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Numerical Investigation in Effective Heat Transfer on Cylindrical Fins

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Abstract—the purpose of this paper is to investigate the overall effectiveness of heat transfer on aluminium casing of high wattage floodlight lamp using cylindrical fins in a steady state condition. A generalized study has been performed on rectangular aluminium plate subjected to white light spectrum of high wattage (more than 200 watt) floodlight lamp.
Index Terms—cylindrical, fins, heat transfer, floodlight, whitelight, Ansys mechanical APDL, finite difference method.

I. INTRODUCTION

In last decade the market growth of halogen lamp has increased exponentially. Due to the vast application of whitelight lamp in outdoor purpose, the development in design is crucial. According to the market survey done by ICIC direct research on Bajaj Electricals Ltd. (BEL), the sales in lighting appliances was estimated to be 23%. The lighting segment of Baja electrical has seen the sale of 500 crore in the year of 2013, followed by 600 crore in 2014 and estimated to be 700 crore in 2015. This significant improvement in market potential of lighting industry demands the efficient and durable design of the product. [1]

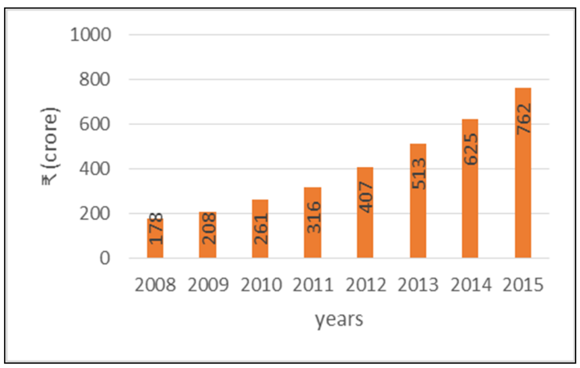

Fig.1. Growth of lighting segment of Bajaj Electricals Ltd.

The high wattage working requirement of floodlight lamp usually results in overheating condition of the fixture and hence it tends to decrease the lamp life. Phenomenon of overheating results in increment of temperature distribution on casing of the lamp. The requirement of high watt in halogen lamp is to initiate and maintain the halogen cycle which results in required luminance. Excessive temperature on the casing can be minimized using proper heat dissipation technique.
In this research paper, an analytical and numerical study has been performed on the rectangular sheet of aluminum exposed to the white light spectrum of the halogen lamp. A cylindrical fin based array has been implemented to observe the overall effectiveness of heat transfer. Undertaking the complex nature of the heat transfer phenomenon, the study has been generalized for pin fin and ideal conditions has been considered in the calculation of temperature distribution along the pin fin and also the steady state condition has been assumed throughout the calculation.

II. LITERATURE REVIEW

In a recent times, majority of research has been done in the field of heat transfer. Numerical study performed by A.Dewan [2] on fin spacing and fin material concludes that the heat transfer increases with decreasing fin spacing. The numerical study has been performed on circular fins attached to the flat surface. The fins were arranged in staggered manner and heat transfer was assumed to be conjugated in nature. A steady state heat transfer analysis has been done by Rasselo J. Moitsheki [3], in this research paper performance of rectangular fins has been calculated using the temperature dependent variables such as thermal conductivity, heat transfer coefficient and internal thermal energy generation. Similarly, an analytical study performed by Akshay Andhare [4] on high wattage floodlight lamp, calculated the temperature distribution on the casing of the floodlight lamp and observed the variation in surface temperature subjected to variation in thermal conductivity and surface area of the casing.

A. Physical Model And Formulation

Presented study on heat transfer is categorized in two parts. The first part comprises the analytical solution to the ideal heat transfer on pin fin, while second part of the study investigate the numerical analysis of the problem using the Ansys multiphysics tool.

Considering the complex phenomenon of heat transfer the presented study concentrates on steady state nature of the heat transfer in ideal condition. The simple geometric cylindrical shape has used as a pin fin. To find out the effective heat transfer on a flat surface subjected to high temperature the variables has been considered in the calculation are length and diameter of the fin, number of the fin. The prescribed values of the temperature distribution on halogen lamp are used from research performed by Akshay Andhare and Samer Khan on temperature distribution on high wattage white light lamp. The values of temperature are listed in table I.

TABLE I

Sr. No.	**Temperature Distribution**		
	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

In the present study, the heat transfer has been calculated by first finding the temperature distribution on the pin fin and then the overall efficiency of a pin fin is calculated. The numerical analysis approach has been considered in the calculation.

B. Abbreviations

1) d: diameter of the pin fin(m)
2) l: length of the pin fin. (m)
3) h: coefficient of convective heat transfer. (W/m^2-K)
4) k: coefficient of conductive heat transfer.(W/m-K)
5) Q: heat transfer (Watt)
6) A: Surface area associated with heat transfer. (m^2)

C. Methodology

The temperature distribution on pin fin is calculated using the fact that the base of the fin is attached to the aluminium plate which is at temperature of 1151.71 K. The surface of the pin fin exhibits the convective heat transfer having coefficient of convective heat transfer of 100 W/m^2-K. Table II shows the information used in calculation of temperature distribution on pin fin.

TABLE II

Sr. No.	Pin fin Parameters		
	Parameter	***Values***	***Unit***
1.	Thermal conductivity	230	W/m-K
2.	Coefficient of convective heat transfer	100	W/m^2-K
3.	temperature at base	1157.71	K
4.	Temperature of surrounding	300	K

The form of finite difference formulation of the boundary condition has been used in the calculation. Equation 1 shows the boundary condition used in the calculation of the temperature distribution on fin. The heat generation inside the fin is assumed to be zero. The axisymmetric geometry of the fin is used to model the 15 nodes on the 2 dimensional cut section of the fin. Figure 1 depicts the elemental distribution on cut section of the fin. The mesh information is enlisted in table III.

$$hA\left(T_{boundary} - T_0\right) + kA\frac{(T_1 - T_0)}{\Delta x} = 0 \tag{1}$$

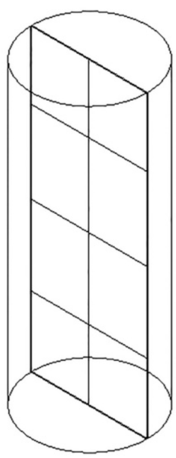

Fig.1 Mathematical Modelling of the fin.

TABLE III

Sr. No.	Meshing Information	
	Parameter	***Values***
1.	Nodes	15
2.	Elements	8
3.	Type	mapped

The length of the fin has been divided into 4 equal sections y, similarly the diameter has been divided into 2 equal sections x. Nodes 1,2,3 are the base nodes at temperature of 1151.75 K and the nodes 5,8,11, are the interior nodes. The boundary nodes 4, 6, 7, 9, 10, 12, 13, 15 experiences the convective heat transfer. Comprising all this information the finite difference method has been used to mathematically model the problem. Equation 2 shows the governing equation of this formulation.

$$Q_{top} + Q_{bottom} + Q_{left} + Q_{right} + G_{element} = \frac{\Delta E_{element}}{\Delta t} = 0 \tag{2}$$

The geometrical parameters of cylindrical fin such as diameter and length are the variables in the study. There are 3 values of diameter and 5 values of length of the fin has been considered. To get the required overall fin effectiveness, the temperature on each node of the fin has been calculated for each case. Table IV represents the number of cases taken for consideration in the calculation.

TABLE IV

Case No.	Cases	
	Diameter (m)	***Length(m)***
1.	0.0015	0.0050
2.	0.0025	0.0050
3.	0.0035	0.0050
4.	0.0015	0.010
5.	0.0025	0.010
6.	0.0035	0.010
7.	0.0015	0.015
8.	0.0025	0.015
9.	0.0035	0.015
10.	0.0015	0.020
11.	0.0025	0.020
12.	0.0035	0.020
13.	0.0015	0.025
14.	0.0025	0.025
15.	0.0035	0.025

After calculating the temperature on each node on a fin in each case, the array of fins has been developed keeping the constant spacing of 0.05 m between the fins. Three values of overall fin effectiveness has been chosen to calculate the number of fins required for suitable amount of heat transfer, which are 5, 10, and 15. The calculation of overall fin effectiveness is based on the fact that the fins are placed on a rectangular sheet of aluminium having width of 0.3 m and length of 0.2 m. Equation 3 has been used in calculating the number of fins.

$$\frac{N.Q_{total}}{Q_{no-fin}} = overall\ fin\ efficiency \tag{3}$$

In the above equation the term $Q_{no-fin}$is the heat transfer from the rectangular sheet of aluminium under ideal condition when no fins are attached to it. While, the term $Q_{total}$is the total heat transfer from the surface when fins attached to it. The Q_{total} embraces the heat transfer from finned as well as un-finned surface. Figure 2 shows the difference between finned and un-finned surface.

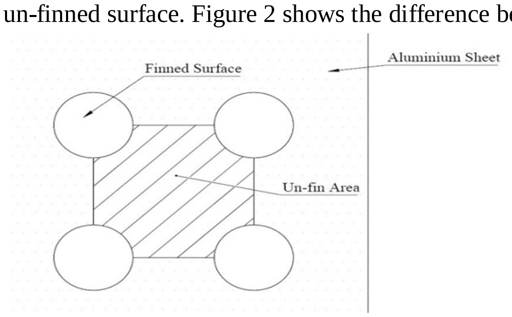

Fig.2 Finned and un-finned surface

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Using the finite difference formulation, the temperature distribution on each node has been find out. The analytical calculation is then validated by performing a numerical analysis in Ansys mechanical APDL. The mathematical model of pin fin has been modelled in Ansys keeping in mind that the cylindrical shape has rotational symmetry. Fig. 3 depicts the mathematical model of the pin fin and elemental distribution on it.

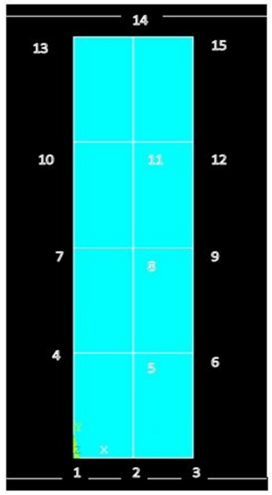

Fig.3 Mathematical model in Ansys.

The boundary condition applied in numerical analysis are the same that were applied in analytical model. And similar steady state analysis has been performed in Ansys. The ideal heat transfer condition has been observed in the numerical analysis.

III. RESULT AND CONCLUSION

The analytical calculation performed on a pin fin lead to the temperature distribution on each node of it. It has been observed that with the variation in geometrical parameter such as diameter and length of pin fin there is change in temperature distribution on each node. While keeping the other parameters constant. Table V-IX shows the temperature distribution on each node of pin fin subjected to change in diameter and length with respect to the base temperature i.e. 1151.75 K.

TABLE V

Temperature Distribution on Nodes			
Nodes	**Cases -1**	**Case-2**	**Case-3**
1.	0	0	0
2.	0	0	0
3.	0	0	0
4.	2.206372	2.166302	1.997446
5.	2.0245	1.975288	1.824132
6.	2.206372	2.166302	1.997446
7.	3.885473	3.791986	3.512579
8.	3.685257	3.568548	3.301637
9	3.885473	3.791986	3.512579
10.	5.142255	4.943669	4.584973
11.	4.945583	4.714933	4.357256
12.	5.142255	4.943669	4.584973
13.	5.959313	5.633196	5.232578
14.	5.812563	5.403846	4.957439
15.	5.959313	5.633196	5.232578

TABLE VI

Temperature Distribution on Nodes			
Nodes	**Cases -4**	**Case-5**	**Case-6**
1.	0	0	0
2.	0	0	0
3.	0	0	0
4.	4.210613	4.328171	4.415562
5.	3.967006	3.991136	4.037973
6.	4.210613	4.328171	4.415562
7.	7.698557	7.671433	7.743163
8.	7.446798	7.308204	7.320766
9	7.698557	7.671433	7.743163
10.	10.67028	10.25388	10.17603
11.	10.42307	9.898816	9.758763
12.	10.67028	10.25388	10.17603
13.	13.04629	12.02138	11.70074
14.	12.90492	11.77931	11.36224
15.	13.04629	12.02138	11.70074

TABLE VII

Temperature Distribution on Nodes			
Nodes	**Cases -7**	**Case-8**	**Case-9**
1.	0	0	0
2.	0	0	0
3.	0	0	0
4.	6.612194	6.27755	6.417633
5.	6.352379	5.883319	5.930511
6.	6.612194	6.27755	6.417633
7.	12.44792	11.38766	11.40725
8.	12.18513	10.97818	10.88678
9	12.44792	11.38766	11.40725
10.	17.75129	15.65483	15.30997
11.	17.49229	15.25407	14.80211
12.	17.75129	15.65483	15.30997
13.	22.41898	18.96373	18.03729
14.	22.28146	18.72846	17.70171
15.	22.41898	18.96373	18.03729

TABLE VIII

Temperature Distribution on Nodes			
Nodes	**Cases -10**	**Case-11**	**Case-12**
1.	0	0	0
2.	0	0	0
3.	0	0	0
4.	9.60718	8.415614	8.334111
5.	9.34177	7.996711	7.791343
6.	9.60718	8.415614	8.334111
7.	18.41819	15.58247	15.06185
8.	18.15272	15.15562	14.49715
9	18.41819	15.58247	15.06185
10.	26.69424	21.8796	20.62493
11.	26.43272	21.46082	20.07354
12.	26.69424	21.8796	20.62493
13.	34.32424	27.15822	24.87509
14.	34.18966	26.92846	24.54716
15.	34.32424	27.15822	24.87509

