iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 3 Issue: IV Month of publication: April 2015

DOI:

www.ijraset.com Volume 3 Issue IV, April 2015
IC Value: 13.98 ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

Condensation and Radiation Modeling Of an Automotive Headlamp

Yuvaraj.C[1], Sangeetha.N[2], Ashok kumar.R[3], Naveenkumar.U[4]
[1]Student, Department of Mechanical Engineering, [2]Associate Professor, Department of Mechanical Engineering,
[3]Account Delevery Manager, [4]Student, Department of Mechanical Engineering,
[1,2,3]Kumaraguru College of Technology ,Pricol Technologies, ,Coimbatore-06

***Abstract*-An automotive headlamp is disclosed to heat fluctuation together with low air exchange the chances of humidity entering the headlamp will therefore enhance the risk for condensation to form on the inner surface of the lamp. The automotive firm today is considerably competitive and tends to focus more on reducing expenses. The consumers demanding high advanced features and styling characteristics likewise transparent optical plastics and low energy dissipating lamps. Because of these reasons dew is formed and it will cause visibility problem from outside.**

Thus it is of great importance for the car manufactures to be able to simulate the condensation before in the design stage and thereby also reduce the cost. This work describes the performing thermal flow simulation on headlamp by using Computational fluid dynamics (CFD) to calculate the dew point temperature. Thus the dew point temperature is correlated with the values found out from analytical methods.

Key words – Headlamp, condensation modeling, Relative humidity, CFD, Analytical

I. INTRODUCTION

This paper deals with the study of internal flow inside the headlamp; the flow inside the headlamp is mainly depends on the natural convection phenomena. The tungsten filament emitting the heat that will heat the surrounding air inside the headlamp enclosure. Due to the phenomena of natural convection process the colder air enters from the bottom ventilation hole that will force the hot air rise to pass through the top ventilation hole [1].

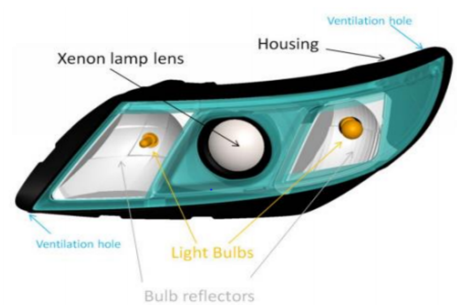


Figure 1 Headlamp

Buoyancy force mechanism is the principle that has been done the above process. Both the natural convection and buoyancy force mechanism together to work with the inside the headlamp. Due to both mechanisms will cause the some water vapour condense out. The condensation will be lead the dew formation inside the headlamp, The experimental tests are very expensive and it is also time consumption, by using CFD (Computational Fluid Dynamics) Analysis it is easy to spot the errors and rectifying it in an easy way.

A. Headlamp

Headlamp is an electrically operated device which is used for light the road ahead. In an automobile field the headlamps; parking and signaling lamps are mainly used for avoiding the road accidents. It can protect and guide the vehicle while driving at night time; other vehicles like an aircraft and train also required to have a headlamp.

An electrically operated modern headlamp is positioned in pairs; one or two on each side of the front of the vehicle. This is a headlamp system and it is required to produce a low and high beam lights. It may be achieved either by an individual lamp for each function or by a single multifunction lamp. High beams make most of their light straight ahead, low beams direct their

International Journal for Research in Applied Science & Engineering
Technology (IJRASET)
light downward either rightward or leftward to enhance safe forward visibility without glare and back dazzle.

B. Headlamp Light Source

The tungsten filament is light source; inside the headlamp bulb or shield beam it is operating in a vacuum or inert gas atmosphere [2]. The power consumption of tungsten filament is small Compared to the newer technology light sources.

II. PROBLEM DESCRIPTION

The headlamp may be subjected to the process of condensation. The corrode can taken place on steels and other metals that are stored in warehouses as result of condensation. The surface damages are happening inside the headlamps by condensation. Condensation will form on any object, when the temperature of the object is at or below the dew point temperature of the air surrounding the object. To calculate the dew point temperature, the thermal flow simulations are performed inside the headlamps. The calculated dew point temperature will predict the condensation. The relative humidity, water vapour pressures, buoyancy forces and natural convection mechanisms are other factors considered for condensation. These factors are mainly influencing the condensation. Relative humidity, vapour pressures, is correlated with the dew point temperature.

