Analytical Investigation On Temperature Distribution Of High Wattage White Light Lamp.

Akshay Andhare, Samer Khan

Abstract: In the recent times, the usage of floodlight is increasing. But, for developing high power (more than 200W of power consumption) floodlight, the problem on radiant heat has not been resolved clearly as ever. So in this paper, the numerical study was conducted to analyze the temperature distributions of general 500 W floodlights. The temperature distribution on lamp was calculated at the instance where lamp gives white light under ideal conditions to see optimum conditions of the life.

Keywords: whitelight; halogencycle; lamp; floodlight; temperature distribution.

I. INTRODUCTION

The manufacturing sector of high wattage lamp has seen vast development in last few decades. Manufacturers of high wattage bulb and its components have chosen to expand their production. The commercial as well as household requirement of high wattage lamp has increased due to the fact that the bright light output from such a lamps are of high quality than that of low wattage lamps. Thus the need for fashionable yet eminence designs are required. Data of market potential for halogen lamp has been used from Danish market survey done by Elmodel-Bolig. It is necessary to analyze the market potential of high wattage floodlight lamp. According to survey, the halogen lamp holds nearly 30.1% of market share in Danish market. From 1990 the market has growing and peaked in 2000. Due to the advantages of high wattage lamps such as long life, a brighter light, control over the amount of light and efficiency. According to the survey report by Elmodel-Bolig, in 2003 the amount of halogen lamps imported were higher than preceding year and in 2005 the amount of halogen lamps imported was up again of around 8.8 million units. [1] Heat accumulation due to high operating temperature is major cause of lamp failure. It also shortened the life of the lamp. The phenomenon is mainly related to high wattage floodlights. As the operating temperature for such a lamp is higher than that of low wattage lamp, the problem of heat accumulation persists. Excess temperatures initiates the halogen cycle which produces white light. The bulb is filled with inert gas which is mixed with minute amount of halogen compound and traces of oxygen. The gases mixture results in known halogen cycle operating under high temperature. Due to the requirement of high temperature to produce the white light in halogen lamp, the heat gets accumulated and hence reduce the lamp life. The heat accumulation in high wattage lamp is relative to the applied voltage and current.

- *Akshay Andhare (Author) Research scholar Mewar University, Gangrar NH 79, Chittorgarh (India)*
- *Samer Khan (Co-Author) Assistant Director, Dept. of Applied Research, Mewar University, Gangrar NH 79, Chittorgarh (India)* *samerkhan@mewaruniversity.co.in*

The overrated and underrated voltage affects the lamp life. The halogen lamps tends to show high color rendering index (CRI) but the efficacy (lumens/watt) of halogen lamp is much lower and usually around 16 to 29. Which means the halogen lamp produces 16 to 29 amount of lumens per 100 watt of electrical input. And thus the remaining 71-84 watts of energy results in heat. [2]

TABLE I.

Sr. No.	Overrated Bulb Wattage		
	Volts (%)	Amps (%)	Life (%)
1.	102	101.0	82
2.	104	102	68
3.	110	105	39

II. LITERATURE REVIEW

A vast amount of research work has been performed in the field of heat generation by high wattage lamp. Experimental work performed by Dan MacIssac, Gary Kanner and Graydon Anderson [4] on incandescent lamp, to understand the basic physic behind the working of incandescent lamp and the behavior of tungsten filament under high temperature concludes the principle of Tungsten-Halide cycle. DCAgrawal [5] numerically calculated the temperature distribution on single ended and double ended coil for high wattage lamps. The research work done was very helpful in deciding the ideal geometry for the filament of high wattage lamp. Robert Siegel and Nibad A Hussain [6] analyzed the combine effect of conduction, convection and radiation on a flat surface. The investigation was crucial in modelling the boundary conditions for present study. Experimental study performed by Ji Hun Yun and Chung Seob Yi [7] marks the temperature distribution of high powered LED floodlight. The experimental study was conducted to analyze the temperature distribution of 170 W LED lamp.

III. PHYSICAL MODEL AND FORMULATION

Ideal condition has been chosen to model the given problem mathematically. Due to the complex nature of heat transfer, the time dependency haven't been used in formulation. The mathematical formulation has been done when the filament is radiating white light at a temperature of 3074 K, and the temperature of halides in the bulb is 2500 K. At this condition the temperature distribution on components of floodlight lamp has been calculated.

A. Abbreviations and Acronyms

- h_{air}: convective heat transfer coefficient of air.
- h_{argon}: convective heat transfer coefficient of argon.
- k_{glass}: conductive heat transfer coefficient of glass.
- $k_{aluminium}$: conductive heat transfer coefficient of aluminum.
- Q_{rad}: Radiation heat transfer.
- Q_{con}: Convection heat transfer
- Q_{cond}: Conduction heat transfer.
- ε : Emissivity of the surface,
- dx: thickness of the surface,
- A: surface area associated with heat transfer.

B. Methodology

For the steady state condition of heat transfer by radiation, conduction and convection the following governing equations has been used,

$$Q'_{rad} = \varepsilon * \sigma * A * T^4 \quad (1)$$

$$Q''_{con} = h * A * \Delta T \quad (2)$$

$$Q'''_{cond} = k * A * dT/dx \quad (3)$$

The temperature required to produce white light form tungsten lamp is 3074 K. This temperature is a result of high resistivity of the tungsten lamp when the 500.354 W of electric power is applied to it. [8] The heated filament heats up the gases present inside the bulb and thus the halogen cycle starts. The operating temperature for halogen cycle is around 2500 K. The heated gas transfers the heat to the inner surface of glass. For simplicity, the profile of the glass taken to be cylindrical having outer diameter of 18 mm and thickness of 1mm. The inner surface of the bulb heats up due to the phenomenon of convection. Parameters listed in table II has been used to calculate the temperature of inner surface of the bulb. The convection heat transfer rate and radiation heat transfer rate plays major role in heating up the inner surface of the bulb. Equation (1) has been used to calculate the heat transfer rate from filament having unit cm^2 area. The values such as convective heat transfer coefficient of air and argon, conduction heat transfer coefficient of glass and aluminum has been adopted from American textbook of physics handbook. [9] The heated inner surface of the bulb then conduct the heat to the outer surface. With the help of Eq. (3) the temperature of the outer surface of the bulb has been calculated. Parameters listed in table III has been used in the calculation. This heated surface of the glass then radiate heat. The heat radiated by the outer surface of the bulb has been calculated by Eq. (1). The air outside the bulb heats up by convection. The parameters used in calculation are listed in table IV. Again the phenomenon of convection plays major role in heating up the inner surface of the aluminum casing. The heated inner surface transmits the heat through conduction to the outer surface of the aluminum casing. For the simplicity of the calculation, the aluminum casing is represented by flat rectangular surface having thickness of 1cm. The parameters used in calculation of temperature distribution on aluminum casing are listed in table V and table VI.

TABLE II.

Sr. No.	Temperature of bulb (inner surface)		
	Parameters	**Values**	**Unit**
1.	Q_{in}	697.8	W
2.	h_{argon}	100	W/m^2-k
3.	Diameter	16E-3	m
4.	T(argon)	2500	K
5.	Length of bulb	200E-3	m

TABLE III.

Sr. No.	Temperature of bulb (outer surface)		
	Parameters	**Values**	**Unit**
1.	Q_{in}	697.8	W
2.	k_{glass}	1.46	W/m-k
3.	Diameter	18E-3	m
4.	T(inner surface)	1805	K
5.	Length of bulb	200E-3	m
6.	Thickness of the bulb	1E-3	m

TABLE IV

Sr. No.	Temperature of Air		
	Parameters	**Values**	**Unit**
1.	Q_{glass}	5754.	W
2.	h_{air}	1000	W/m^2-k
3.	Diameter	18E-3	m
4.	T(outer surface)	1762.71	K
5.	Length of bulb	200E-3	m

TABLE V

Sr. No.	Temperature of Casing (inner surface)		
	Parameters	**Values**	**Unit**
1.	Q_{in}	5754.80	W
2.	h_{air}	1000	W/m^2-k
3.	Length	200E-3	m
4.	Width	300E-3	m
5.	T(air)	1253.62	K

TABLE VI

Sr. No.	Temperature of Casing (outer surface)		
	Parameters	**Values**	**Unit**
1.	Q_{in}	5754.80	W
2.	$k_{aluminium}$	240	W/m-k
3.	Length	200E-3	M
4.	Width	300E-3	M
5.	T(inner surface)	1157.71	K
6.	thickness	15E-3	m

IV. Result and Conclusion

According to the numerical study performed in steady state condition with ideal parameters, it can be seen that the heat accumulation on high powered floodlight depends on following parameters; (a) geometry of the lamp, (b) material of the casing and (c) input electric power. Fig, I represents the variation of surface temperature Fig. I represents the variation of surface temperature on housing of the high wattage lamp subjected to the variation in temperature. According to the graph, the increment in surface area of the housing results in decrement of its surface temperature. The same behavior can be seen with decrement in surface area. Thus the surface area of the housing of high wattage floodlight lamp has vital role in its surface temperature. The variation of surface temperature with the variation in thermal conductivity of the housing material can be seen in Fig. II. The temperature distribution on the surface area of the hosing varies exponentially with the increment in the conductivity of the material. The increment in the conductivity results in the increment of the surface temperature of the housing. As the halogen cycle requires high temperature to produce white light, the high temperature increases the risk of high heat accumulation and thus decreases the life of the lamp. Table VII list the temperature distribution on the idealized floodlight model. From the present work it can be concluded that, in white light spectrum, the operating temperature on floodlight is high enough which can initiate the overheating and thus affect the lamp life. By using proper heat dissipation technique this can be minimized which can be done by variation in the surface areas as shown in the data of Fig. I.

TABLE VII

Sr. No.	Result		
	Temperature	**Values**	**Unit**
1.	Temperature Glass(inner)	1805	K
2.	Temperature Glass(outer)	1762.71	K
3.	Temperature Air	1253.62	K
4.	Temperature Aluminum (inner)	1157.71	K
5.	Temperature Aluminum (outer)	1151.71	K

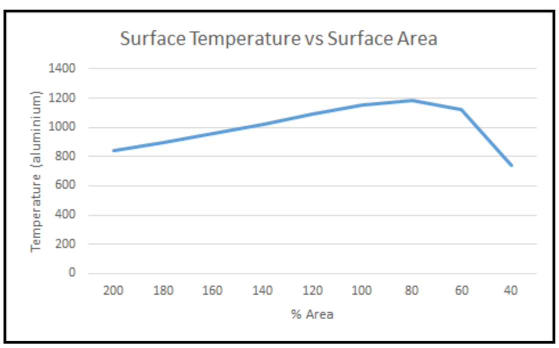

***Fig. I**- Variation in surface area*

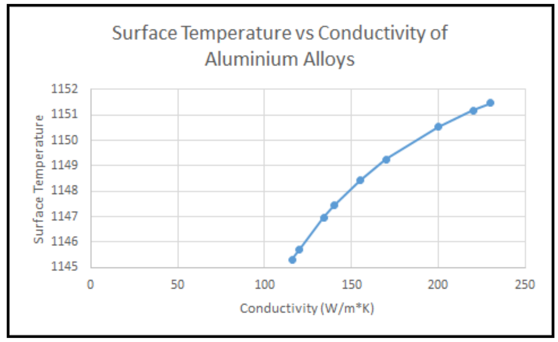

***Fig. II** Variation in thermal conductivity.*

References

[1] Catinet, The market for Halogen Lighting, 2006, pp 1-3

[2] Energy star fact sheet,[www.energystar.gov]

[3] GE Lighting Data Sheet, Aug-2013,pp. 3, [www.gelighting.com/eu]

[4] Gary Kanner et al. ,"Basic Physics of Incadescent Lamp",The physics Teacher, vol 37, Dec 1999, pp.520-525

[5] D.C.Agrawal,"The Coiling Factor in Tungsten Filament Lamp",Lat.Am.J.Phys.Educ., Vol. 5, june 2011.

[6] Robert Seigel and Nihad A Hussain."Combined Radiation, Convection and Conduction for a System with Partially Transmitting Wall",Lewis Research Centre, June 1975,pp. 4-5.

[7] Ji Hun Yun et al. "Experimenatal Study on Temperature Distribution on High Powered LED Floodlight.",ISBN-978-1-61804-097-8.

[8] W.E.Forsythe and A.G.Worthing, "Properties of Tungston and Characteristics of Tungston Lamps",American Astronomical Society.

[9] Albert A. Bennett et al."American Institute of Physics Handbook", 2nd edition, MacGraw Hill Book Company, 1975, pp.4:1-4: