DESIGN AND FABRICATION OF INDUCED DRAFT COOLING TOWER

[1]Luke Justin Johnson .G,[2]Sivakumar D.B, [3]Dr. T. Senthilkumar
1- P.G. Scholar, Dept. of Mechanical Engineering, University College of Engineering, Tiruchirappalli, India
2- Assistant Professor, Dept. of Mechanical Engg, University College of Engineering, Tiruchirappalli, India
3- Professor & Dean, Dept. of Mechanical Engg, University College of Engineering, Tiruchirappalli, India

Abstract: **Cooling tower is an essential component of Thermal Power plant, Air-Conditioning plant and Chemical plant etc. Basically cooling tower are heat rejection devices used to transfer heat from hot water to the atmosphere air. In this paper includes working principal of counter flow induced draft cooling tower, design using computer Aided Three Dimensional Interactive Application modeling software and working prototype is fabricated with reduced scale factor. Also to calculate the performance analysis for various parameters i.e. Range, Approach, effectiveness and evaporation loss of cooling tower with the influence of inlet water temperature and mass flow rate of water and air.**

Key words- Cooling tower, Range, Approach, Effectiveness and Efficiency, CATIA, Fabrication Etc.

I. INTRODUCTION

Cooling towers are heat removal devices used to transfer process waste heat to the atmosphere. Cooling towers make use of evaporation whereby some of the water is evaporated into a moving air stream and subsequently discharged into the atmosphere.

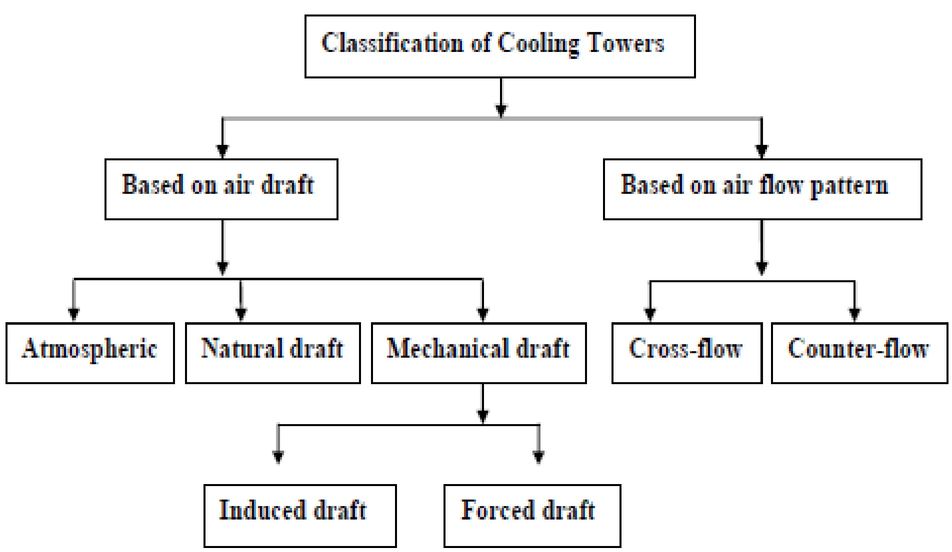

Fig 1. Classification of cooling towers

Induced Draft Cooling Tower

A mechanical draft cooling tower is fixed with a top fan at the discharge which pulls air through tower. The fan induces hot moist air out the discharge. The produce low entering and high exiting air velocities, reducing the possibilities of recirculation in which discharge air flows back into the air intake.

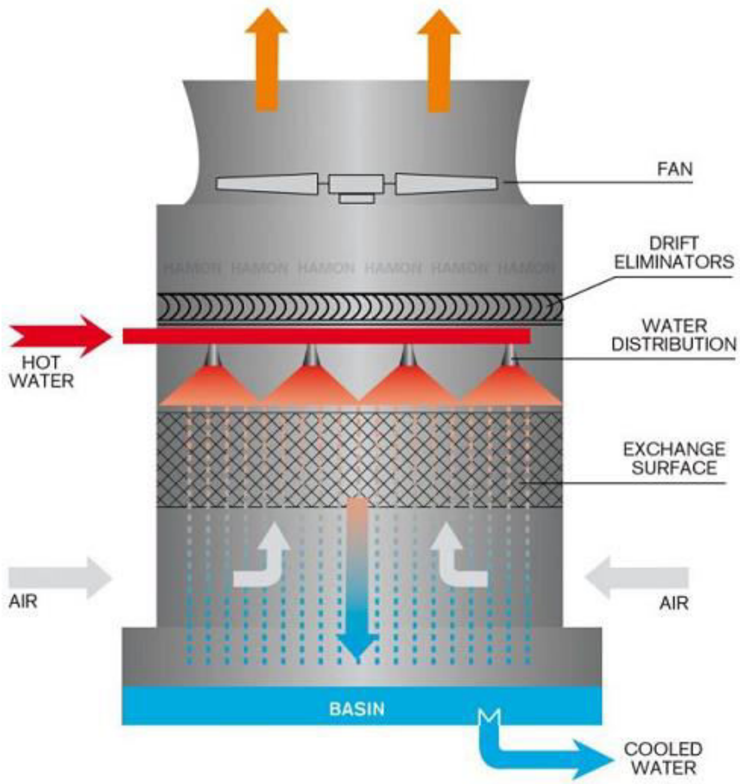

Fig 2. Induced Draft Cooling Tower

II. COOLING TOWER DESIGN CONSIDERTION

Once a tower characteristic has been established between the plant engineer and the manufacturer, the manufacturer must design a tower that matches the value. The required tower size will be a function of:

a. Cooling range
b. Approach to wet bulb temperature
c. Mass flow rate of water
d. Wet bulb temperature
e. Air velocity through tower or individual tower cell

These measured parameters and then used to determine the cooling tower performance in several ways.

[NOTE: CT – Cooling Tower, CW – Cooling Water]

T_1 - T_2 = temperature difference between inlet and outlet water

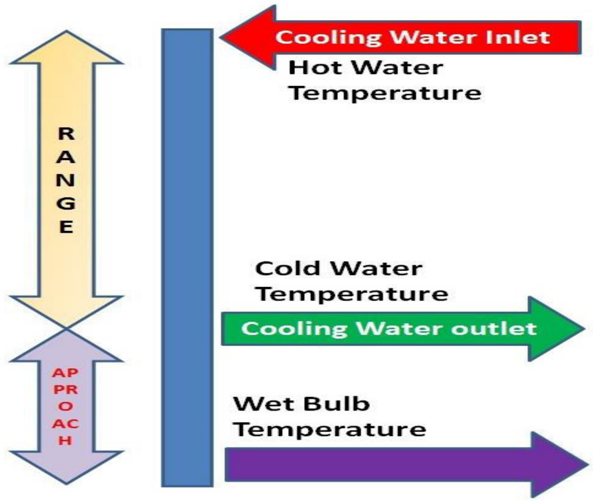

Fig 3. Tower characteristic chart

A. Range

Range is the difference between the cooling tower water inlet and outlet temperature. A high CT Range means that the cooling tower has been able to reduce the water temperature effectively, and is thus performing well.

CT Range (°C) = [CW inlet temp - CW outlet temp] (1)

B. Approach

Approach is the difference between the cooling tower outlet cold water temperature and ambient wet bulb temperature. The lower the approach is better the cooling tower performance. Although, both range and approach should be monitored, the 'Approach' is a better indicator of cooling tower performance.

CT Approach = [CW outlet temp - Wet bulb temp] (2)

C. Wet Bulb Temperature

Wet bulb temperature is an important factor in performance of evaporative water cooling equipment. It is a controlling factor from the aspect of minimum cold water temperature to which water can be cooled by the evaporative method. Thus, the wet bulb temperature of the air entering the cooling tower determines operating temperature levels throughout the plant, process, or system. Theoretically, a cooling tower will cool water to the entering wet bulb temperature, when operating without a heat load. However, a thermal potential is required to reject heat, so it is not possible to cool water to the entering air wet bulb temperature, when a heat load is applied. The approach obtained is a function of thermal conditions and tower capability.

Theoretically, a cooling tower will cool water to the entering wet bulb temperature. In practice, however, water is cooled to a temperature higher than the wet bulb temperature because heat needs to be rejected from the cooling tower.

A pre-selection of towers based on the design wet bulb temperature must consider conditions at the tower site. The design wet bulb temperature also should not be exceeded for more than 5 percent of the time. In general, the design temperature selected is close to the average maximum wet bulb temperature in summer.

Confirm whether the wet bulb temperature is specified as ambient (the temperature in the cooling tower area) or inlet (the temperature of the air entering the tower, which is often affected by discharge vapors recycled into the tower). As the impact of recirculation cannot be known in advance, the ambient wet bulb temperature is preferred.

D. Effectiveness

Effectiveness is the ratio between the range and the ideal range (in percentage), i.e. difference between cooling water inlet temperature and ambient wet bulb temperature,

Effectiveness = Range / (Range + Approach) **(3)**

CT Effectiveness (%) = (CW in temp - CW out temp) / (CW in temp - WB temp) x 100 **(4)**

E. Cooling capacity

Cooling capacity is the heat rejected in kCal/hr or TR, given as product of mass flow rate of water, specific heat and temperature difference.

F. Evaporation loss

Evaporation loss is the water quantity evaporated for cooling duty. Theoretically the evaporation quantity works out to 1.8 m^3 for every 1,000,000 kCal heat rejected. The following formula can be used;

Evaporation loss (m^3/hr) = 0.00085 x 1.8 x circulation rate (m^3/hr) x (T_1-T_2) **(5)**

III. TECHNICAL PARAMETERS

Table 1: Input parameters

Parameters	Value	Units
Inlet Temperature of Water (T_1)	36	deg °C
Outlet Temperature of water (T_2)	30	deg °C
Inlet Temperature of Air (t_1)	27	deg °C
Outlet Temperature of Air (t_2)	38	deg °C
Wet bulb Temperature (WBT)	28	deg °C
Relative Humidity (RH)	80	%
Mass Flow rate (m)	326	m^3/hr
Allowable Evaporation Loss	0.99	%
Height (H)	3	m

A Psychrometric chart is a graphical representation of the psychrometric process of air. Psychrometric includes physical and thermodnamic properties such as dry blub temperature, wet bulb temperatrure, humidity enthalpy and air density.

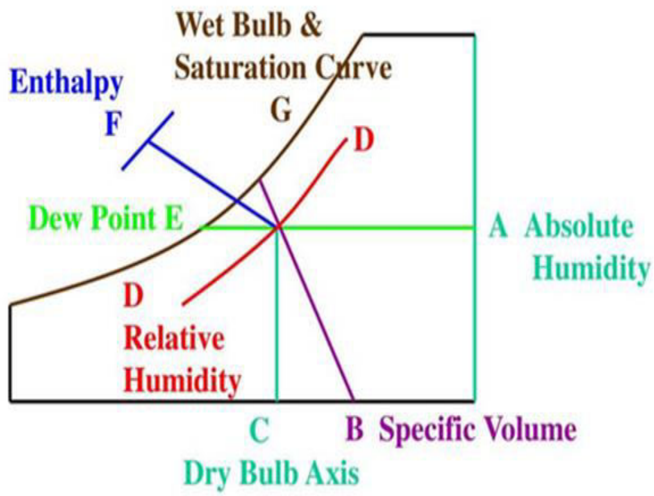

Fig. 4. Psychrometric Chart

A Psychrometric chart can be used in two different ways. The first is done by plotting multiple data points that represent the air conditions at a specific time, on the chart. Then, overlaying an area that identifies the "comfort zone".

A Psychrometric chart is an important tool for HVAC engineers to carry out heat load or cooling load calculations and find solutions to various air condition related problems. Read an overview of the components included in a psychrometric chart.

By using psychometric chart take output are mentioned below

Table 2: Output Parameters

Parameters	Value	Units
Enthalpy of water at inlet (H_{w1})	159.3	KJ/Kg
Enthalpy of water at outlet (H_{w2})	134.2	KJ/Kg
Enthalpy of air at inlet (H_{a1})	73.57	KJ/Kg
Enthalpy of air at outlet (H_{a2})	115.3	KJ/Kg
Specific volume of air at inlet (V_{s1})	0.876	m^3/Kg
Specific volume of air at outlet (V_{s2})	0.92	m^3/Kg
Specific Humidity of air at inlet (W_1)	0.018	Kg/Kg
Specific Humidity of air at outlet (W_2)	0.031	Kg/Kg

Thermal Calculation

Approach

Approach (CTA) = Outlet temperature of water (T_2) - Wet bulb temperature (WBT)

CTA = 30 °C – 28°C
CTA = 2°C

Range

Range (CTR) = Inlet temperature of Water (T_1) - Outlet temperature of Water (T_2)

CTR = 36°C – 30°C
CTR = 6°C

Heat Loss by water (HL)

$HL = M \times Cp \times (T_1 - T_2)$
HL = 52000 x 4.186 x (36 - 30)
HL = 1306032 KJ / hr

Volume of Air Required (V)

$(V) = (HL \times V_{s1}) / [(H_{a2} - H_{a1}) - (W_2 - W_1) \times Cp \times T_2]$

V = (1306032 x 0.876 / [(159.3 – 134.2) – (0.031 – 0.018) x 4.186 x 30]
V = 1142444.16 / [(25.1) – (0.013) x 125.58]
V = 48682.05 m^3 / hr

Capacity of Each fan (C)

C = Volume of Air Required / No. of fan
C = 48682.05 / 4
C = 12170.51 m^3 / hr

Heat Gain by Air (HG)

Heat Gain by Air $HG = V \times [(Ha_2 - Ha_1) - (W_2 - W_1) \times Cp \times T_2] / Vs_1$

HG = 48682.05 x [(115.3 - 73.57) – (0.031 – 0.018) x 4.186 x 30] / 0.876
HG = 1889296.81/0.876
HG = 2156731.52 KJ/hr

Mass of Air Required (M_a)

Mass of Air Required (M_a) = Volume of air required / Specific volume of air at inlet temperature

$M_a = V / V_{s1}$
$M_a = 48682.05 / 0.876$
$M_a = 55573.12$ Kg/hr

Quantity of Make-Up Water (M_{mak})

$M_{mak} = V \times (W_2 - W_1) / V_{s2}$
$M_{mak} = 48682.05 \times (0.031 - 0.018) / 0.92$
$M_{mak} = 687.90$ kg/hr

Now, taking Evaporating loss in calculation
$M_{mak} = 687.90 \times [1 + (0.99/ 100)]$
$M_{mak} = 964.7$ Kg/hr

Efficiency (η)

$\eta = (T_1 - T_2) / (T_1 - WBT) \times 100$
$\eta = (36 - 30)/ (36 - 28) \times 100$
$\eta = 75$ %

Effectiveness (ε)

$\varepsilon = (T_1 - T_2) / (T_1 - t_1)$
$\varepsilon = (36 - 30) / (36 - 27)$
$\varepsilon = 0.67$

DRIFT LOSS (DL)

DL = (0.20*m)/100
DL = (0.2*52000)/100
DL = 104 kg/hr.

WINDAGE LOSS (WL)

WL= 0.005* m
WL= 0.005*52000
WL= 260 kg/hr.

EVAPORATION LOSS (EL)

$EL = 0.00085 \times 1.8 \times m \times (T_1 - T_2)$
$EL = 0.00085 \times 1.8 \times 52000 \times (36 - 30)$
EL = 477.36 Kg/hr

WATER BALANCE EQUATION

M = WL+ EL + DL
M = 260 + 477.36 + 104
M = 841.26 kg/hr.

BLOW DOWN LOSS (BL)

No of cycles= (XC/XM)

Where

XC is concentration of solids in circulating water
XM is concentration of solids in make-up water

(XC/XM) = [(M/(M-EL)]
(XC/XM) = [841.26/(841.36-477.36)]
(XC/XM) = 2.31

BL = [EL/ (CYCLES-1)]
BL = (477.36 / (2.31 – 1))
BL = 364.4 kg/hr.

IV. MODELING PROCESS

Using the above calculation designed a model with reduced scale factor in CATIA modeling software.

Computer aided three dimensional interactive application is a multi-platform software suite for computer-aided design (CAD), computer-aided manufacturing (CAM), computer-aided engineering (CAE), PLM and 3D, developed by the French company Dassault System. Biggest advantage of this software is user-friendly.

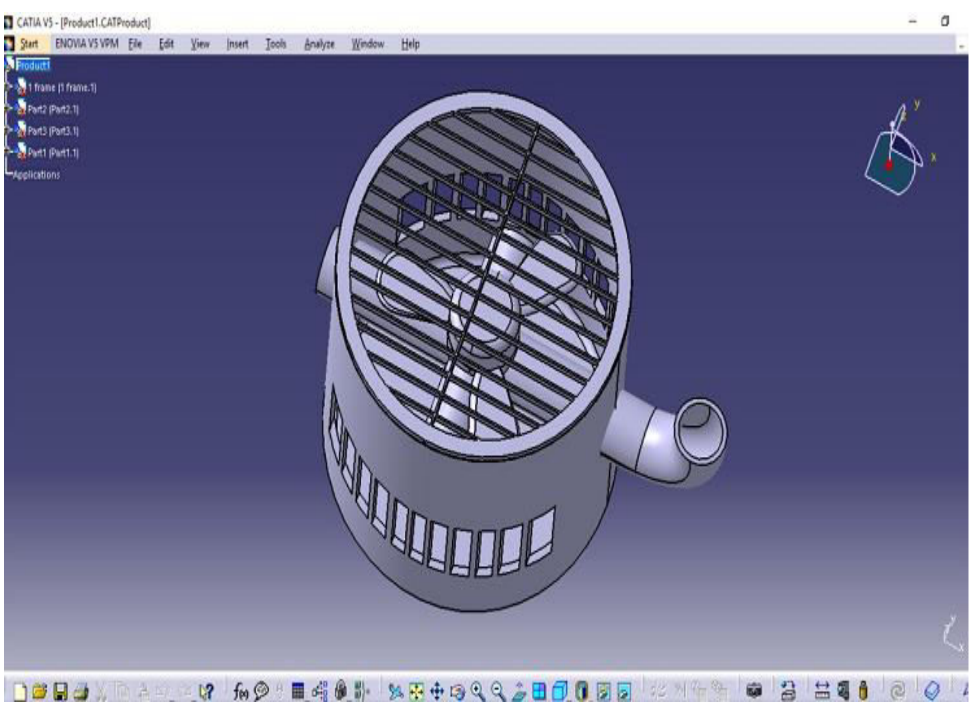

Fig 5. Top view of Cooling Tower Model

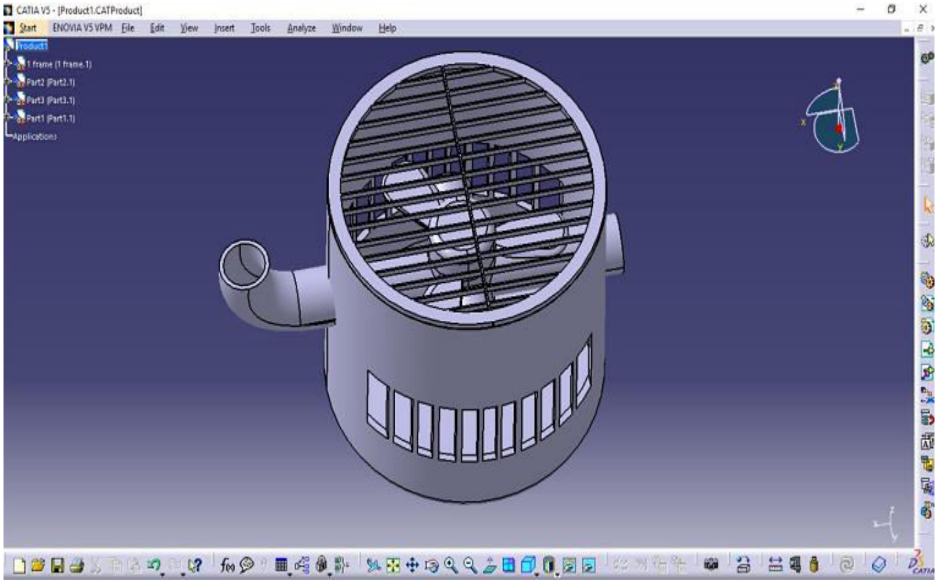

Fig 6. Front view of Cooling Tower Model

Scale Factor is 10:1
Diameter – 2 Meters
Height – 4 Meters
Fan – 1 No.

V. COMPONENTS OF A COOLING TOWER

A. Fills

Although cooling tower fill is often acceptably referred to as a heat transfer surface, such terminology is not true in its strictest sense. The heat transfer surface in the classic cooling tower is actually the exposed surface of the water itself. The fill is merely a media by which more water surface is caused to be exposed to the air (increasing the rate of heat transfer), and which increases the time of air-water contact by retarding the progress of the water (increasing the amount of heat transfer).

B. Drift Eliminators

The purpose of Drift eliminator is to reduce the drift loss in cooling tower. Drift eliminators normally kept next to fills in the air flow path thereby reducing the drift loss. Drift loss is the loss of entrained water through hot air to atmosphere. Drift eliminators normally made up of PVC. More number of passes through drift eliminator decreases the drift loss but increases the pressure drop thereby increasing fan power consumption

C. Cooling Tower Fans

Main part of the cooling tower components. Cooling Tower fans are normally made from Aluminum, Fiber Reinforced Plastic (FRP), Glass fiber and hot dipped galvanized steel are commonly used as fan materials. FRP being light in weight, impellers made up of FRP reduces the power requirements of the fan. Cooling tower fan blades pitch angle is varied depending on seasonal requirements. Cooling tower Fan Blade Pitch angle is the angle made by the fan with the plane. Normally during summer season, the air density is low. So the fan blade pitch angle is increased to increase the capacity of the fan.

Evaporative cooling is also known as adiabatic saturation of air is a thermodynamic process. When a hot and humid air passes over a wet surface, the water evaporates and air loses its sensible heat and gains equal amount of load heat of water vapor thereby reducing its temperature.

Fig 7. Materials

The most common evaporative cooling system uses a wetted pad through which air is passed at uniform rate to make it saturated.

VI. RESULTS AND DISCUSSION

By using the model with reducing scale factor, the prototype is fabricated sucessfully with good working condition.

Fig. 8. Fabricated Cooling tower

VII. CONCLUSION

In this paper, the designing, working principles of induced draft counter flow cooling tower and working prototype is fabricated with reduced scale factor. This paper also includes perforamance analsis calaculation for various paramaters and the prototpe output matched for approximately 400TR Chiller plant.

REFERENCE

[1] R. Ramkumar, "Thermal Performance of Forced Draft counter Flow Cooling tower with Expanded Wire Mesh Packing", International Journal Technical and Physical Problems of Engineering (IJTPE), 3(6),2011, 19-23.

[2] Mahendran and Mukund, "Design and Fabrication of Mini Draft Cooling tower", International Conference on Explorations and Innovation in Engineering and Technology, 25(3), 2016, 92-95.

[3] Badran AA (2003). Performance of cool towers under various climates in Jordan. Energy Build., 35: 1031 – 5

[4] Pannkoke T (1996). Cooling tower basics. Heat, Piping, Air Cond., 68:137–55.

[5] Sirok B, Blagojevic B, Novak M, Hocevar M, Jere F (2003). Energy and mass transfer phenomena in natural draft cooling towers. Heat transf. Eng., 24: 66 – 75.

[6] Charles R. Nicolson, Understanding Cooling Water Treatment Saves, Author House, 2004 IJSER.

[7] Dileep KJ, Dileep Kumar Baniya, Anoop Chandra Kurup, Arun Varghese et.al, "Design and Fabrication of Cooling Tower", Department of Mechanical Engineering, Bangalore Technological Institute, India, pp. 27-37, 2017.

[8] Mahendran, Mukund, Muralidharan, "Design and Fabrication of Mini draft cooling tower", Asst. Prof., Mechanical Engineering, Student, K. Ramakrishnan college of Technology, samayapuram, Trichy, pp. 92-96, 2016.

[9] Asst. Prof. Upasna Sethi, Asst. Prof. Manisha Kumari, Asst. Prof. Dharini Shah et.al, "A review in design and performance analysis of cooling tower", Assistant Professor, Mechanical Engineering Department, Vadodara Institute of Engineering College, pp. 1553-1556, 2016.

[10] Michael Blocher, "Heat and mass transfer in a cooling tower with special attention to the tower characteristic ratio", Dept. of Energy Sciences, Faculty of Engineering, Lund University, Box 118, 22100 Lund, Sweden, 2008

[11] Sunil J. Kulkarni, Ajaygiri K. Goswami et.al, "Studies and Experimentation on Cooling Towers: A Review", Assistant Professor, Chemical Engineering

[12] Manoj Kumar Chopra, Rahul Kumar, An Investigation In Performance Improvement Of Counter Flow Induced Draft Cooling Tower, International Research Journal Of Engineering And Technology, Volume-4, Issue-8, August 2017, E-ISSN:2395-0056, P-ISSN:2395-0072.

AUTHOR(S) BIOGRAPHY

Luke Justin Johnson. G is P.G. Scholar in Thermal Engineering, University College of Engineering (BIT Campus), Tiruchirappalli and completed his B.E, Aeronautical Engineering in MAM School of Engineering, Tiruchirappalli. He is having three years of teaching experience in Mechanical Engineering field and one and half year experience as a Project Engineer in Construction Sector. He is the member of IAENG.

Sivakumar D.B is currently working in University College of Engineering (BIT Campus), Tiruchirappalli as an Assistant Professor, Department of Mechanical Engineering and Pursuing Phd. He is specialized in Thermal Engineering completed PG in same field and having 19 years of experience in teaching and one year Industrial experience. He published around 30 Journals.

Dr. T. Senthilkumar is currently working in University College of Engineering (BIT Campus), Tiruchirappalli as a Professor and Dean for Department of Mechanical Engineering. He completed his Phd in Welding area and having 23 years of experience in teaching and 8 years of research experience in Industries. He is having memberships in several Technical Associations. He published around 250 Journals and few books.