Relative humidity is the measure of water vapour that is presented in the air, which is defined as the ratio of actual vapour pressure to the saturation vapour pressure [5]. The water vapour present in the air is more; the vapour pressure is the higher. At a given temperature, if the air is holding water vapour which is equal to the maximum then the air is said to be saturated. The partial pressure exerted by the water vapour under saturated conditions is known as saturation vapour pressure.

$RH = 100e/e_s$ Where e = actual vapour pressure. e_s = Saturated vapour pressure.

The atmospheric air mainly consists of five substances; nitrogen, oxygen, argon, carbon dioxide and water vapour. The relative humidity can be expressed as the amount of water vapour that can be obtained by air. And is controlled by the by temperature and pressure of the air, therefore the maximum relative humidity varies with two parameters. Condensation is constitute as small water droplets and can be seen as fog. Buoyancy force is play an important role in the condensation; due to the buoyancy force it will push the lighter fluid upward replaced by heavier fluid. The dimension of the buoyancy force is equal to the weight of the fluid displaced by the body. That is,

$$F_{buoyancy} = \rho_{fluid}\, g\, V_{body}$$

Where ρfluid is the average density of the fluid (not the body), g is gravitational acceleration, and V body is volume of the portion of the body immersed in the fluid. Natural convection heat transfer mechanism is essential function in the condensation phenomena. Where any fluid motion occurs by natural means like buoyancy. The fluid motion in natural convection, however, is frequently not noticeable because of the low velocities are involved. The heat transfer coefficient of natural convection is a strong function of velocity; the higher the velocity, higher the convection heat transfer coefficient. The low fluid velocities are involved in the natural convection, typically less than 1m/s.

Figure 2 Condensation Has Taken Place on Headlamps

A. Condensation Heat Transfer

The parameters considered that are natural convection, buoyancy force, vapour pressure and dew point temperature mainly influencing the condensation; these parameters have correlation with each other.

B. Natural Convection

Many popular heat transfer applications include natural convection as the primary mechanism of heat transfer. Few examples are cooling of electronic equipment likewise power transistors, TVs, and VCRs; heat transfer from electric baseboard heaters or steam radiators; heat transfer from the refrigeration coils and power transmission lines; and heat transfer from the bodies of

International Journal for Research in Applied Science & Engineering Technology (IJRASET)

animals and human beings. The space vacated by the hot air in the vicinity of an any object is replaced by the cooler air nearby, and the presence of cooler air in the vicinity of an any object speeds up the cooling process. The rise of hot air and the flow of cooler air into its place continue until the object is cooled to the temperature of the surrounding air [3]. The motion that results from the continual replacement of the heated air in the vicinity of an any object by the cooler air nearby is called a natural convection current, and the heat transfer that is enhanced as a result of this natural convection current is called natural convection heat transfer.

C. Buoyancy Force

In a gravitational arena, there is a net force that press forward a light fluid placed in a heavier fluid. The impel force exerted by a fluid on a body fully or partially immersed in it is called the buoyancy force [3]. The net altitude force acting on a body is the difference between the weight of the body and the buoyancy force. That is,

$$\begin{aligned} F_{net} &= W - F_{buoyancy} \\ &= \rho_{body}\, g\, V_{body} - \rho_{fluid}\, g\, V_{body} \\ &= (\rho_{body} - \rho_{fluid})\, g\, V_{body} \end{aligned}$$

Therefore body immersed in a fluid will experience a “weight loss “in an amount equal to the weight of the fluid it displaces. This is known as Archimedes’ principle [7]. The dimension of the natural convection heat transfer between a surface and a fluid is directly related to the flow rate of the fluid. If the higher the flow rate, the higher the heat transfer rate. The buoyancy force is developed by the density difference between the heated (or cooled) fluid adjacent to the surface and the fluid surrounding it, and it is proportional to this density difference and the volume occupied by the hot fluid. It is also well known that whenever two Bodies in contact (solid–solid, solid–fluid, or fluid–fluid) are correlated, a friction force develops at the contact surface in the direction opposite to that of the motion. If the liquid water temperature increases, then evaporation will temporarily exceed condensation, and the number of water molecules in the air will increase until a new equilibrium is reached [6].

D. Governing Equation

Governing equations solved by the software for this study in tensor Cartesian form are Continuity and Momentum equations.

Continuity equation:

$$\rho\left(\frac{\partial u_j}{\partial x_j}\right)=0$$

Momentum equation:

Momentum x:

$$\rho\frac{\partial u}{\partial t} = \rho g_x - \frac{\partial p}{\partial x} + \mu\left(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} + \frac{\partial^2 u}{\partial z^2}\right)$$

Momentum y:

$$\rho\frac{\partial v}{\partial t} = \rho g_y - \frac{\partial p}{\partial x} + \mu\left(\frac{\partial^2 v}{\partial x^2} + \frac{\partial^2 v}{\partial y^2} + \frac{\partial^2 v}{\partial z^2}\right)$$

Momentum z:

$$\rho\frac{\partial w}{\partial t} = \rho g_z - \frac{\partial p}{\partial x} + \mu\left(\frac{\partial^2 w}{\partial x^2} + \frac{\partial^2 w}{\partial y^2} + \frac{\partial^2 w}{\partial z^2}\right)$$

Where,

ρ = density, g = gravitational force

III. METHODOLOGY

A. Analytical Calculation

The heat transfer on the headlamp associated with convection, conduction and radiation. The combined convection and radiation heat transfer occur on the outside of the headlamp. The heat transfer from the outer to inner lens is carried by conduction process. The heat transfer through the fluid inside headlamp enclosure is happened by convection. The calculated values are validated by CFD simulation, behind which the simulation has been solved through continuity momentum and conservation of energy equations.

B. Convection

Natural convection is generally recognized as movement of air induced by temperature variation and is also known as buoyancy

International Journal for Research in Applied Science & Engineering Technology (IJRASET)

driven flow. When temperature of the fluid increases, the density will decrease; hence the warmed air will start to move upward, being replaced by cold air moving in from below [1].

The intensity of natural convection can be measured by the magnitude of Rayleigh number. The Rayleigh number indicates the difference between viscous and buoyancy forces in the fluid and large value indicates the strong natural convection effects. The prandtl number explains the fluids kinematic viscosity and thermal diffusivity.

$$G_r = \frac{\beta g L^3 \rho^2 \Delta T}{\mu^2}$$

$$R_a = G_r P_r = \frac{\beta g L^3 \Delta T}{\gamma \alpha}$$

When the fluid is in motion, the heat is transfer transferred by the convection.

$$\dot{Q}_{convection} = hA(T_s - T_\infty)$$

C. Conduction

When two surfaces have a temperature difference, the energy is transferred between two by conduction. Conduction generally takes place in or between interaction surfaces and solids. The heat transfer occurs consecutively from hotter region to coder region due to temperature gradient between the two [4]. Heat that is being transferred through a medium by conduction can be expressed as;

$$\dot{q}_n = -k \frac{\Delta T}{\Delta n}$$

D. Radiation

The energy exposed by an energy source is explained as radiation of electromagnetic waves. These waves do not require any medium to be transferred and radiation is therefore quickest in vacuum as nothing restricts the electromagnetic waves. Electromagnetic waves are distributed over a wide spectrum of wave lengths. Where a spectrum part has vast differences in their properties compared to other parts of the spectrum. Each and every body emits the thermal radiation with temperature above absolute zero that is above zero degree Kelvin. The radiation emitted from body can be expressed by Stefan-Boltzmann law below.

$$\dot{Q}_{radiation} - \varepsilon \sigma A({T_s}^4 - {T_\infty}^4)$$

Emissivity is material property and the emissivity is one for black body and close to zero for highly reflective material. The glossy surface of a reflector has an emissivity value between 0.05 to 0.1, at the same time dark collared surfaces have values up to 0.98. Emissivity of the material depends on the wavelength, surface temperature and the incoming radiation angle. Surface can emit, transmit or absorb radiation, the amount of radiation that is being absorbed by a surface is denoted by α, body that take in all incoming light has an absorption coefficient of one. Temperature of the body rises due to absorption of radiation .both the emissivity Ɛ and absorption α depends on the surface temperature and wavelength of incoming radiation.

E. Surface Temperature of Outer Glass

Outside of the headlamp the heat transfer is happen by combined convection and radiation process.

$Q = h (T_4-T_\infty) + Ɛσ (T_4- T_\infty)$

Where Q = Heat flux from solar radiation 700 W /m^2, h = combined convection and radiation heat transfer co- efficient 50 W /m^2.k, Ɛ= emissivity of glass 0.9, σ = Stefan – Boltzmann constant 5.67 x 10^{-8} w/m^2 K^4, T_∞ = temperature of air sufficiently far from the surface 298.15K.

Substitute all above values in equation the T_4 = 37.70°C.

F. Surface Temperature of Inner Glass

Conduction heat transfer through glass;

Q = k A dt/dx

Where k = thermal conductivity of the glass 0.67 w/m k, dt = (T_3-T_4), dx = glass thickness, q /a = 700 w /m^2. Substitute all

International Journal for Research in Applied Science & Engineering Technology (IJRASET)

above values into equation, the T_3 = 41.88°C.

G. Temperature of Air inside the Headlamp

Temperature of air inside the headlamp

$Q = h (T_2 - T_3)$

Where Q = Heat flux from solar radiation 2685.7 W /m^2, h = combined convection and radiation heat transfer co- efficient 50 W /m^2.k

Substitute above values in to equation the T_2 = 95.44°C.

H. *Surface Temperature of Bulb*

$Q = h (T_1 - T_\infty) + \mathcal{E}\sigma (T_1 - T_\infty)$

Where Q = Heat flux 2685.7 W /m^2, h = convection heat transfer co-efficient 7.854W/m^2.k, Ɛ = emissivity of glass 0.9, σ = Stefan – Boltzmann constant 5.67 x 10^{-8} w/m^2 K^4, T_∞ = temperature of air sufficiently far from the surface 298.15K.

Substitute above values into equation the T_1 = 169.4°C.

IV. SIMULATIONS

In this paper CFD study for 2d geometry of headlamp is studied. Radiation heat transfer modeling has been done by discrete ordinate model by CFD analysis. This model is very handy for prediction of condensation.

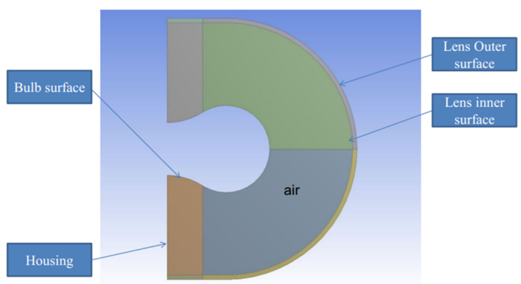


Figure 3 Geometry

A. Boundary Condition

Table1
Boundary Conditions

model	settings
space	3d
time	steady
viscous	Laminar model
Wall treatment	Enhanced wall treatment
radiation	Discrete ordinate model

In the closed domain contain the atmospheric air; it may be considered as dry air. The dry air also consists of some amount of water vapour. By using the cfd analysis could be validate the temperature of outer lens, inner lens and interior air temperature of headlamp geometry. The combined natural convection and radiation plays an important role in radiation heat transfer analysis.

V. RESULTS AND DISCUSSIONS

The air flow inside the headlamp is happened by both the natural convection and radiation. The water vapour is condensing out when the inner lens temperature is below its interior air temperature.

A. Absolute Pressure

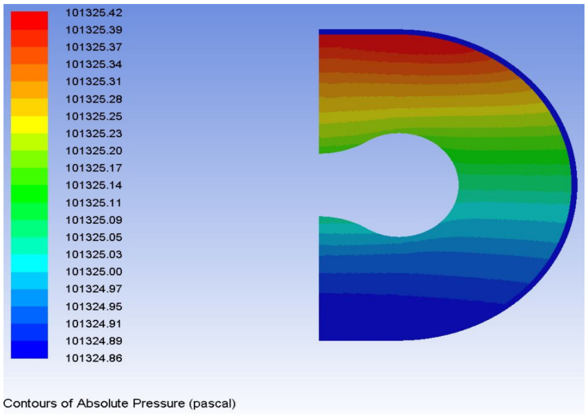


Fig 4 Absolute Pressure of Headlamp.

B. Total Temperatur

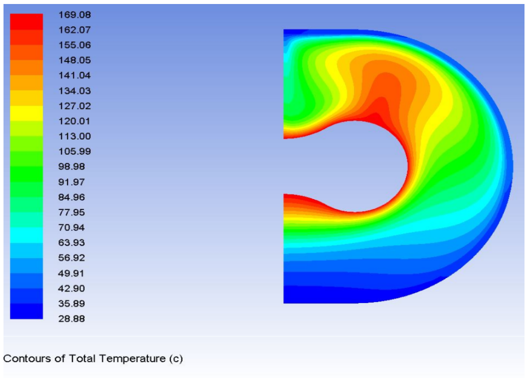


Fig 5 Total Temperature of Headlamp.

C. Temperature of Inner Lens, Outer lens and Interior Air.

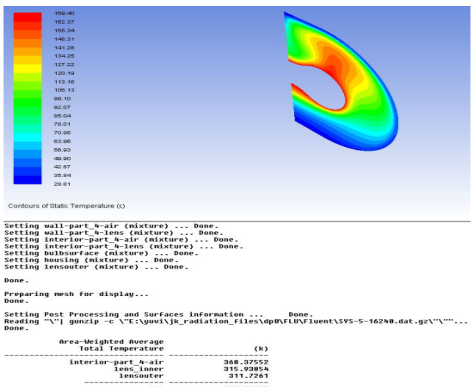


Fig 6 Temperature of Inner Lens, Outer Lens and Interior Air Temperature.

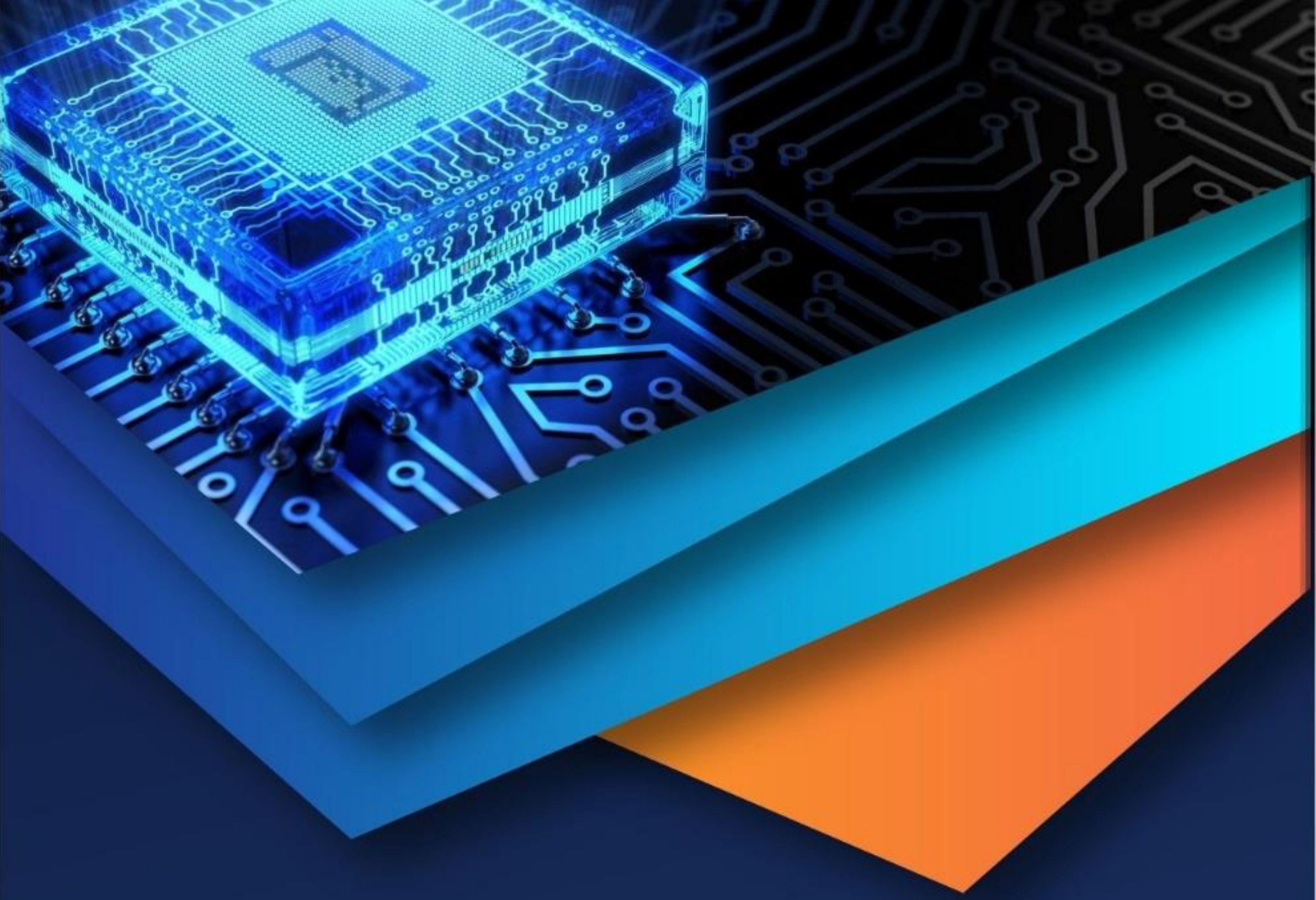
The analytical calculated values are validated by the CFD simulation. Which values are lies on within allowable ranges, thus the condensation of water vapour is predicted by radiation heat transfer modeling.

VI. CONCLUSION

In this paper clearly stated that the condensation occur when the inner lens temperature drops below the interior air temperature. The prediction of condensation can be stated by using the discrete ordinate model in anasys fluent package. When the relative humidity of air has 100%, which has hold maximum amount of water vapour in it. While further addition of water vapour into it, it will condense out. The density of moist air is too high in bottom of the headlamp geometry because of temperature rise on the top of the headlamp geometry, and due to the gravitational force the water droplets are slide down on bottom of headlamp geometry.

REFERENCES

[1] Johan Brunberg, Mikael Aspelin "Cfd modeling of headlamp condensation" master's thesis in automotive engineering ISSN 1652-8557 division of vehicle engineering and autonomous systems chalmers university of technology swedon.
[2] J.Langebach, S. Senin, Ch. Karcher " experimental study of convection and radiation interaction in a headlight model using pressure variation" Experimental Thermal and Fluid Science 32 (2007) 521–528.
[3] Furkan Sokmen k Erhan Pulat, Nurettin Yamankaradeniz,Salih Coskun "Thermal computations of temperature distribution and bulb heat transfer in an automobile headlamp" Heat Mass Transfer (2014) 50:199–210.
[4] Mendes N, Philippi P.C. "A method for predicting heat and moisture transfer through multilayered walls based on temperature and moisture content gradients" International Journal of Heat and Mass Transfer 48 (2005) 37–51.
[5] Erik Preihs General Motors Europe "Automotive Headlamp - Analytic Solution and Measurements of Condensation inside a Headlamp" Excerpt from the Proceedings of the 2006 Nordic COMSOL Conference.
[6] Yunus A cengel, Afshin J.Ghajar "A text book of heat and mass transfer" page no 581-629.
[7] Yunus A cengel, John M.Cimbala "a text book of fluid mechanics" page no 183-223.
[8] Yunus A cengel, Michael A.Boles "a text book of thermodynamics" page no 727-751.



10.22214/IJRASET

INDEX COPERNICUS 45.98

IMPACT FACTOR: 7.129

TOGETHER WE REACH THE GOAL

IMPACT FACTOR: 7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY