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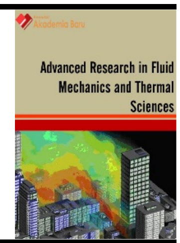

Modelling and Simulation of Car Radiator: Effects of Fins under the Atmospheric Condition of Kano, Nigeria

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ABSTRACT

Car engine cooling system takes care of the excess energy produced during its operations. The key component of the cooling system is the radiator whose performance is affected by various parameters including atmospheric temperature. This paper presented a numerical study on the effects of fins in the performance of car radiator under the atmospheric temperature of Kano State of Nigeria. Honda Civic 2000 car radiator model was modelled in SolidWorks using reverse engineering and the model was ran in ANSYS with water as the cooling fluid. In order to increase the cooling effects of the radiator, fins were attached to the geometry which increased its surface area. The outlet temperature of the coolant is determined for 12 months with April and August recorded the maximum and minimum temperatures of 70.39°C and 66.5°C for radiator without fin and 52.3°C and 47.4°C for finned radiator respectively. Results shown that when fins are attached to the radiator modelled, a 25% decreases in the outlet temperature is recorded. In terms of energy dissipation, finned radiator dissipates 74% of the cooling energy while radiator without fin dissipates only 40.8%. Finned aluminium radiator is preferred for the atmospheric condition of Kano because of its more heat rejection with relatively small size. In addition, the atmospheric condition of Kano shows a great influence on the radiator performance as best performance was recorded at lower atmospheric temperature.

1. Introduction

During the dry season in Kano, car engine cooling system efficiency is low due to high temperature. This is because most of the car radiators are not compatible with Kano weather in the dry season, this leads to frequent overheating of our engines. With high atmospheric temperature and enormous heat generated inside the combustion chamber, heat dissipation by the radiator is not effective to prevent frequent overheating which may cause serious damage to the engine. Radiator plays an important role in automobile, as it dissipates about one-third of the total heat generated in the internal combustion engine after useful work has been done [1].

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The effectiveness with which waste heat is transferred from engine walls to the surrounding is crucial in preserving the material integrity of the engine and enhancing the performance of the engine. Radiators performance is influenced by the radiator material, fins, air and coolant flow rate, air temperature, heat exchange period, the coolant used and coolant inlet temperature. [2]. The cooling system in an automobile consists of various components such as a radiator, radiator hose, pump, etc as shown in Figure 1.

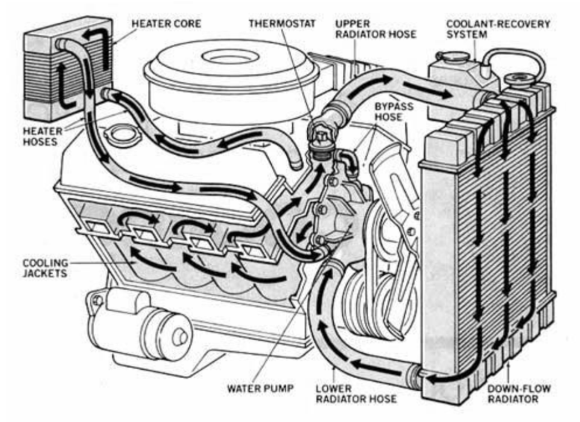


Fig. 1. Cooling system component

2. Automotive Cooling Systems

Modern automotive internal combustion engines generate a huge amount of heat. This heat is created when the gasoline and air mixture is ignited in the combustion chamber. This explosion causes the piston to be forced down inside the engine, levering the connecting rods, and turning the crankshaft, creating power. Metal temperatures around the combustion chamber can exceed 2500° F [3]. To prevent overheating of the engine oil, cylinder walls, pistons, valves, and other components by these extreme temperatures, it is necessary to effectively dispose of the heat.

It has been stated that a typical average-sized vehicle can generate enough heat to keep a 5-room house comfortably warm during zero degree weather excluding the heat rejected through the exhaust. Approximately 1/3 of the heat in combustion is converted into power to drive the vehicle and its accessories. Another 1/3 of the heat is carried off into the atmosphere through the exhaust system. The remaining 1/3 must be removed from the engine by the cooling system (Figure 2). Modern automotive engines have basically dumped the Air Cooled System (ACS) for the more effective Liquid Cooled System to handle the job [1].

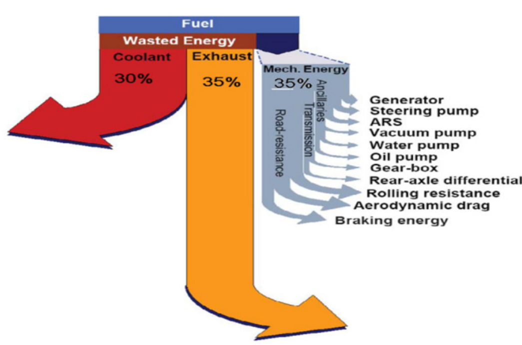


Fig. 2. Energy distribution in a vehicle

3. Previous Studies

Back in 1970's, the first generation automobiles use copper/brass radiator because they were the widely metal available at that time [4]. Then in the wake of oil crisis, major automobile manufacturers in Europe and US tend to invent lighter cars and trucks to cope with the current situation and reduced oil consumption. For radiators, this translated to aluminum which is lower in density compared to copper/brass and able to handle heat fairly well despite its manufacturing shortcomings. Furthermore, aluminum is less expensive than copper/brass. As a result, for the past 20 years, aluminum has taken the first place as the metal for radiator for new cars [4]. Various studies were conducted to study the effects of some design parameters on the performance of radiator which is aimed at improving cooling effects.

Oliet *et al.,* [2] studied different factors which affects radiator performance such as air and coolant flow, fin density and air temperature. It is observed that heat transfer and performance of radiator is strongly affected by air and coolant mass flow rate. As the air and coolant flow increases, cooling capacity also increases. When air inlet temperature increases, heat transfer and thus, cooling capacity decreases. Smaller fin spacing and higher louvered fin angle have higher heat transfer. Fin density can increase till it blocks the air flow and heat transfer rate decreases.

Yandav *et al.,* [5] presented a parametric study on automobile radiator performance. The following were observed at the end of the study;

- *Influence of observed mass flow*; cooling capacity of the radiator has a direct relationship with the coolant flow rate. There is a corresponding increase in the effectiveness and cooling capacity.
- *Influence of coolant inlet temperature*; with the increase in the temperature of the coolant, the cooling capacity of the radiator increases [5].

An experiment conducted by Seth and Joshua [6], the effect of clay soil deposit on radiator performance. Results showed that; the inlet and outlet temperature of the radiator coolant increases as percentage area covered with clay soil increases. The engine seizes to operate at 100% coverage of the radiator surface. This is due to excessive overheating of the engine parts. This research also explores the same principle using mathematical modeling technique, the NTU method used also established the same findings as the data obtained via experimentation.

Chavan *et al.,* [7] conducted an experiment and found out that it is difficult for a circular fan to cover the whole surface area of the conventional radiator which is rectangular as it creates lower density zones at corner giving less heat transfer. The authors proposed the elimination of the corners and develop circularly shaped radiator which is compact, more efficient and leads to maximum power consumption to drive a fan and maximum utilization of air flow.

The use of dimple surface to improve forced convection heat transfer was described by Pitambar and Shambhu [8]. Heat transfer enhancement is based on the principle of scrubbing action of cooling fluid inside the dimple. Surface dimples promote turbulent mixing in flow and enhance heat transfer. An experimental set up has been designed and fabricated to study the effect of the dimpled surface on heat transfer in a rectangular duct. When dimpled surface was compared with flat surface tubes, results shown a heat transfer enhancement over the later one.

Trivedi *et al.,* [9] illustrated the effect of Tube pitch for a best-configured radiator for optimum performance. Results showed that heat transfer increases as the surface area of the radiator assembly are increased. This leads to change the geometry by modifying the arrangement of tubes in automobile radiator to increase the surface area for better heat transfer. The modification in the arrangement of tubes in the radiator is carried out by studying the effect of pitch of tube by CFD analysis using CFX. Results show that as the pitch of tube is either decreased or increased than the optimum pitch of tubes, the heat transfer rate decreases [9].

The stability of Aluminum to copper radiator was investigated by Anand [10] and concluded that aluminum can perform effectively with some modification in some parameters like the surface area and the fins geometry. With Aluminum radiator, benefits which include the cost of about 49% savings, weight reduction of 52.08%, better performance and reliability as there is no any field failure within the stipulated lifespan. The researcher implemented reverse engineering in order to achieve the design analysis and improvement for car radiator element.

A car radiator with louvered fin was modeled by Ranjeet and Vishwa [11] using CATIA V5 software and studied its performance with pre-processing ANSYS 14. Due to computational time a section of the radiator was studied to compare the conventional coolant with nanofluid (SiC). The result obtained shows that;

i. The loss in temperature across the tube length with water as coolant is 18°C while with nano-fluid as coolant the temperature loss is 24°C.
ii. The pressure drop also increases within air and coolant mass flow rate through the radiator.
iii. About 6% increase in cooling capacity with the use of louver fin heat exchanger with nano-fluid compare to conventional coolant with the same model.

Although there are numerical studies presented on the performance of car radiator for various locations, there is no report (to our knowledge) for the atmospheric condition of Kano, Nigeria, hence the aim of the present study. Developing a model for studying the of car radiator under the atmospheric condition of Kano will help in addressing the problems of overheating of an engine. Hence it is imperative to conduct this research as no report based on the atmospheric condition of Kano and no detailed analysis and simulation of material effect.

4. Governing Equations

4.1 Mass Conservation Equation (or Continuity Equation)

The unsteady, three-dimensional mass conservation equation at a point in a compressible fluid can be written as follows:

$$\frac{\partial \rho}{\partial t} + div(\rho . u) = 0 \tag{1}$$

The first term on the left-hand side is the rate of change in time of the density (mass per unit volume). The second term describes the net flow of mass out of the element across its boundaries and is called the convective term.

4.2 Momentum Conservation Equations

Newton's second law states that the rate of change of momentum of a fluid particle equals the sum of the forces on the particle. It distinguishes two types of forces on fluid particles: surface forces (viscous and pressure forces) and body forces (gravity, centrifugal and electromagnetic forces).

The x-component of the momentum equation is found by setting the rate of change of x-momentum of fluid particle equal to the total force in the x-direction on the element due to surface stresses plus the rate of increase of x-momentum due to sources:

$$\rho \frac{\Delta u}{\Delta t} = \frac{\partial(-p+\tau_{xx})}{\partial x} + \frac{\partial \tau_{yx}}{\partial y} + \frac{\partial \tau_{zx}}{\partial z} + S_{Mx} \tag{2}$$

4.3 Energy Equation

The energy equation is derived from the first law of thermodynamics which states that the rate of change of energy of a fluid particle is equal to the rate of heat added to the fluid particle plus the rate of work done on the particle

$$\rho\frac{\Delta E}{\Delta t} = -div(pu) + \left[\frac{\partial(u\tau_{xx})}{\partial x} + \frac{\partial(u\tau_{yx})}{\partial y} + \frac{\partial(u\tau_{zx})}{\partial z} + \frac{\partial(v\tau_{xy})}{\partial x} + \frac{\partial(v\tau_{yy})}{\partial y} + \frac{\partial(v\tau_{zy})}{\partial z} + \frac{\partial(w\tau_{xz})}{\partial x} + \frac{\partial(w\tau_{yz})}{\partial y} + \frac{\partial(w\tau_{zz})}{\partial z}\right] + div(k.gradT) + S_E \quad (3)$$

4.4 Navier-Stokes Equations

$$\rho\frac{DV}{Dt} = -\nabla P + \rho g + \mu\nabla^2 V \quad (4)$$

The governing equations contain as further unknowns the viscous stress components τ_{ij}. The most useful forms of the conservation equations for fluid flows are obtained by introducing a suitable model for the viscous stresses τ_{ij}.

5. Radiator Dimensions

The automotive radiator is a compact heat exchanger, made up of four major components such as coolant inlet tank, outlet tank, pressure cap and core. The main subcomponents of the core are coolant tubes and fins. Honda Civic 2000 (Figure 3) radiator was used in the present study whose dimensions were obtained using reverse engineering [12]. The model of the radiator was generated using SolidWorks 2014, based on its specifications shown in Table 1. Figure 4 shows a complete and cross-section of the model generated.

Fig. 3. Honda Civic car radiator

Table 1
Specifications of Honda Civic Radiator

S/N	Part Dimension	Unit
1	Pipe Diameter Inlet/Outlet	26mm
2	Radiator core height	320mm
3	Radiator core length	350mm
4	Diameter of cooling pipe	2mm
5	Thickness of fin	0.8mm
6	Width of fin	20mm
7	Number of fin in a single column	180
8	Number of fin columns	34
9	Total number of fins	6120
10	Total number of cooling pipes	33
11	Distance between two pipes	7.5mm
12	Distance between two fins	1.9mm

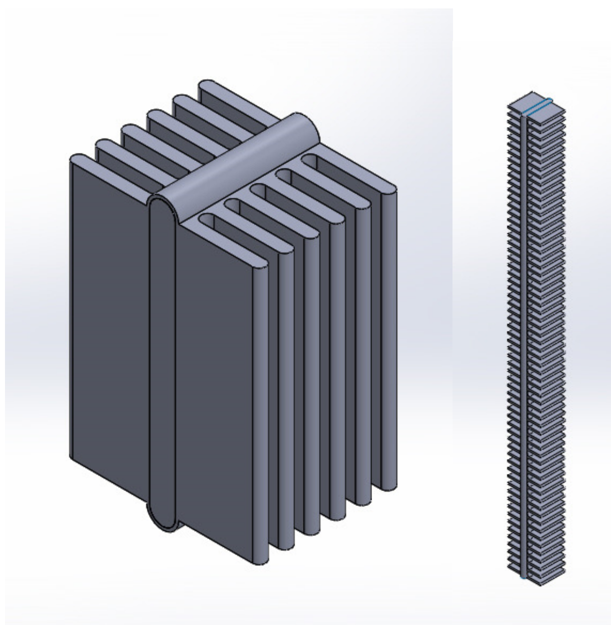


Fig. 4. Radiator model

6. Ansys Fluent

ANSYS Fluent software contains the broad physical modeling capabilities needed to model flow, turbulence, heat transfer and reaction for industrial application. Advanced solver technology provides fast, accurate Computational Fluid Dynamics (CFD) results, flexible moving and deformation meshes, and superior parallel scalability. The interactive solver setup, solution and post-processing capabilities of ANSYS Fluent makes it easy to pause calculation, examine result with integrated post-processing, change any setting and continue calculation within a single application. Case and data files can be read into ANSYS CFD-Post for further analysis with advanced post-processing tools and side-by-side comparison of different cases.

6.1 Ansys Setup

For the implementation of analysis pre-processing software, ANSYS 15.0 is used for one tube radiator. This software is useful in analyzing the fluid properties at operating temperatures in estimating the velocity and temperature distribution of coolant and air cross flow automotive radiator.

The numerical simulation approach is adopted using the theory of three-dimensional computational fluid dynamics and flow direction is studied with the help of Fluent. With this approach, it was able to generate three-dimensional patterns for the temperature of coolant and air, inside and outside the radiator respectively.

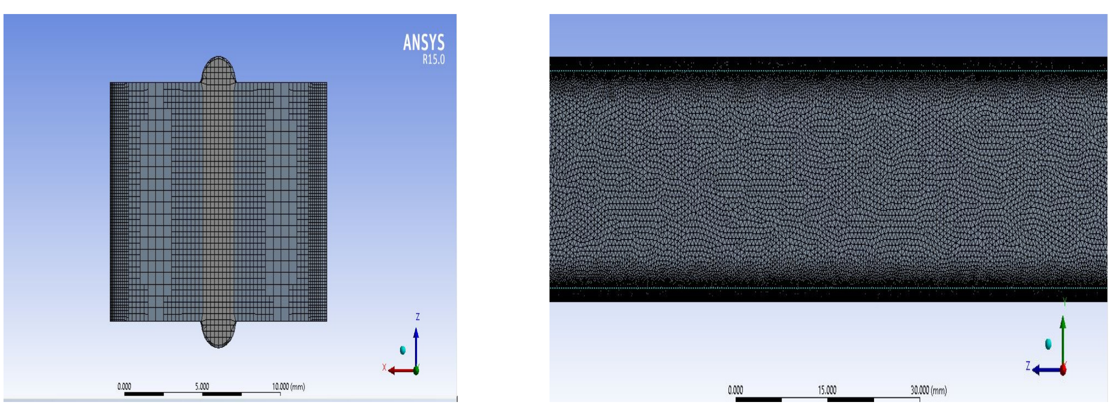
As the model analysis is difficult with available resources, 33 cooling tubes model are reduced to one cooling tube model (this is to reduce the meshing and the computational time) which gives the same result, as in the specific ratio. The radiator model containing only a single tube with and without fins is imported from SolidWorks to ANSYS fluent through a neutral file format (STEP).

6.2 Ansys Mesh

The one tube radiator with fluid as water domain and solid as tube domain is named as an inlet, outlet and wall surface. This tube is used to optimize the meshing method to be adopted in the cause of this project. Tetrahedron method is used with three different relevance centers named fine, medium and coarse mesh surface geometry as shown in Table 2. The meshing parameter was set for an ideal case to obtain the best meshing to be adopted for the accurate result and less computational time.

Table 2
Mesh Parameters

		Default settings	
Physics Preference		CFD	
Solver Preference		Fluent	
		Sizing	
Relevance Centre	**Fine**	**Medium**	**Coarse**
Smoothing	Medium	Medium	Medium
Nodes	1,033,657	1,057,466	1,067,798
Elements	4,540,110	4,628,462	4,651,774
Mesh Quality	0.1398	0.122	0.1283
Aspect Ratio	25.07	41.26	24.84



(a) (b)

Fig. 5. (a) fin and (b) no fin mesh of a radiator tube

7. Grid Independent Test

Grids independence was determined using the ANSYS Mesh software and found for 320mm x 20mm x 2mm. The grid independence test for the physical model performed to determine the most suitable method of the mesh faces. In this study, tetrahedral cells were used to mesh the surfaces of the tube wall, and the surfaces of the water domain, as shown in Figure 6. Grid independence was checked using different grid systems, and three mesh faces were considered, coarse, medium and fine for the same radiator model. The mesh quality and aspect ratio have been determined for all three mesh faces, and the results all agreed with each other. All three mesh faces could have been used, and in this study, the mesh face with 4,628,462 elements was adopted because it was the best in terms of accuracy.

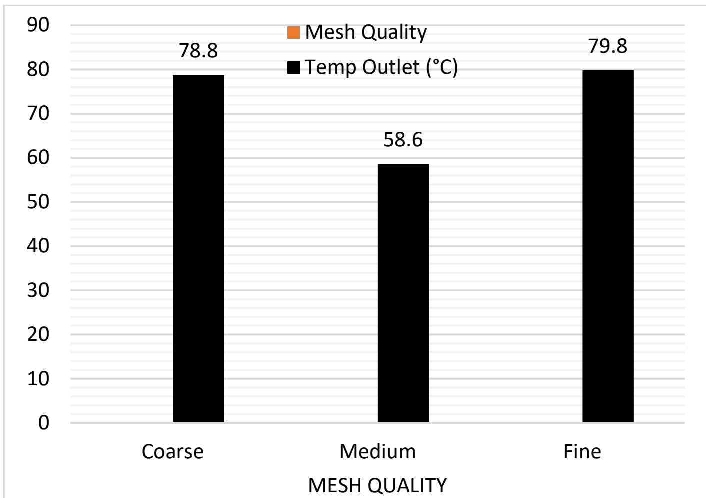


Fig. 6. Grid Test of a Radiator Model

7.1 Grid Independent Test on Medium Smoothing

For the radiator model to be independent of mesh type; three cases were run on medium smoothing in order to choose the best in terms of computational time, a number of elements and the result obtained. The meshing details are depicted in Table 3 below.

Table 3
Grid Test

Parameter	Case1	Case2	Case3
Node	1,231,730	374,077	1,396,952
Element	5,364,768	1,483,963	6,220,000
Mesh Quality	0.135	0.090	0.135
Aspect Ratio	28.57	43.47	27.00
Minimum sizing (mm)	0.123	0.125	0.12
Curvature angle	9.40°	18.0°	7.8°
Temp. Outlet (°C)	80.2	79.2	84.4

7.2 Observations

- Case 1, has medium curvature angle, minimum sizing, aspect ratio, number of elements and nodes in comparison with the other cases.

- Case 2, has the lowest number of elements, node and has the lowest mesh quality, its aspect ratio is higher, minimum sizing is higher and also has the highest curvature angle among the three cases.
- Case 3, also another modified medium smoothing mesh has the highest number of nodes, elements. It has the least minimum face size, the angle of curvature and aspect ratio.
- In terms of computational time, it took Case 1 about 7 hours to complete predefined iteration, Case 2 spent 3 hours and Case 3 spent 6 hours.
- Using defined Ansys settings, the outlet temperature of Case 2 is lowest, then Case 1 and Case 3.

7.3 Justification

- In terms of computational time, it took case 1 about 7 hours to complete predefined iteration, case 2 spent 3 hours and case 3 spent 6 hours.
- Using defined Ansys settings, the outlet temperature of case 2 is lowest, then case 1 and case 3.

8. Materials

The performance of car radiator will be based on two materials. The material with the best result will be recommended for Kano environs. The amount of heat dissipated is a function of the type of material and its sizing. Water, a universal coolant is used as the cooling media because of its high latent heat of vaporization, high boiling point, and its relative abundance.

Table 4
Water Properties

Property	Units	Value(s)
Density	kg/m3	998.2
Specific Heat (Cp)	J/kg – K	4182
Thermal Conductivity (K)	W/m-K	0.60
Viscosity	kg/m-s	0.001003
Molecular Weight	kg/kgmol	18.0152
Thermal Expansion Coefficient	1/K	0

Table 5
Aluminum Properties

Property	Units	Value(s)
Density	kg/m^3	2719
Specific Heat (Cp)	J/kg-K	871
Thermal Conductivity (K)	W/m-K	202.4
Yield Strength	N/m^2	68.94e+06
Shear Modulus	N/m^2	2.70e+7
Thermal Expansion Coefficient	1/k	2.04e-05

9. Atmospheric Temperature

The meteorological data of Kano for a period of six years (2009-20014) was obtained from Nigerian Meteorological Agency, a board that is responsible for providing accurate meteorological data to Nigerian airspace station. The monthly average atmospheric temperature was calculated from the data and is presented in Figure 7.

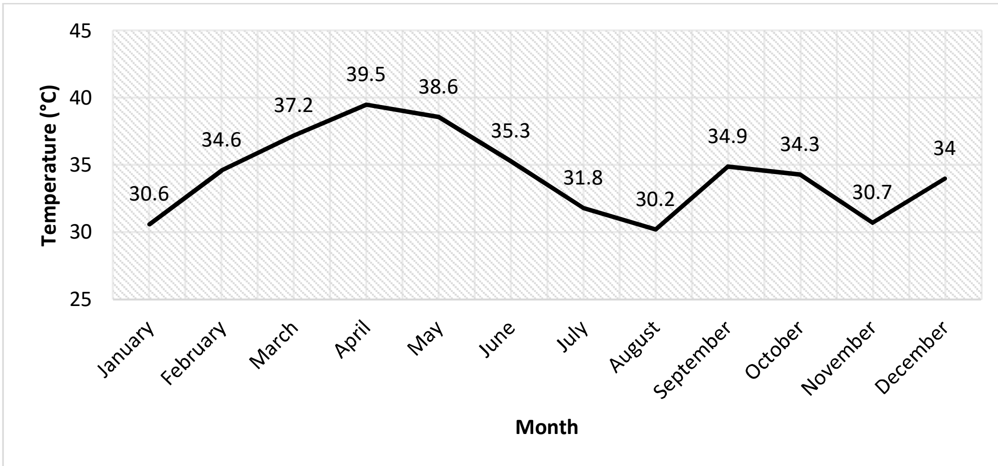


Fig. 7. Graph of average monthly temperature of Kano (2009-2014)

10. Assumption

In order to carry out the studies the following assumptions were made;
1. Constant coolant flow rate and fluid temperatures at both the inlet and outlet temperatures, i.e. the steady state.
2. There was no phase change in the coolant.
3. Heat loss by coolant was only transferred to the cooling air, thus no other heat transfer mode such as radiation was considered.
4. Coolant fluid flow was in a fully developed condition in each tube.
5. All dimensions were uniform throughout the radiator and the heat transfer of surface area was consistent and distributed uniformly.
6. The thermal conductivity of the radiator material was considered to be constant.
7. There were no heat sources and sinks within the radiator.
8. There was no fluid stratification, losses and flow misdistribution. The heat transfer process in the radiator was studied as a forced convective heat transfer.

The analysis was run across 12 months of the year using the average monthly temperature of Kano shown in Figure 7, with aluminum as the radiator material radiator as captioned above.

The value of heat transfer coefficient for each month was obtained using the convection heat transfer relation:

$$Q = hA\Delta T \tag{5}$$

where;
Q is the energy use in cooling the engine
A is the unit area
ΔT is temperature difference (Coolant inlet temp – Atmospheric temp)

Table 6
Result

Month	T_{in} (°C)	T_{atmp} (ºC)	h (W/m^{2}K)	T_{out} (°C)
January	95.0	30.6	258.85	66.90
February	95.0	34.6	275.99	69.50
March	95.0	37.2	288.41	67.50
April	95.0	39.5	300.36	70.39
May	95.0	38.6	295.57	70.25
June	95.0	35.3	279.23	67.19
July	95.0	31.8	263.77	69.13
August	95.0	30.2	257.25	66.50
September	95.0	32.1	265.02	69.35
October	95.0	34.9	277.37	69.47
November	95.0	34.3	274.63	69.47
December	95.0	30.7	259.25	68.98

11. Results and Discussions

11.1 Radiator without Fins

The average atmospheric temperature of Kano varies from 30.2°C in August to 39.5°C in April as shown in Figure 7. Figure 8 shows the monthly average outlet temperature of the coolant leaving the radiator for the configuration without fins. It can be seen from such figure that when the atmospheric temperature is high, the outlet temperature of the radiator (water coolant temperature) tends to be high. Hence, April has the highest radiator outlet temperature because of its high atmospheric temperature. This results in low heat exchange between the coolant and the atmospheric air because they are close. For this reason, the car radiator tends to overheat when the atmospheric temperature is relatively high unless there proper cooling.

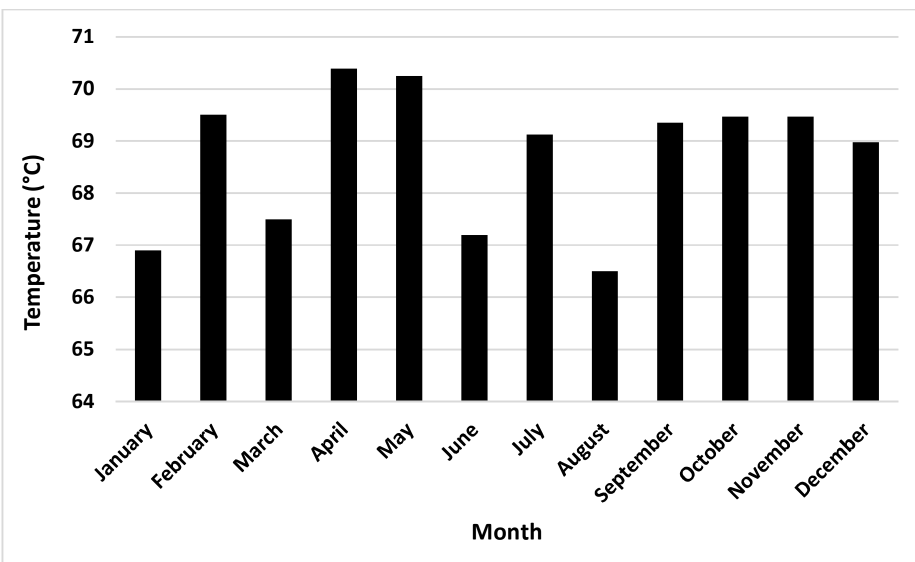


Fig. 8. Monthly average radiator outlet temperature without fins

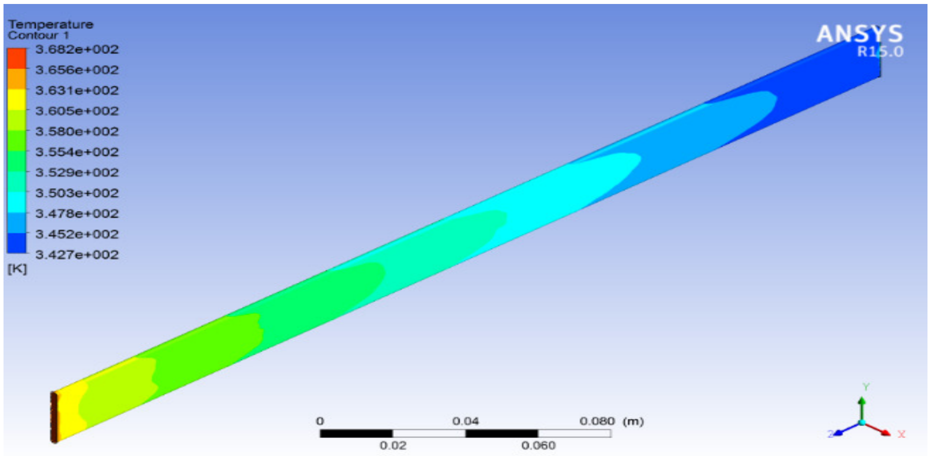


Fig. 9. Temperature contour of February

11.2 Radiator with Fins

The quantity of heat transfer is a function of surface area and the heat transfer coefficient as reported by Cengel [13]. For the heat transfer coefficient been a complicated function, the surface area is increased by attaching fins to the material geometry. The model was run using same boundary conditions as in section 11.1 but with fins attached to the radiator and the outlet, temperatures were recorded. Table 7 shows the monthly average outlet temperatures and the convective heat transfer coefficients for each month of the year.

Table 7
Result of Fins Effect

Month	T_{in} (°C)	T_{atmp} (ºC)	h (W/m^{2}K)	T_{out} (°C)
January	95.0	30.6	258.85	47.60
February	95.0	34.6	275.99	49.66
March	95.0	37.2	288.41	51.05
April	95.0	39.5	300.36	52.30
May	95.0	38.6	295.57	51.66
June	95.0	35.3	279.23	50.03
July	95.0	31.8	263.77	48.02
August	95.0	30.2	257.25	47.40
September	95.0	32.1	265.02	48.36
October	95.0	34.9	277.37	49.82
November	95.0	34.3	274.63	49.50
December	95.0	30.7	259.25	47.65

Fins are attached to the radiator to increase the cooling effect by increasing the surface area of the radiator. Consider the radiator with aluminium material as depicted in Figure 10.

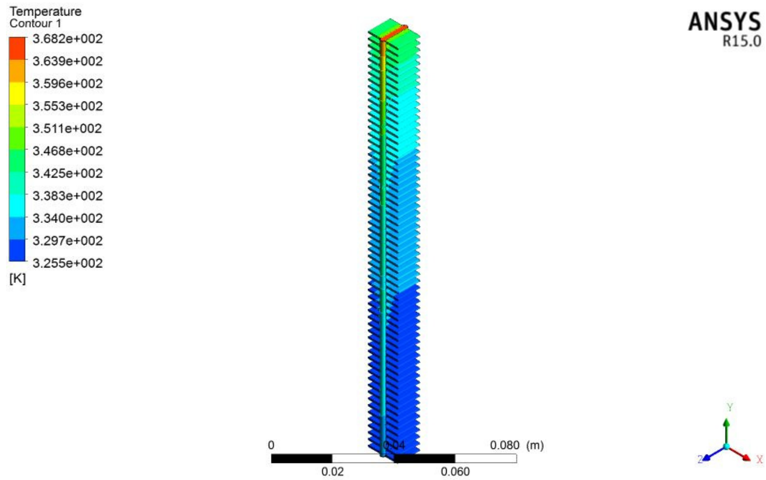


Fig. 10. Temperature contour of finned tube

11.2 Comparison of Temperature with and without Fins

Figure 11 compare aluminium radiator with and without a fin. For January the outlet temperature when fins are not used is 66.9°C while with fins, the temperature is 47.6°C, which shows about 25% decreased in outlet temperature for the finned model. This shows that more heat is dissipated to the atmosphere when fins are used compared those without fins. This trend is the same for all the months, which implies addition of fin on the radiator geometry significantly increase the heat removal from the coolant, hence decrease in the outlet temperature. Thus, the theory behind using fins to improve the cooling effects by improving the surface area is satisfied.

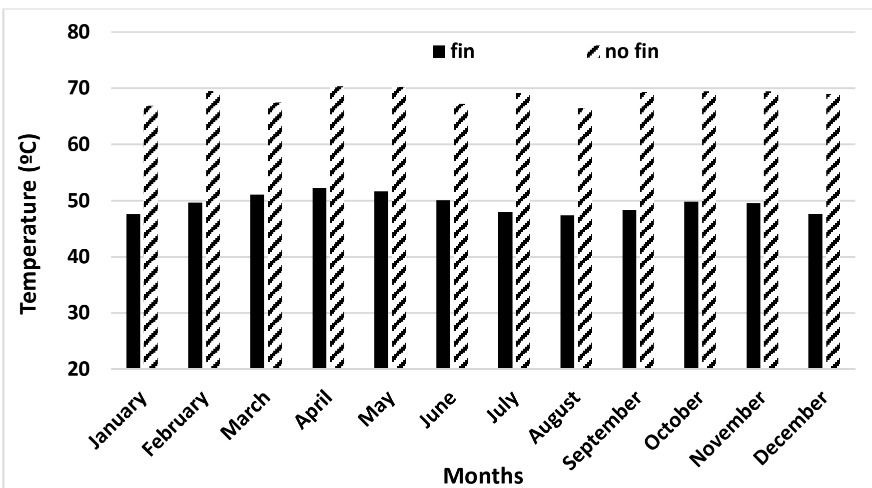


Fig. 11. Outlet temperature of the radiator with and without fins

12. Quantity of Energy Dissipation

Using the convection Heat transfer equation (5), the quantity of cooling energy was calculated for each month. Since the Honda Civic radiator generate about 50KW of energy [12] and one-third of it is used for cooling as stated by Lin [1]. The result obtained is shown below.

12.1 Effect of Energy Dissipation without Fins

Knowing that about one-third of the total energy generated by the car engine [1], the car radiator with aluminum when no fins attached dissipate about 44% of the cooling energy as in January. The highest amount of energy dissipation is recorded in March, which is up to 48%. In December, the lowest amount of energy dissipation is recorded which is about 40.6% as shown in Figure 12.

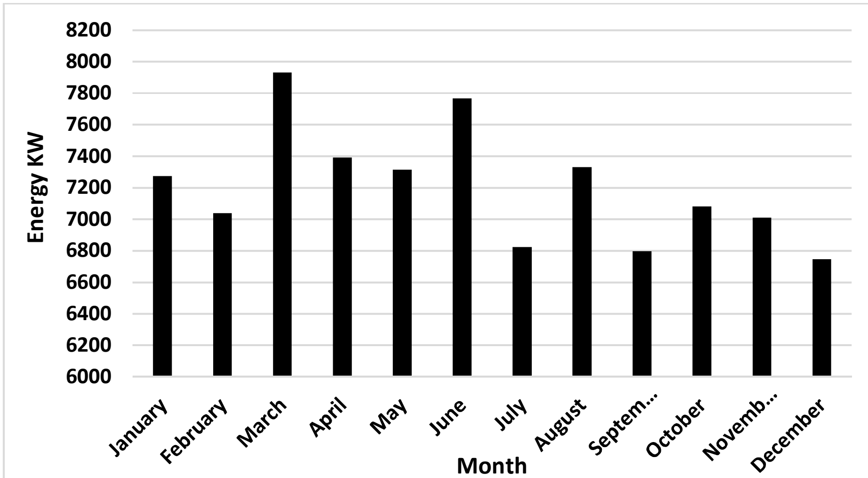


Fig. 12. Quantity of energy dissipated by radiator without fins

12.2 Effect of Energy Dissipation with Fins

Finned radiators dissipated more heat than radiators having no fins. In October, aluminum radiator dissipates about 75.1% of the overall cooling energy. These show that the cooling capacity of radiator increases when fins are used as shown in Figure 13. The amount of cooling is a function of outlet temperature, lower outlet temperature implies higher cooling. Therefore, aluminum radiator provides more cooling effect than copper. Highest energy dissipation is recorded in March and the lowest in December which is about 77% and 73.4% respectively.

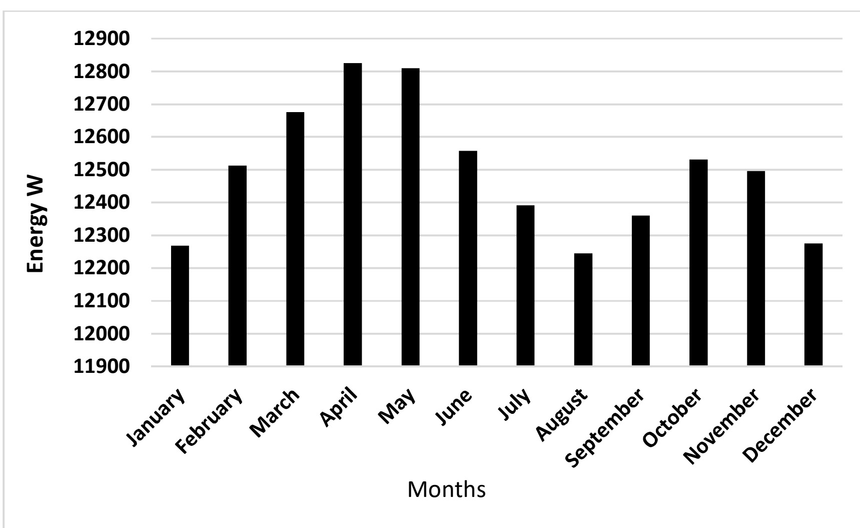


Fig. 13. Quantity of energy dissipated by radiator with fins

12.3 Comparison of Energy Dissipation with and without Fins

Figure 14 shows the radiator cooling energy compared with and without fins. As expected, the cooling capacity when fins are used is much higher. Using September as an example, the cooling performance with fins and without fins are 74% and 40.8% respectively. Therefore, 54.9% of cooling energy is obtained in September with the use of fins. The highest and lowest amount of cooling as stated above is in March and December which shows 62.6% and 54.9% respectively.

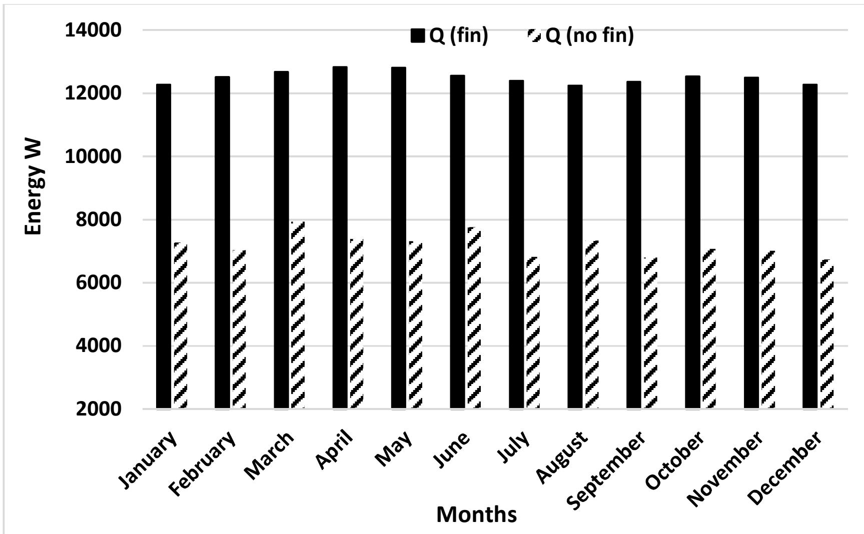


Fig. 14. Energy dissipated (with and without fins)

13. Conclusion

The efficiency of the internal combustion engine cooling system depends mainly on the performance of its cooling units. The main unit in this system is the radiator. A thermal model of car radiator was successfully modeled, the variation of outlet temperature under aluminum material was analyzed with fins and without fins on the radiator geometry and the amount of cooling energy was also determined for the radiator with fins and without fins. Both results were compared to vividly show the influence of fins as the emphasis in the theory and the result proved to be valid as the efficiency of the radiator increases with the use of fins.

From the data collected, the maximum and minimum atmospheric temperature of Kano was 39.5^{o}C and 30.2^{o}C in April and August respectively.

With fins are attached to the geometry, a temperature drop of about 25% is recorded for the aluminum radiator. This clearly shows the significance of fins in improving the performance of car radiators. The quantity of energy dissipate by radiator varies from one month to another and the material. Form the results shown above, with March as peak heat dissipated month, aluminum dissipate up to 48% cooling energy no fins are used. As expected, fins increase the cooling efficiencies of the radiators up to 77%.

The atmospheric condition has a great influence because high performance is recorded at lower atmospheric temperatures.

14. Recommendations

The use of finned radiator material cannot be overemphasized because it increases the efficiency of radiator without increasing the overall size of the radiator. It has been proved that fins affect the efficiency of the radiator. For advanced study, the following recommendations are put forward;

1. Fin geometry should be redesigned to achieve the optimum fin model.
2. Nanofluid coolant should be used provide more cooling.
3. Circular cross-section radiators should be used for circular cooling fans to avoid heat concentrated zones at the edge of rectangular radiators.

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