fan, thermostat, storage tank. Generally water and ethylene glycol are used as a cooling medium. However, the poor thermal ability inherent by conventional fluids puts a limitation on heat transfer to give the best performance. Therefore, it is important to develop a new heat transfer fluid which can give high thermal performance compare to common fluid. The latest technological advancement an emerging a new class of coolants called NANO FLUIDS (Nano particles with base materials). Nanofluids, for the first time, have been introduced by Choi as a suspension of nano-sized particles into conventional fluids such as water, ethylene glycol, propylene glycol, oil, and so forth. Compare to conventional fluid the Nano fluids have greater heat transfer, effective thermal conductivity, diffusivity and Brownian motion. Nano fluids used in the various application like microelectronics, transportation, manufacturing and bio engineering.

1.1 Nanofluids

Scientific community has achieved significant and swift advances in finding various practical applications of nanofluids. Nanofluids are prepared by dispersing the nano-sized particles in a base fluid. Applications of nanofluids are almost unlimited. For instance, they can be used for cooling of electronic devices, medical applications, fuel cells, solar energy systems, and car engine lubrication. Measuring thermophysical characteristics of nanofluids such as thermal

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conductivity and dynamic viscosity is an important subject for applying nanofluids in the referred systems in which heat transfer is carried out at high temperatures such as heat exchangers and car engines. Viscosity of a coolant in heat exchangers plays a leading role in required pump power. Also, thermal conductivity affects coolant flow characteristics. It is worth to note that, it is essential for car engine lubricants to maintain their viscosity at high temperatures. In addition, thermo physical characteristics of fluids used as coolants in automotive applications can affect the size of the system and provide an engine with smaller dimensions. Many studies have been conducted on thermo physical characteristics of nanofluids. Also, some studies have introduced new correlations for predicting the behavior of nanofluids. Most of these correlations are function of temperature and solid volume fraction. Although these models do not have a theoretical basis, they are broadly utilized in engineering applications, because of their simplicity in the correlation of experimental data. In order to estimation of dynamic viscosity and thermal conductivity from experimental data, another method which has been used in recent years is artificial neural.

Nano fluids is a fluid containing nanometre sized particles called nanoparticles. These particles are dispersed with the base fluids. Particles are further classified according to diameter coarse particles (10.00 to 2.50 nm), fine particles (2.50 to 100 nm), and ultrafine particles (1 to 100 nm). The Nano particles used in Nano fluids are made of metals, oxide and carbide. Solid particles are added they conduct heat much better than a liquid. Common base fluids include water, ethylene glycol and oil. Most of the research work done as Al2O3, CuO, TiO2, MgO etc.

2. Literature Review

R. S. Vajjha et. al. [20] numerically studied a three-dimensional laminar flow and heat transfer with two different nanofluids, Al_2O_3 and Cuo, in an ethylene glycol and water mixture circulating through the flat tubes of an automobile radiator and evaluate their superiority over the base fluid. They shows that Heat transfer for Al_2O_3 and Cuo nanofluids with varying particle volumetric concentrations exhibit substantial increase in the average heat transfer coefficient with concentration. For example, at a Reynolds number of 2000, the percentage increase in the average heat transfer coefficient over the base fluid for a 10% Al_2O_3 nanofluid is 94% and that for a 6% CuO nanofluid is 89%. For the same amount of heat transfer, the pumping power requirement is 82% lower for a Al_2O_3 nanofluid of 10% concentration and 77% lower for a CuO nanofluid of 6% concentration when compared to the base fluid.

V. Vasu et. al. (13) theoretically analyzed the Al_2O_3 + H_2O nano-fluid as coolant on automobile flat tube plain fin compact heat exchanger. The analysis was carried out using effectiveness-NTU rating method. A detailed flow chart of the numerical method and correlations used for Al_2O_3 + H_2O nano-fluid were also presented along with the graphical presentation of the characteristics. The analysis showed that the cooling capacity of nano-fluid was far better than the conventional coolants.

Sundar et al. (21)experimentally estimated the thermal conductivity of ethylene glycol and water mixture based Al_2O_3 and CuO nano-fluids at different volume concentrations and temperatures. The base fluid used was a mixture of 50:50% (by weight) of ethylene glycol and water (EG/W), and the particle concentration of up to 0.8% and the temperature range from 15^oC – 50^oC were considered.

The experimental investigation showed that both the nano-fluids exhibited higher thermal conductivity compared to base fluid. Also, for the same volume concentration and temperature, CuO nano-fluid's thermal conductivity was more compared to Al_2O_3 nano-fluid. Furthermore, a new correlation was developed based on the estimation of thermal conductivity of both the nano-fluids.

J. Sarkar et.al. [04]This paper presents the exergetic analysis and optimization of a transcritical carbon dioxide based heat pump cycle for simultaneous heating and cooling applications. A computer model has been developed first to simulate the system at steady state for different operating conditions and then to evaluate the system performance based on COP as well as exergetic efficiency, including component wise irreversibility. The chosen system includes the secondary fluids to supply the heating and cooling services, and the analyses also com-prise heat transfer and fluid flow effects in detail. The optimal COP and the exergetic efficiency were found to be functions of compressor speed, ambient temperature and secondary fluid temperature at the inlets to the evaporator and gas cooler and the compressor discharge pressure. An optimization study for the best allocation of the fixed total heat exchanger inventory between the evaporator and the gas cooler based on heat transfer area has been conducted.

The exergy flow diagram (Grassmann diagram) shows that all the components except the internal heat exchanger contribute significantly to the irreversibilities of the system. Unlike a conventional system, the expansion device contributes significantly to system irreversibility. Finally, suggestions for various improvement measures with resulting gains have been presented to attain superior system performance through reduced component irreversibilities.

Dong et al. [06] Performed experimental studies on the air side heat transfer and pressure drop characteristics for 20 types of multi-louvered fin and flat tube heat exchangers. They conducted a series of tests for air Reynolds numbers of 200-2500 based on the louver pitch with the different fin pitch, fin length, fin thickness, fin louver angle and flow extent at a constant tube side flow rate of 2.8 m^3/h. The air side thermal performance data were examined using the effectiveness-NTU approach. The effect of the heat transfer and pressure drop for the different geometry parameters were noted in terms of Colburn j-factor and Fanning friction f-factor as a function of Reynolds number.

The studies showed that the correlations for j and f factors predicted the experimental data within a rms error of ±10%

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and ±12%, and the mean deviations were 4.1% and 5.6%, respectively.

3. Mathematical Modeling and Simulation

Based on the first and second law of thermodynamics, the Numerical model was developed including heat transfer and fluid flow effects. Following assumptions were taken for analysis:

1) All properties of coolants and air are assumed to be constant.
2) Heat rejected by coolants will be fully absorbed by air.
3) All processes are assumed to be steady state.

The louvered fin cross flow radiator is selected as compact heat exchanger for this project, which is diesel engine with turbo-charged of type TBD 232V-12, where fluid is unmixed. The radiator is having of 644 tubes made of brass material with 346 continuous fins made of Aluminium alloy. Thermal conductivity of fin material is 177W/m-K. The coolant used in this study is water with nano particles i.e. nano fluids.

3.1 Air Side calculation

Table 3.1: Fluid parameters and normal operating conditions [14]

S.NO.	Description	Air
1	Fluid mass rate (Wa)	10-20kg/s
2	Fluid inlet temperature(Tai)	283-323K
3	Core Width (L)	0.6m
4	Core height (H)	0.5m
5	Core depth (D)	0.4m

Table 3.2: Surface core geometry of flat tubes, continuous fins [14]

S. No	Description	Air side
1	Fin pitch	4.46fin/cm
2	Fin metal thickness t	0.0001m
3	Hydraulic diameter Dha	0.00351m
4	Min free flow area/frontal area σa	0.780
5	Total heat transfer area/total volume αa	886 m^2/m^3
6	Fin area/Total area β	0.845

Table 3.3: Thermal physical properties of air [23]

S.No	Thermal physical properties	Air
1	Density(kg/m^3)	1.1614
2	Specific heat (J/kg K)	1007
3	Viscosity($N\text{-}s/m^2$)	**0.00001846**

Table 3.4: Specification of louvered fin parameters [9]

1	F_P	2 mm
2	F_H	8 mm
3	L_D	36.6 mm
4	LP	1.2 mm
5	LH	6.5 mm
6	LA	28

1. Air Frontal area

A_{fra}= L* H Eq.1

2. Core mass velocity of air is expressed as [19]

$$G_a = \frac{W_a}{A_{fr}\sigma_a} \quad \text{Eq.2}$$

3. Velocity of air

$$u_a = \frac{G_a}{\rho_a} \quad \text{Eq.3}$$

4. Reynolds number expression [9]

$$\mathrm{Re}_a = \frac{G_a D_{ha}}{\mu_a} \quad \text{Eq.4}$$

Hydraulic Diameter

$D_{ha}=4*\sigma_a/\alpha_a$ Eq.5

5. Heat transfer coefficient, ha can be expressed as [19]

$$h_a = \frac{j_a G_a c_{p,a}}{Pr_a^{2/3}} \quad \text{Eq.6}$$

6. Colburn factor [06]

$$j_a = 0.26712\,\mathrm{Re}_a^{-0.1944} \times \left(\frac{La}{90}\right)^{0.257} \times \left(\frac{F_p}{L_p}\right)^{-0.5177} \times \left(\frac{F_h}{L_p}\right)^{-1.9045} \times \left(\frac{L_h}{L_p}\right)^{1.7159} \times \left(\frac{L_d}{L_p}\right)^{-0.2147} \times \left(\frac{t}{L_p}\right)^{-0.05}$$

Eq.7

7. Plate fin efficiency, η can be expressed as [19]

$$\eta = \frac{\tanh ml}{ml} \quad \text{Eq.8}$$

Where,

$$m = \sqrt{\frac{2h_a}{kt}}$$

8. Total surface temperature effectiveness, can be expressed as [19] $\eta_o = 1 - \frac{A_f}{A}\left(1-\eta_f\right)$ Eq.9

3.2 Nanofluid Side calculation

Table 3.5: Thermal physical property of base fluid [28]

Physical Properties	Water
Density (Kg/M^3)	992
Viscosity (Kg/ms)	0.00065
Thermal Conductivity (W/m^0C)	0.633
Specific heat (J/kg^0C)	4174

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Table 3.6: Thermal physical properties of nano particles [15]

S. No	Thermal physical properties	(Al_2O_3)	CuO	MgO
1	Density (kg/m^3)	3970	6500	2900
2	Specific heat (J/kg K)	765	535.6	923
3	Conductivity (W/m K)	40	20	48.4

Table 3.7: Fluid parameters and normal operating conditions [14]

S.No	Description	Coolant
1	Fluid mass rate	3-7kg/s
2	Fluid inlet temperature	355-375K
3	Core Width	0.6m
4	Core height	0.5m
5	Core depth	0.4m

Table 3.8: Surface core geometry of flat tubes, continuous fin [14]

S.No	Description	Coolant side
1	Hydraulic diameter D_h	0.373cm
2	Min free flow area/frontal area σ	0.129
3	Total heat transfer area/total volume α	138 m^2/m^3

1. Coolant side Frontal area of
A_{frn}= L* D Eq.10
2. Core mass velocity of coolant is expressed as [19]

$$G_{nf} = \frac{W_{nf}}{A_{fr}\sigma_{nf}} \qquad \text{Eq.11}$$

3. Velocity of coolant

$$u_{nf} = \frac{G_{nf}}{\rho_{nf}} \qquad \text{Eq.12}$$

4. Viscosity of nanofluid for Water and ethylene glycol based coolant is calculated based on following correlation [03]

$$\mu_{nf} = \mu_f \left(1 - 0.19\phi + 306\phi^2\right) \qquad \text{Eq.13}$$

5. $C_{p,nf}$ and ρ_{nf} were calculated based on correlations obtained from [09]

$$c_{p,nf} = \frac{(1-\phi)\rho_f c_{p,f} + \phi\rho_p c_{p,p}}{\rho_{nf}}$$

$$\rho_{nf} = (1-\phi)\rho_f + \phi\rho_p \qquad \text{Eq.14}$$

6.Reynolds number expression for nanofluid [19]

$$\mathrm{Re}_{nf} = \frac{G_{nf} D_{h,nf}}{\mu_{nf}} \qquad \text{Eq.15}$$

7. Heat transfer coefficient can be expressed as [19]

$$h_{nf} = \frac{Nu_{nf} k_{nf}}{D_{h,nf}} \qquad \text{Eq.16}$$

8. K_{nf} of nano-fluid for water and ethylene glycol as coolant is calculated based on correlation from [1]

K_{nf} = k_p+2 k_{bf}-2(k_{bf}- $k_{p)}$ Φ/ k_p+2 k_{pf}+2(k_{bf}- $k_{p)}$ Φ *k_{bf} + $5*10^4$β*ρ_{bf}*C_{pbf}* Φ *[k*Tni/($\rho_{p*}d_p$)]$^{1/2}$ *[(- 134.63+1722.3 * Φ) + (0.4705-6.04* Φ) Tni]

Where the particle related empirical parameter
β=0.0137*(100* $\nu_p)^{-.8229}$Φ $_{<0.01}$
β =0.0011*(100* $\nu_p)^{-.7272}$ Φ $_{>0.01}$ Eq.17

9. Nusselt number for nanofluid is expressed as [10]
$Nu_{nf} = 0.021(Re_{nf})^{0.8}(Pr_{nf})^{0.5}$ Eq.18

10. Prandtl number expression for nanofluid is [19]

$$\mathrm{Pr}_{nf} = \frac{\mu_{nf} c_{p,nf}}{k_{nf}} \qquad \text{Eq.19}$$

11. Overall heat transfer coefficient, based on air side can be expressed as bellow, where wall resistance and fouling factors are neglected. [19]

$$\frac{1}{U_a} = \frac{1}{\eta_o h_a} + \frac{1}{\left(\frac{\alpha_{nf}}{\alpha_a}\right) h_{nf}} \qquad \text{Eq.20}$$

12. Heat exchanger effectiveness for cross-flow unmixed fluid can be expressed as [19]

$$\varepsilon = 1 - \exp\left[\frac{NTU^{0.22}}{C^*}\exp\left(-C^* NTU^{0.78} - 1\right)\right] \qquad \text{Eq.21}$$

13. Number of heat transfer unit is expressed as [19]

$$NTU = \frac{U_a A_{fr,a}}{C_a}$$

Where $C^* = \frac{C_{\min}}{C_{\max}}$ Eq.22

14. Total heat transfer rate can be expressed as [19]

$$Q = \varepsilon C_{\min}\left(T_{nf,in} - T_{a,in}\right) \qquad \text{Eq.23}$$

3.3 Second law analysis

The Guoy–Stodola theorem provides the basis for calculation of irreversibility in heat exchangers, which is the quantitative measure of the exergy loss in the process and is related to entropy generation as [11]

$$I = T_0 S_{gen} \qquad \text{Eq.24}$$

3.4 Irreversibility due to fluid friction

The dissipative forces arising on account of fluid friction also contribute significantly to irreversibility, in the form of pressure drop. Taking working fluid as an ideal gas, the thermodynamic loss due to fluid friction is given as [12]

$$(S_{gen})_{\Delta p} = \left[W\frac{\Delta P}{\rho T}\right]_{nf} + (WR)_a \ln\left[\frac{p_{in}}{p_{out}}\right]_a \qquad \text{Eq.25}$$

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At the outlet of the heat exchanger, pressure can be considered to be atmospheric. The exergy loss by the hot fluid (nanofluid) is given by [04]

$$\Delta Ex_{nf} = Q - T_0 \left[WC_p \ln\left(\frac{T_{in}}{T_{out}}\right) - W\frac{\Delta P}{\rho T} \right]_{nf} \qquad \text{Eq.26}$$

Similarly, the exergy gain by cold fluid (air) is given by [04]

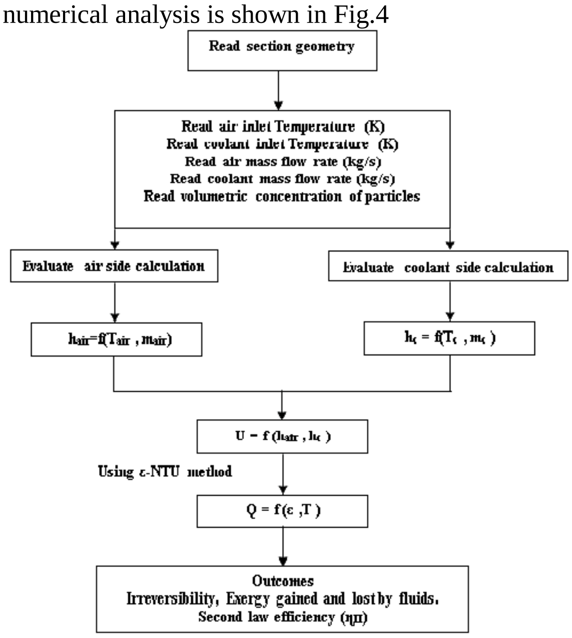
$$\Delta Ex_a = Q - T_0 \left[WC_p \ln\left(\frac{T_{out}}{T_{in}}\right) + WR\ln\left(\frac{P_{in}}{P_{out}}\right) \right]_a \qquad \text{Eq.27}$$

The Second law efficiency (η_{II}) is the ratio of the minimum exergy which must be consumed to do a task divided by the actual amount of exergy consumed in performing the task, is given by [04].

$$\eta_{II} = \frac{\Delta Ex_a}{\Delta Ex_{nf}} = 1 - \frac{I}{\Delta Ex_{nf}} \qquad \text{Eq.28}$$

3.5 Simulation procedure and validation

For implementing the analysis, a computer program in C++ has been made for the compact heat exchanger (Automobile Radiator). This program is very useful in estimating the fluid properties at various operating temperatures, surface core geometry of cross flow heat exchanger, heat transfer coefficients, second law efficiency, overall heat transfer coefficients and heat transfer rate. The flowchart for the numerical analysis is shown in Fig.4



Flow Chart 1: Flow chart of the numerical method [41]

4. Validation

4.1 variation of inlet mass flow rate of air `

The figure below shows the behavior of heat transfer or cooling capacity or total heat transfer rate with respect to mass flow rate of air. As it is clear from figure that heat transfer rate is increasing as we increase mass flow rate of air because increasing in overall heat transfer coefficient and the effectiveness for cooling is goes on decreasing because NTU is decreasing. Coolant based on MgO nano particles has greatest cooling capacity. However, CuO and Al_2O_3 based nano fluids also shows good cooling capacity. Further, mixture of 60% water and 40% EG fluids shows very poor cooling capacity when compared with nano fluid based coolant. Other parameters like mass flow rate of coolant (Mc=5 kg/s), inlet temperature of air (Ta=303K), Inlet temperature of coolant (Tc=363K) and volume concentration of nano particles (V_n=2%) are held constant when mass flow rate of air varies from 10kg/s to 20kg/s. it is clear from figure that 60W:40EG based coolants has very low cooling capacity as compared with coolant based on nano particles.

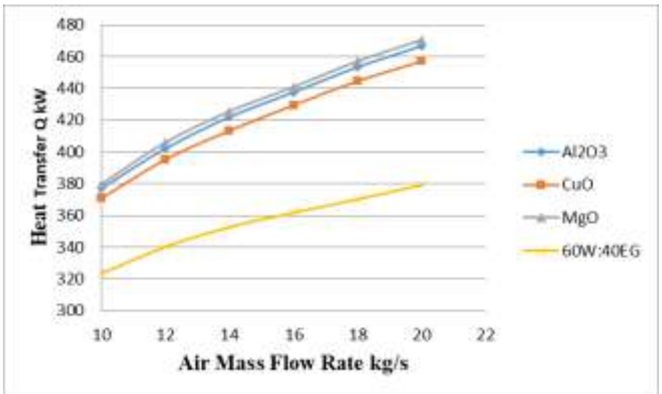


Figure 1

The figure below shows the variation in second law efficiency with respect to variation in mass flow rate of air from 10kg/s to 20kg/s when other parameters are held constant. Second law efficiency decreasing sharply as we increase mass flow rate of air because irreversibility continuously increasing. Irreversibility is increasing because exergy gained by air (cold fluid) is decreased.

Second law efficiency of mixture of 60% water and 40% EG coolant is less as compared to nano fluid coolants. The figure shows that nano fluids based on MgO have highest second law efficiency as compared to other nano fluids. CuO and Al_2O_3 show almost same behavior. Irreversibility of mixture of 60% water and 40% EG coolant is very high as compared to nano fluids based on Al_2O_3, CuO and MgO. Nano fluids based on MgO have higher irreversibility as compared to other nano fluids. It is clear from above discussion that second law efficiency is less when we mix nano particles in base fluid. It means that using nano particles in base fluid decreases irreversibilities which results in higher second law efficiency which is beneficial for radiator cooling system.

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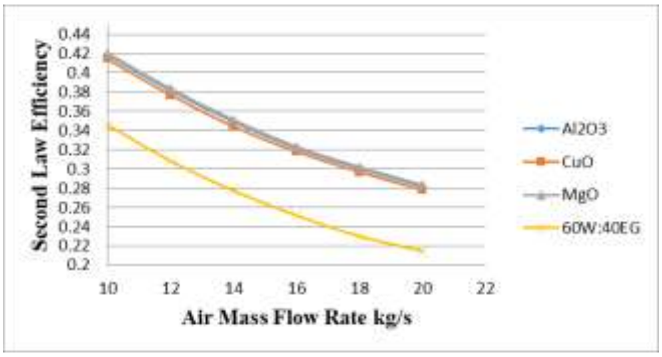

Figure 2

Figure below shows the variation in pumping power with respect to mass flow rate of air. Pumping power remains constant throughout variation in mass flow rate of air from 10kg/s to 20 kg/s when other parameters remain constant. It is clear from figure that pumping power required for nano particle based nano fluid is less as compare to mixture of 60% water and 40% EG based fluid. Pumping power required for MgO based nano fluid is very high as compared to Al_2O_3 and CuO based nano fluids. However, pumping power requirement is very less for 60:40W:EG mixture.

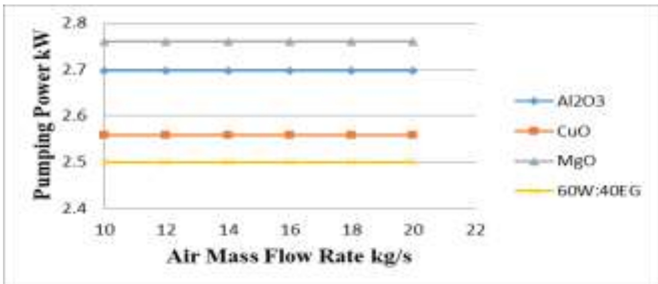

Figure 3

4.2 variation of inlet mass flow rate of coolant

Figure below shows the variation of cooling capacity with variation in mass flow rate of coolant (4 kg/s to 6kg/s) when other operating parameters like mass flow rate of air (Ma=15kg/s), Inlet temperature of air (Ta=303K), Inlet temperature of coolant (Tc=363K) and volume concentration of nano particles (Vn=2%) are held constant. As it is clear from figure that heat transfer rate is increasing as we increase mass flow rate of coolant because increasing in overall heat transfer coefficient and the effectiveness for cooling is goes on decreasing because NTU is decreasing. Coolant based on MgO nano particles has greatest cooling capacity.

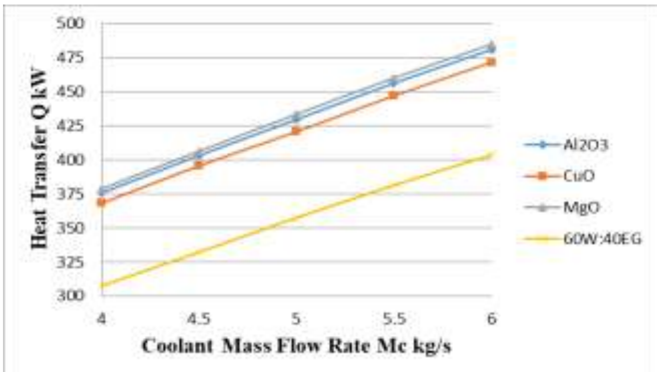

Figure 4

The figure below shows the variation in second law efficiency with respect to variation in mass flow rate of coolant from 4 kg/s to 6 kg/s when other parameters are held constant. Second law efficiency increasing sharply as we increase mass flow rate of air because irreversibility continuously decreasing. Irreversibility is decreasing because exergy lost by coolant (hot fluid) is increased.

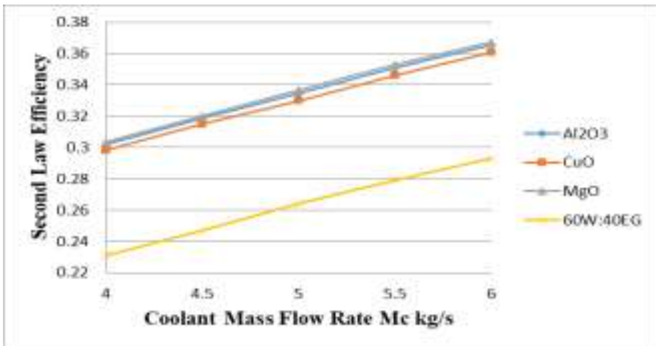

Figure 5

Figure below shows the variation in pumping power with respect to mass flow rate of coolant. Pumping power increase sharply with increase in mass flow rate of coolant from 4kg/s to 6 kg/s when other parameters remain constant. It is clear from figure that pumping power required for CuO based nano fluid is less as compare with other nano fluids and mixture of 60% water and 40% EG based fluid.

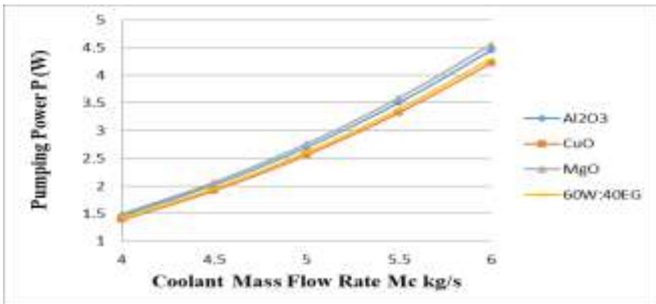

Figure 6

Figure below shows the variation in pressure drop with variation in mass flow rate of coolant. It is clear from chart that pressure drop is very less for 60%W:40%EG as compared to nano fluids. Nano fluids based on MgO has very high pressure drop as compared to other nano fluids.

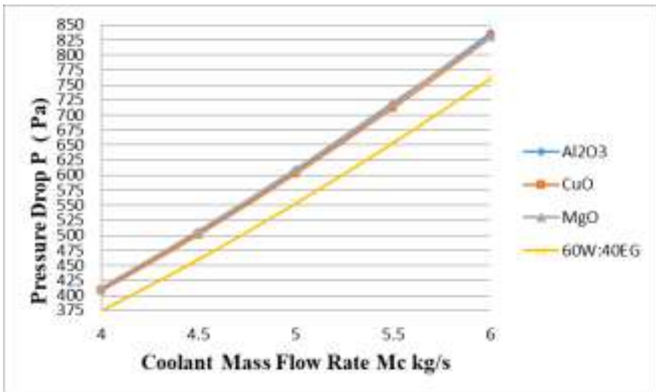

Figure 7

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4.3 Variation of inlet temperature of air

The figure below shows the behavior of heat transfer with respect to inlet temperature of air. As it is clear from figure that heat transfer rate is decreasing as we increase inlet temperature of air because decreasing in cooling temperature difference. Coolant based on MgO nano particles has greatest cooling capacity. However, CuO and Al_2O_3 based nano fluids also shows good cooling capacity. Further, mixture of 60% water and 40% EG fluids shows very poor cooling capacity when compared with nano fluid based coolant.

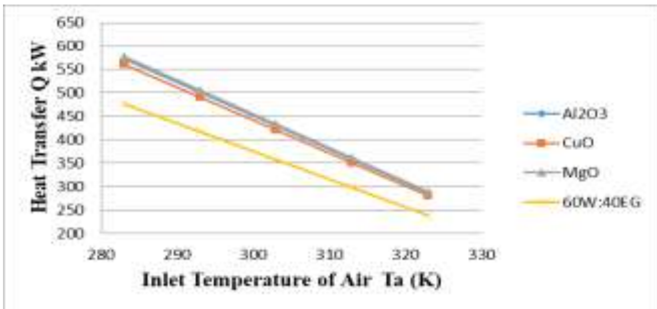

Figure 8

Figure below shows variation of second law efficiency with variation of inlet temperature of air from 283 K to 323 K. as it is clear from figure that second law efficiency goes on decreasing with increase in inlet temperature of air. Second law efficiency is decreasing because exergy gained by air and exergy lost by coolant both are decreasing.It is very clear from figure 14 that 60%W:40%EG coolant has least second law efficiency as compared to nano fluids. MgO based nano fluids shown highest second law efficiency.

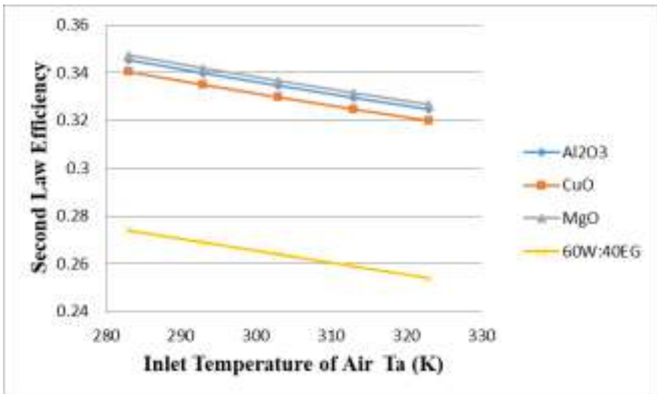

Figure 9

4.4 variation of inlet temperature of coolant

The figure below shows the behavior of heat transfer or cooling capacity or total heat transfer rate with respect to inlet temperature of air. As it is clear from figure that heat transfer rate is increasing as we increase inlet temperature of air because increasing in cooling temperature difference. Coolant based on MgO nano particles has greatest cooling capacity. However, CuO and Al_2O_3 based nano fluids also shows good cooling capacity. Other parameters are held constant when inlet temperature of coolant varies from 353K to 373K. it is clear from figure that 60W:40EG based coolants has very low cooling capacity as compared with coolant based on nano particles.

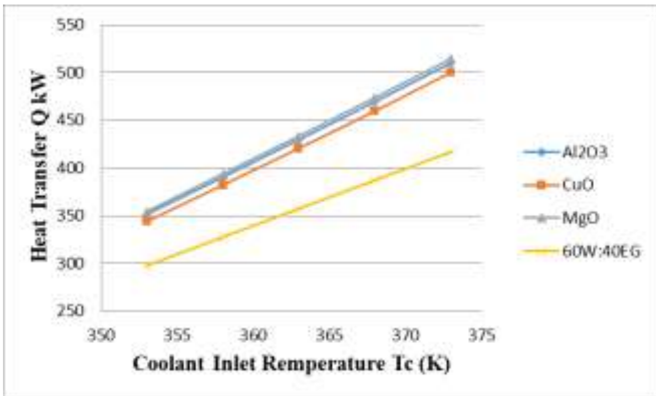

Figure 10

As it is clear from below figure that second law efficiency is increasing with increasing in inlet temperature of coolant from 353 K to 373 K. Exergy gained by cold fluid (air) and irreversibility is also increasing with increase in coolant inlet temperature. 60%W:40%EG coolant has low second law efficiency as compared to nano fluids. Nano fluids based on MgO shows better performance as compared to other nano fluids.

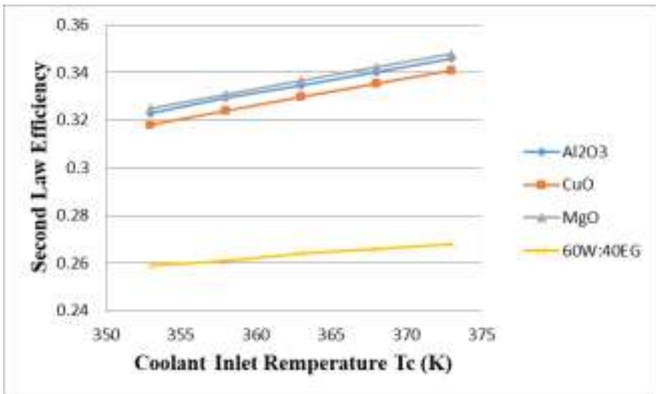

Figure 11

The figure below illustrates the variation of cooling capacity, second law efficiency, Pumping power and pressure drop with respect to nano particles concentration over a range of 1% to 5%.

4.5 variation of volume concentration of nano particles

The graph shows that cooling capacity and second law efficiency decreases in the value as we increase the volume concentration of nano sized particles. However with comparing zero percent nano particles i.e. 60%Wand 40%EG coolant only, cooling capacity and second law efficiency is very high. With increase in volume concentration of nano particles after 2% cooling capacity and second law efficiency experiences a decrease in the value because effect of increasing viscosity is more prominent than the increasing thermal conductivity after optimum concentration value. This unusual phenomenon can also be traced probably to the nano particles sedimentation on the solid wall when the volume fraction of the nano particles is relatively higher and formation of a porous layer which reduces the convection

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based heat transfer to layer conduction. At about 1% to 3% of particles concentration, nano fluids showed superior cooling capacity and second law efficiency than 60%Wand 40%EG only. MgO based nano fluids have highest second law efficiency and cooling capacity as compared to other nano fluids.

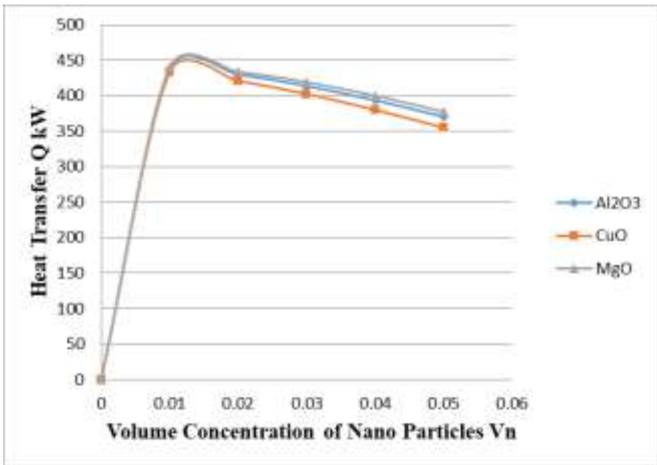

Figure 12

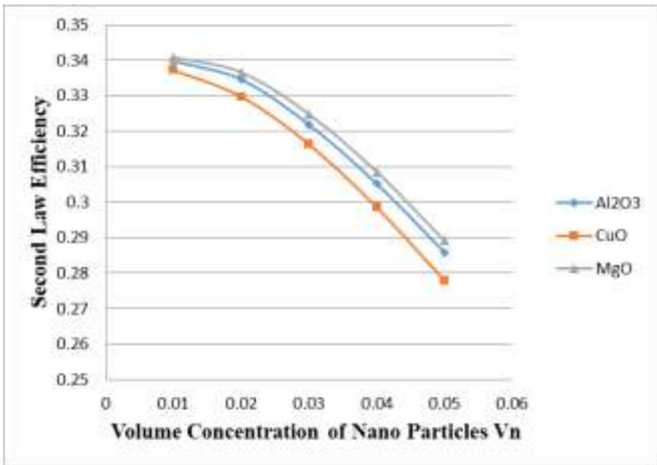

Figure 13

5. Comparison

Table 5.1: Value of Total heat transfer and Second law efficiency for comparison

Sr. No	Coolant type	Value of Total heat transfer rate	Value of second law efficiency
1	Mixture of 60%Water & 40% EG (Base Fluid)	357.452	0.264
2	Base Fluid with Al_2O_3	429.773	0.334
3	Base Fluid with CuO	420.737	0.329
4	Base Fluid with MgO	433.456	0.336

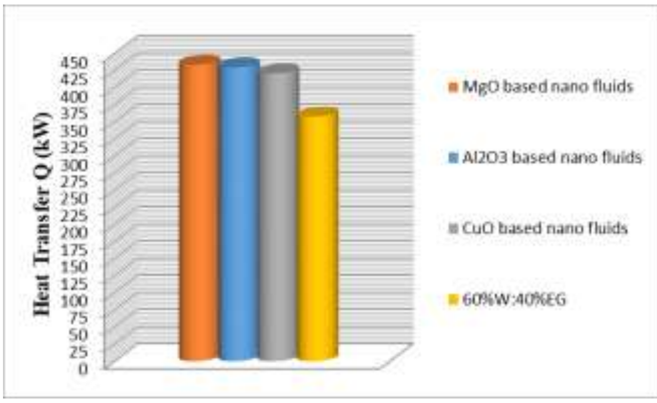

Figure 14

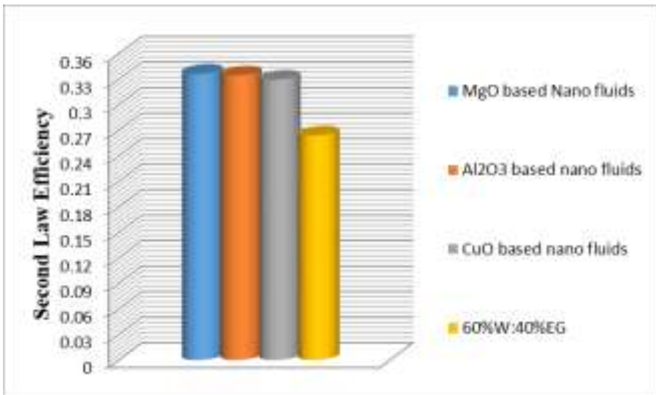

Figure 15

It is clear from table …and figure no…….that by using nano particles in the mixture of water and ethylene glycol the total heat transfer rate and second law efficiency can be increased. It has been seen that approximately 15 to 18% increment in total heat transfer rate while 19 to 21.5% increment in second law efficiency. MgO based nano fluids shows good cooling capacity as well as better utilization of energy as compared to other nano particles in base fluid.

6. Conclusions and Future Work

In the present project work, very minutely parametric study on the louvered fin cross flow heat exchanger (Radiator), which is compressed ignition turbo-charged engine of type TBD 232V-12, has been done by ε –NTU method by using three nanofluids viz. Al_2O_3, CuO and MgO in the base fluid of 60%water and 40% ethylene glycol. A computer program in C++ language has been written for calculating the total heat transfer rate and Second Law Efficiency (Appendix A). The following conclusions can be brought from the study:

a) The total heat transfer rate of the radiator has been found higher, when nano-fluids were used as coolants rather than of base fluids only. An increment of 15% to 18% was seeing in the total heat transfer rate of the radiator using nano-particles in the base fluid. Nano fluid based on MgO, Al_2O_3 and CuO, having total heat transfer rate grater then 18%,17%, and 15% respectively of base fluid coolant only. MgO based nano fluids shows highest total heat transfer rate as compared to other nano fluids.
b) The second law efficiency of the radiator has been found higher, when nano-fluids were used as coolants rather than of base fluids only. An increment of 19% to 21.5%

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was seeing in the second law efficiency of the radiator using nano-particles in the base fluid. Nano fluid based on MgO, Al_2O_3 and CuO, having second law efficiency grater then 21.42%,20.95%, and 19.75% respectively of base fluid coolant only. MgO based nano fluids shows highest second law efficiency as compared to other nano fluids.

c) With increase in mass flow rate of air total heat transfer rate increase while second law efficiency decrease. On the other hand, with increase in mass flow rate of coolant both total heat transfer rate and second law efficiency increase.
d) With increase in inlet temperature of air both total heat transfer rate and second law efficiency decrease. On the other hand, with increase in inlet temperature of coolant both total heat transfer rate and second law efficiency increases.
e) With increase in volume concentration of nano particles total heat transfer rate and second law efficiency is firstly increased till 1% of volume concentration of nano particles. But, decrement in both the parameters has been seen after 1% addition in value of volume concentration of nano particles. However, till 3% volume concentration, value of both the parameter is increased as compared to base coolant only.

7. Future Work

a) To develop a versatile experimental set up having different fin geometries, for keen observations and analysis.
b) To calculate experimentally the performance of compact heat exchanger using nano-fluid as coolant.
c) To enhance the cooling capacity, and second law efficiency of automobile radiator employing hybrid nano-particles e.g. SiC, TiO_2 etc. in base fluids of Water and mixture of water and anti freezing agent.
d) To experimentally evaluate the performance of automobile radiator employing varied base fluids apart from Water.
e) To develop software programs for the aforementioned parameters in computer languages apart from C++.

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