A Review Paper on Analysis of Automobile Radiator

Ramesh J. Ladumor[1] Prof. V. Y. Gajjar[2] Prof. K. K. Araniya[3]
[1]M.E.Student [2,3]Professor
[1,2,3]Department of Mechanical Engineering
[1,2]Shree S'ad Vidya Mandal Institute of Technology, Bharuch, Gujarat, India [3]F.E.T.R.Bardoli, Gujarat, India

Abstract— An Automotive engine cooling system takes out of excess heat produced during engine operation. An automobile cooling system regulates engine surface temperature for engine optimum efficiency. Recent advancement and development in engine for power forced engine cooling system to develop new strategies to improve its performance efficiency. Also to reduce fuel consumption along with controlling engine emission to mitigate environmental pollution norms. This paper throws light on parameters which influence radiator performance along with reviews some of the conventional and modern approaches to enhance radiator performance. This review paper Focus on the various research papers regarding experimental, CFD and Numerical analysis to improving automobile radiator efficiency.

Key words: CFD (computational fluid dynamics), Cooling System, Radiator.

I. INTRODUCTION

Radiators are heat exchangers used to transfer heat or thermal energy from one medium to another for the purpose of cooling and heating. Automobile radiator is used to cool down automotive engine. If it's not done various problems like knocking, piston deformation, cylinder deformation etc. can happen. If radiator works properly cooling system will work properly in turn engine performance will increase.

Radiators are used for cooling internal combustion engines, mainly in automobiles but also in piston-engine aircraft, railway locomotives, motorcycles, stationary generating plant or any similar use of such an engine. Internal combustion engines are often cooled by passing a liquid called engine coolant through the engine block, where it is heated, then through the radiator itself where it loses heat to the atmosphere, and then back to the engine in a closed loop. Engine coolant is usually water-based, but may also be oil. It is common to employ a water pump to force the engine coolant to circulate, and also for an axial fan to force air through the radiator [22], [23].

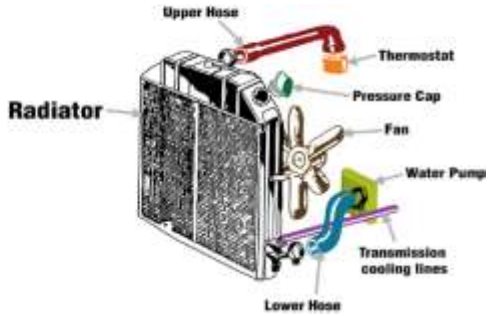

Fig.1.Radiator with its Components

II. LITERATURE SURVEY

Yiding Cao and KhokiatKengskool [1], had gave application of the heat pipe in an automotive engine was introduced. In this application, heat pipes were incorporated into the radiator of the automotive engine for more efficient heat transfer. The cooling load of the radiator can be increased for heavy-duty engines, while the power consumption of the cooling fan can be reduced for higher energy efficiency.

Heat pipes including two-phase closed thermo siphon were two-phase heat transfer devices with an effective thermal conductance hundreds of times higher than that of copper. For the terrestrial applications, gravity was often used to assistant the return of the liquid condensate and no wick structure was needed inside the heat pipe. A small amount of working liquid was filled in a tube or other type of container. Air was evacuated from the container and the container was sealed. Heat was applied to the evaporator section, which causes the liquid to vaporize. The vapor then flows from the hotter section due to the higher vapor pressure to the colder section of the heat pipe, where it was condensed. The liquid condensate then returns to the evaporator section from the condenser section under the assistance of gravity.

Hwa-Ming Nieh, Tun-Ping Teng, Chao-Chieh Yu [2], and This study adopt an alumina (Al_2O_3) and titanium (TiO_2) Nano-coolant to enhance the heat dissipation performance of an air-cooled radiator. The two-step synthesis method is used to produce different concentrations of Al_2O_3 and TiO_2/water (W) Nano fluid by using a 0.2 wt. % chitosan dispersant, and the Nano fluid is mixed with ethylene glycol (EG) at a 1:1 volume ratio to form NC1 to NC6(Nano Coolant). The experiments were conducted to measure the thermal conductivity, viscosity, and specific heat of the NC with different concentrations of nanoparticles and sample temperatures, and then the NC was used in an air-cooled radiator to evaluate its heat dissipation capacity, pressure drop, and pumping power under different volumetric flow rates and heating temperatures.

The experimental results show that the heat dissipation capacity and the EF of NC are higher than EG/W, and that the TiO_2 NC are higher than Al_2O_3 NC in most of the experimental data. The enhanced percentage of the average EF increases as the concentration and volumetric flow rate of the TiO_2 NC increases.

M. Naraki and S.M. Peyghambarzadeh [3], In this research, the overall heat transfer coefficient of CuO/water Nano fluids is investigated experimentally under laminar flow regime (100 _ Re _ 1000) in a car radiator. The Nano fluids in all the experiments have been stabilized with variation of pH and use of suitable surfactant. The results show that the overall heat transfer coefficient with Nano fluid is more than the base fluid. The overall heat transfer coefficient increases with the enhancement in the Nano fluid concentration from 0 to 0.4 vol. %. Conversely, the overall heat transfer coefficient decreases with increasing the Nano fluid inlet temperature from 50 to 80 C.

In this article, the experimental overall heat transfer coefficient in the automobile radiator has been measured using CuO/water Nano fluid at different air and liquid volumetric flow rates, various Nano fluid concentrations and several inlet temperatures of the liquid. Also, the results have been statistically analyzed using Taguchi method.

Rahul Tarodiya, J. Sarkar, J. V. Tirkey [4], the used of "Nano fluids" have been developed and these fluids offer higher heat transfer properties compared to that of conventional automotive engine coolants. Energetic analyses as well as theoretical performance analyses of the flat fin tube automotive radiator using Nano fluids as coolants have been done to study its performance improvement. Effects of various operating parameters using Cu, SiC, and Al_2O_3 and TiO_2 Nano fluids with 80% water-20% ethylene glycol as a base fluid are presented in this article. Use of Nano fluid as coolant in radiator improves the effectiveness, cooling capacity with the reduction in pumping power. SiC-80% H_2O-20% EG (base fluid) yields best performance in radiator having plate fin geometry followed by Al_2O_3-base fluid, TiO_2-base fluid and Cu-base fluid. The maximum cooling improvement for SiC is 18.36%, whereas that for Al_2O_3 is 17.39%, for TiO_2 is 17.05% and for Cu is 13.41% as coolants. Present study reveals that the Nano fluids may effectively use as coolant in automotive radiators to improve the performance.

Efeovbokhan, Vincent Enontiemonria, Ohiozua, OhiremeNathaniel [5], The cooling properties of a locally formulated coolant (sample C) vis-a-vis, its boiling characteristics and specific heat capacity were investigated alongside with a common coolant-water (as sample A) and a commercial coolant (sample B). The results of the investigation showed that sample C gave the best performance compared to the other two samples A and B: the boiling points of sample C was 110^0C, sample A 100^0C, and sample B 101^0C. This means that the possibility of a boil-out of sample C from the radiator is little compared to samples A and B. Also, for the same quantity of coolant more heat would be required to raise sample C to its boiling point than for samples A and B. In other word, better cooling would be achieved using sample C.

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

S.M. Peyghambarzadeh, S.H. Hashemabadi, M. Naraki, Y. Vermahmoudi, [7], the heat transfer performance of the automobile radiator is evaluated experimentally by calculating the overall heat transfer coefficient (U) according to the conventional Ɛ-NTU Technique. Copper oxide (CuO) and Iron oxide (Fe_2O_3) nanoparticles are added to the Water at three concentrations 0.15, 0.4, and 0.65 vol. % with considering the best pH for longer stability. In these experiments, the liquid side Reynolds number is varied in the range of 50-1000 and the inlet liquid to the radiator has a constant temperature which is changed at 50, 65 and 80 ^{0}C. The effects of these variables on the overall heat transfer coefficient are deeply investigated.

- Nano fluids showed greater heat transfer performance comparing with water.
- Increasing liquid and air Re increases the overall heat transfer coefficient.
- Increasing the inlet liquid temperature decreases the overall heat transfer coefficient.

D. Madhesh, R. Parameshwaran, S. Kalaiselvam, [8] an investigate the heat transfer potential and rheological characteristics of copper–titania hybrid Nano fluids using a tube in the tube type counter flow heat exchanger. The Nano fluids were prepared by dispersing the surface functionalized and crystalline copper–titania hybrid Nano composite in the base fluid, with volume concentrations ranging from 0.1% to 2.0%. The surface functionalized and highly crystalline nature of hybrid nano composite have contributed to the creation of effective thermal interfaces with the fluid medium, thereby enabling the achievement of achieving improved thermal conductivity and heat transfer potential of Nano fluids. The effective thermal conductivity and diffusion kinetics of hybrid nano composite in the fluid medium paved the way for the improved heat transfer Characteristics of hybrid nano fluid.

Navid Bozorgan, Komalangan Krishnakumar, Nariman Bozorgan [9] , The heat transfer relations between airflow and Nano fluid coolant have been obtained to evaluate local convective and overall heat transfer coefficients and also pumping power for Nano fluid flowing in the radiator with a given heat exchange capacity. In the present study, the effects of the automotive speed and Reynolds number of the Nano fluid in the different volume concentrations on the radiator performance are also investigated. The overall heat transfer coefficient of Nano fluid is greater than that of water alone and therefore the total heat transfer area of the radiator can be reduced. However, the considerable increase in associated pumping power may impose some limitations on the efficient use of this type of Nano fluid in automotive diesel engine radiators.

L. Syam Sundar, Manoj K. Singh, Igor Bidkin, Antonio C.M. Sousa [10] , A magnetic Nano fluid was prepared by dispersing magnetic Ni nanoparticles in distilled water. The Nano-particles were synthesized by chemical co-precipitation method and characterized by X-ray diffraction and atomic force microscopy. The average particle size was measured by the dynamic light scattering method. Thermal conductivity and absolute viscosity of the Nano fluid were experimentally determined as a function of particle concentration and temperature. In addition, the Nusselt number and friction factor were experimentally estimated as a function of particle concentration and Reynolds number for constant heat flux condition in forced convection apparatus with no phase change of the Nano fluid flowing in a tube. The experiments were conducted for a Reynolds number range of 3000–22,000, and for a particle concentration range from 0% to 0.6%. The results indicate that both Nusselt number and friction factor of the Nano fluid increase with increasing particle volume concentration and Reynolds number. For 0.6% volume concentration, the enhancement of Nusselt number and friction factor is 39.18% and 19.12%, respectively, as compared to distilled water under the same flow conditions. It was verified the classical Gnielinski and Notter–Rouse correlations under predict the Nusselt number of the Nano fluid; therefore, new generalized correlations are proposed for the estimation of the Nusselt number and friction factor based on the experimental data.

Changhua Lin, Jeffrey Saunders, Simon Watkins [11], A theoretical model for the calculation of Specific Dissipation (SD) was developed. Based on the model, the effect of ambient and coolant radiator inlet temperatures on SD has been predicted. Results indicate that the effect of ambient and coolant inlet temperature variation on SD is small (less than 2%) when ambient temperature varies between 10 and 50°C and coolant radiator inlet temperature between 60 and 120°C. The effect of coolant flow rate on SD is larger if there is a larger flow rate variation. Experimental results indicate that a 1 % variation at 1.0 L/s will cause about ±0.6% SD Variation. Therefore the flow rate should be carefully controlled.

Shaolin Maoa, Changrui Cheng, Xianchang Li, Efstathios E. Michaelides [12], A thermal/structural coupling approach is applied to analyze thermal performance and predict the thermal stress of a radiator for heavy-duty transportation cooling systems. Bench test and field test data show that non-uniform temperature gradient and dynamic pressure loads may induce large thermal stress on the radiator. A finite element analysis (FEA) tool is used to predict the strains and displacement of radiator based on the solid wall temperature, wall-based fluid film heat transfer coefficient and pressure drop. These are obtained from a computational fluid dynamics (CFD) simulation. The FEA results predict the maximum value of stress/strain and target locations for possible structural failure and the results obtained are consistent with experimental observations. The results demonstrate that the coupling thermal/structural analysis is a powerful tool applied to heavy-duty cooling product design to improve the radiator thermal performance, durability and reliability under rigid working environment.

M.M. Elias, I.M. Mahbubul, R. Saidur, M.R. Sohel, I.M. Shahrul, S.S. Khaleduzzaman, S. Sadeghipour [13] , Nano fluid is a new type of heat transfer fluid with superior thermal performance characteristics, which is very promising for thermal engineering applications. This paper presents new findings on the thermal conductivity, viscosity, density, and specific heat of Al_2O_3 Nano particles dispersed into water and ethylene glycol based coolant used in car radiator. The Nano fluids were prepared by the two-step method by using an ultrasonic homogenizer with no surfactants. Thermal conductivity, viscosity, density, and specific heat have been measured at different volume concentrations (i.e. 0 to 1 vol. %) of nanoparticles and various temperature ranges (i.e. from 10 °C to 50 °C). It was found that thermal conductivity, viscosity, and density of the Nano fluid increased with the increase of volume concentrations. However, specific heat of Nano fluid was found to be decreased with the increase of nanoparticle volume concentrations. Moreover, by increasing the temperature, thermal conductivity and specific heat were observed to be intensified, while the viscosity and density were decreased.

Adnan M. Hussein, R.A. Bakar, K. Kadirgama, K.V. Sharma [14], The increasing demand of Nano fluids in industrial applications has led to increased attention from many researchers. In this paper, heat transfer enhancement using TiO_2 and SiO_2 nano powders suspended in pure water is presented. The test setup includes a car radiator, and the effects on heat transfer enhancement under the operating conditions are analyzed under laminar flow conditions. The volume flow rate, inlet temperature and Nano fluid volume concentration are in the range of 2–8 LPM, 60–80 °C and 1–2% respectively. The results showed that the Nusselt number increased with volume flow rate and slightly increased with inlet temperature and Nano fluid volume concentration. The regression equation for input (volume flow rate, inlet temperature and Nano fluid volume concentration) and response (Nusselt number) was found. The results of the analysis indicated that significant input parameters to enhance heat transfer with car radiator. These experimental results were found to be in good agreement with other researchers' data, with a deviation of only approximately 4%.

Adnan M. Hussein, R.A.Bakar, K.Kadirgama [15], The heat transfer enhancement for many industrial applications by adding solid Nano- particles to liquids is significant topics in the last10years.This article included the friction factor and forced convection heat transfer of SiO_2 Nano particle dispersed in water as a base fluid conducted in a car radiator experimentally and numerically. Four different concentrations of Nano fluids in the range of 1–2.5 vol% have been used. The flow rate changed in the range of 2–8 LPM to have Reynolds number with the range 500–1750. The results showed that the friction factor decreases with an increase in flow rate and increase with increasing in volume concentration. Furthermore, the inlet temperature to the radiator has in significantly affected to the friction factor. On the other side, Nusselt number increases with increasing in flow rate, Nano fluid volume concentration and inlet temperature. Meanwhile, application of SiO_2 Nano fluid with low concentration scan enhance heat transfer rate up to 50% as a comparison with pure water. The simulation results compared with experimental data, and there is a good agreement. Likewise, these results compared to other investigators to be validated.

C. Oliet, A. Oliva, J. Castro, C.D. Perez-Segarra [16], A set of parametric studies performed on automotive radiators by means of a detailed rating and design heat exchanger model developed by the authors. This numerical tool has been previously verified and validated using a wide experimental data bank. A first part of the analysis focuses on the influence of working conditions on both fluids (mass flows, inlet temperatures) and the impact of the selected coolant fluid. Following these studies, the influence of some geometrical parameters is analyzed (fin pitch, louver angle) as well as the importance of coolant flow lay-out on the radiator global performance. This work provides an overall behavior report of automobile radiators working at usual range of operating conditions, while significant knowledge-based design conclusions have also been reported. The results show the utility of this numerical model as a rating and design tool for heat exchangers manufacturers, being a reasonable compromise between classic Ɛ-NTU methods and CFD.

Rahul A. Bhogare B. S. Kothawale [17], Nano fluids are potential heat transfer fluids with enhanced thermo physical properties and heat transfer performance can be applied in many devices for better performances (i.e. energy, heat transfer and other performances). Evaluating the heat transfer enhancement due to the use of Nano fluids has recently become the center of interest for many researchers. This newly introduced category of cooling fluids containing ultrafine nanoparticles (1–100 nm) has displayed fascinating behavior during experiments including increased thermal conductivity and augmented heat transfer coefficient compared to a pure fluid. In this paper, a comprehensive literature on the applications and challenges of Nano fluids have been compiled and reviewed in Automobile sector.

A. Witry, M.H. Al-Hajeri, Ali A. Bondok [18], the thermal performance of an automotive radiator plays an important role in the performance of an automobile cooling system and all other associated systems. For a number of years, this component has suffered from little attention with very little changing in its manufacturing cost, operation and geometry. As opposed to the old tubular heat exchanger configurations used in automotive radiators, plate heat exchangers currently form the backbone of today's process industry with their advanced performance Reaching levels the designers of tubular heat exchangers can only dream of the aluminums roll-bonding technique widely used in manufacturing the cooling compartments for domestic refrigeration units is one of the cheapest methods for heat exchanger manufacturing. Using this technique, it is possible to manufacture a wide range of heat exchanger configurations that can help augment heat transfer whilst reducing pressure drops. CFD results obtained for a patterned plate heat exchanger using the CFD code FLUENT show tremendous levels of possible performance improvement on both sides of the heat exchanger.

For the internal flow, heat transfer augmentation caused by the repetitive impingement against the dimple obstructions renders such geometries equal to those of aerospace industry pin-fins whilst lowering pressure drops due to the wider cross-sectional areas. For the external flows, the wider and wavy nature of the surface area increases heat transfer leaving the addition of extra surface roughness add-ons as an option.

S.M. Peyghambarzadeh, S.H. Hashemabadi, M. Seifi Jamnani, S.M. Hoseini [19], In this paper, forced convective heat transfer in a water based Nano fluid has experimentally been compared to that of pure water in an automobile radiator. Five different concentrations of Nano fluids in the range of 0.1-1 vol. % have been prepared by the addition of Al_2O_3 nanoparticles into the water. The test liquid flows through the radiator consisted of 34 vertical tubes with elliptical cross section and air makes a cross flow inside the tube bank with constant speed. Liquid flow rate has been changed in the Range of 2-5 lit/min to have the fully turbulent regime ($9*10^3 < Re < 2.3*10^4$). Additionally, the effect of fluid inlet temperature to the radiator on heat transfer coefficient has also been analyzed by varying the temperature in the range of 37-49^{0}C. Results demonstrate that increasing the fluid circulating rate can improve the heat transfer performance while the fluid inlet temperature to the radiator has trivial effects. Meanwhile, application of Nano fluid with low concentrations can enhance heat transfer efficiency up to 45% in comparison with pure water.

Gokhan Sevilgen, Muhsin Kilic [20], A three-dimensional steady-state numerical analysis was performed in a room heated by two-panel radiators. A virtual sitting manikin with real dimensions and physiological shape was added to the model of the room, and it was assumed that the manikin surfaces were subjected to constant temperature. Two different heat transfer coefficients for the outer wall and for the window were considered. Heat interactions between the human body surfaces and the room environment, the air flow, the temperature, the humidity, and the local heat transfer characteristics of the manikin and the room surfaces were computed numerically under different environmental conditions. Comparisons of the results are presented and discussed. The results show that energy consumption can be significantly reduced while increasing the thermal comfort by using better-insulated outer wall materials and windows.

S. Vithayasai, T. Kiatsiriroa, A. Nuntaphan [21], the effect of electric field on the performance of automobile radiator is investigated in this work. In this experiment, a louvered fin and flat tube automobile radiator was mounted in a wind tunnel and there was heat exchange between a hot water stream circulating inside the tube and a cold air stream flowing through the external surface. The electric field was supplied on the airside of the heat exchanger and its supply voltage was adjusted from 0 kV to 12 kV. From the experiment, it was found that the unit with electric field pronounced better heat transfer rate, especially at low frontal velocity of air. The correlations for predicting the air-side heat transfer coefficient of the automobile radiator, with and without electric field, at low frontal air velocity were also developed and the predicted results agreed very well with the experimental data.

III. Conclusions

From the review of literature, it can be analyzed the Automobile radiator cooling system is very important in an internal combustion engine. From literature survey, different findings are concluded.

- The efficiency of radiator increase by inserting heat pipe in radiator core.
- The heat capacity dissipation and the efficiency factor (EF) of Nano coolant (NC) are higher than ethyl glycol-water (EG/W), and the TiO_2 NC are higher than Al_2O_3 NC. The overall heat transfer coefficient increases with enhancing volumetric flow rate of the Nano fluid significantly.
- Cooling capacity and effectiveness increase with increase in mass flow rate of air and coolant. Also increasing the inlet liquid temperature decreases the overall heat transfer coefficient.
- The overall heat transfer coefficient decreases with increasing inlet temperature of the Nano fluid.
- Nano fluid offer higher heat-transfer properties compared to that of conventional automotive engine coolant.
- Requirement of pumping power reduce with the use of Nano fluid in radiator.
- A blend of 50/50 mix of water and ethylene glycol in which corrosion inhibitors have been incorporated is much more effective than using water and ethylene glycol alone. While water alone is good coolant but the enormous corrosion problems associated with it, is enough to discourage its use.
- The heat transfer behaviour of the Nano fluid were highly depended on the particle concentration, the flow condition and depended on the temperature.

Acknowledgment

I would like to express my special thank of gratitude to my teacher as well as Principal, H.O.D and teaching staff of mechanical engineering department for providing their valuable guidance and overwhelming support to carrying out this work.

References

[1] Yiding Cao and KhokiatKengskool, "An Automotive Radiator Employing Wickless Heat Pipes" Florida International University, Miami, Conference Paper, 1992.
[2] Hwa-Ming Nieh, Tun-Ping Teng, Chao-Chieh Yu "Enhanced heat dissipation of a radiator using oxide nano-coolant". International Journal of Thermal Sciences 77, 252-261, 2014.
[3] M.Naraki and S.M. Peyghambarzadeh, "Parametric study of overall heat transfer coefficient of CuO/water Nano fluids in a car radiator". International Journal of Thermal Sciences 66, 82-90, 2013.
[4] RahulTarodiya, J. Sarkar, J. V. Tirkey, "Performance of flat fin tube automotive radiator using Nano fluids as coolants". National Conference on Emerging Trends in Mechanical Engineering ETME – 2012.
[5] Efeovbokhan, Vincent Enontiemonria, Ohiozua, Ohireme Nathaniel, "Comparison of the cooling effects of a locally formulated car radiator coolant with water and a commercial coolant". The International Journal of

Engineering And Science (IJES), Volume- 2 Issue 01, Pages- 254-262, 2013.

[6] S.M. Peyghambarzadeh , S.H. Hashemabadi , S.M. Hoseini , M. SeifiJamnani "Experimental study of heat transfer enhancement using water/ethylene glycol based Nano fluids as a new coolant for car radiators". International Communications in Heat and Mass Transfer 38, 1283–1290, 2011.

[7] S.M. Peyghambarzadeh, S.H. Hashemabadi, M. Naraki, Y. Vermahmoudi," Experimental study of overall heat transfer coefficient in the application of dilute Nano fluids in the car radiator".Applied Thermal Engineering 52, 8-16, 2013.

[8] D. Madhesh, R. Parameshwaran, S. Kalaiselvam" Experimental investigation on convective heat transfer and rheological characteristics of Cu–TiO2 hybrid nanofluids".Experimental Thermal and Fluid Science 52, 104–115, 2014.

[9] Navid Bozorgan, Komalangan Krishnakumar, Nariman Bozorgan," Numerical Study on Application of CuO-Water Nano fluid in Automotive Diesel Engine Radiator ".Modern Mechanical Engineering,130-13, Sep.2012.

[10] L. Syam Sundar, Manoj K. Singh, Igor Bidkin, Antonio C.M. Sousa, " Experimental investigations in heat transfer and friction factor of magnetic Ni Nano fluid flowing in a tube". International Journal of Heat and Mass Transfer 70, 224–234, 2014.

[11] Changhua Lin , Jeffrey Saunders , Simon Watkins, " The Effect of Changes in Ambient and Coolant Radiator Inlet Temperatures and Coolant Flow rate on Specific Dissipation". SAE Technical Paper Series, 01-0579, 2000.

[12] Shaolin Maoa, Changrui Cheng, Xianchang Li, Efstathios E. Michaelides, "Thermal/structural analysis of radiators for heavy-duty trucks". Applied Thermal Engineering 30 1438-1446, 2010.

[13] M.M. Elias, I.M. Mahbubul, R. Saidur, M.R. Sohel, I.M. Shahrul, S.S. Khaleduzzaman, S. Sadeghipour, " Experimental investigation on the thermo-physical properties of Al2O3.nanoparticles suspended in car radiator coolant". International Communications in Heat and Mass Transfer 54, 48–53, 2014.

[14] Adnan M. Hussein, R.A. Bakar, K. Kadirgama, K.V. Sharma, " Heat transfer enhancement using Nano fluids in an automotive cooling system". International Communications in Heat and Mass Transfer 53, 195–202, 2014.

[15] Adnan M. Hussein, R.A.Bakar, K.Kadirgama, "Study of forced convection Nano fluid heat transfer in the automotive cooling system". Case Studies in Thermal Engineering 50–61, 2014.

[16] C. Oliet, A. Oliva, J. Castro, C.D. Perez-Segarra, "Parametric studies on automotive radiators". Applied Thermal Engineering 27, 2033–2043, 2007.

[17] Rahul A. Bhogare B. S. Kothawale, "A Review on applications and challenges of Nano-fluids as coolant in Automobile Radiator". International Journal of Scientific and Research Publications, Volume 3, 1 ISSN 2250-3153, Issue 8, August 2013.

[18] A. Witry, M.H. Al-Hajeri, Ali A. Bondok, "Thermal performance of automotive aluminium plate radiator". Applied Thermal Engineering 25, 1207–1218, 2005.

[19] S.M. Peyghambarzadeh, S.H. Hashemabadi, M. Seifi Jamnani, S.M. Hoseini, "Improving the cooling performance of automobile radiator with Al2O3/water Nano fluid". Applied Thermal Engineering 31, 1833-1838, 2011.

[20] Gokhan Sevilgen, Muhsin Kilic, " Numerical analysis of air flow, heat transfer, moisture transport and thermal comfort in a room heated by two-panel radiators". Energy and Buildings 43, 137–146, 2011.

[21] S. Vithayasai, T. Kiatsiriroa, A. Nuntaphan, "Effect of electric field on heat transfer performance of automobile radiator at low frontal air velocity". Applied Thermal Engineering 26 2073–2078, 2006.

[22] Pawan S. Amrutkar, Sangram R. Patil & S. C. Shilwant, "Automotive Radiator - Design And Experimental Validation". International Journal of Automobile Engineering Research and Development (IJAuERD) ISSN 2277-4785 Vol. 3, 1-10 Issue 4, Oct 2013.

[23] Pawan S. Amrutkar, Sangram R. Patil, "Automotive Radiator Performance – Review". International Journal of Engineering and Advanced Technology (IJEAT) ISSN: 2249 – 8958, Volume-2, Issue-3, February 2013.

[24] Upendra Kulshrestha, Gaurav Kumar Manu Augustine and Sanjay Mittal, "CFD Analysis of Automobile Radiator – A Review". International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622, March 2014.