TABLE IX

Temperature Distribution on Nodes			
Nodes	Cases -13	Case-14	Case-15
1.	0	0	0
2.	0	0	0
3.	0	0	0
4.	13.18423	10.85642	10.35862
5.	12.91682	10.42561	9.785839
6.	13.18423	10.85642	10.35862
7.	25.56414	20.42343	19.01218
8.	25.29881	19.9896	18.42612
9	25.56414	20.42343	19.01218
10.	37.41082	29.11173	26.46735
11.	37.15016	28.68594	25.89428
12.	37.41082	29.11173	26.46735
13.	48.61196	36.75594	32.53752
14.	48.48021	36.53068	32.21631
15.	48.61196	36.75594	32.53752

The analytical method has been used to calculate the temperature distribution on pin fin. Similarly, a numerical study has been performed in Ansys and the results from both the study are observed. Fig. 4 illustrates the accuracy of analytical calculation validated by computer generated numerical solution for the case-2 having 0.0025 m of diameter and 0.0050 m of length of pin fin. The thermal simulation performed in Ansys shows 99.79 % of resemblance with our analytical calculation. The contour plot of nodal solution has been illustrated in fig.5. The high resemblance of Ansys generated solution and our analytical study means the results has been validated and can be used for future calculation.

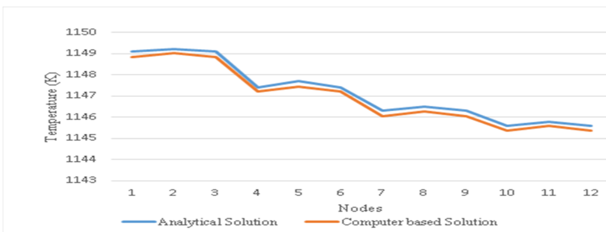

Fig. 4 comparison of analytical solution with computer based simulation

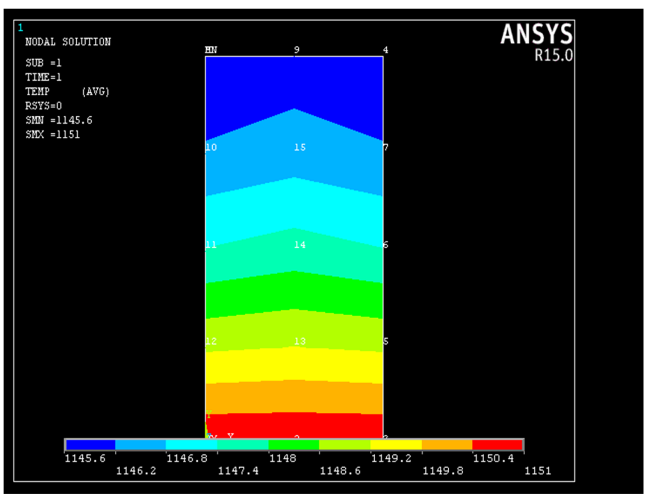

Fig.5 Contour plot of nodal solution- temperature.

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As our analytical study was accurate, we then proceed to find out the number of fins required for overall efficiency of 5, 10, and 15 by using equation 3. Table X-XII lists the number of fins required in each case to reach the overall fin efficiency of 5, 10 and 15.As we can see the more slender the fine, the less number of fins will be required for effective heat transfer.

TABLE X

Overall fin effectiveness = 5	
Cases	**Number of fins**
case-1	232.00
case-2	230.00
case-3	228.00
case-4	228.00
case-5	223.00
case-6	219.00
case-7	224.00
case-8	217.00
case-9	210.00
case-10	220.00
case-11	211.00
case-12	202.00
case-13	216.00
case-14	205.00
case-15	195.00

TABLE XI

Overall fin effectiveness = 10	
Cases	**Number of fins**
case-1	928.00
case-2	468.00
case-3	464.00
case-4	464.00
case-5	454.00
case-6	445.00
case-7	455.00
case-8	441.00
case-9	427.00
case-10	447.00
case-11	428.00
case-12	411.00
case-13	440.00
case-14	417.00
case-15	397.00

TABLE XII

Overall fin effectiveness = 15	
Cases	**Number of fins**
case-1	1392.00
case-2	701.00
case-3	695.00
case-4	695.00
case-5	680.00
case-6	667.00
case-7	683.00
case-8	661.00
case-9	641.00
case-10	671.00
case-11	642.00

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case-12	617.00
case-13	659.00
case-14	625.00
case-15	595.00

From the analytical study and numerical study performed on pin fin, it can conclude that with the increment in diameter there is decrement in heat transfer for a fin having fixed length. And that is why the slender types of fins are more preferable for efficient heat transfer. Fig. 6-8 illustrates the relation between number of fins and slenderness ratio of the pin fin for overall pin fin effectiveness of 10.

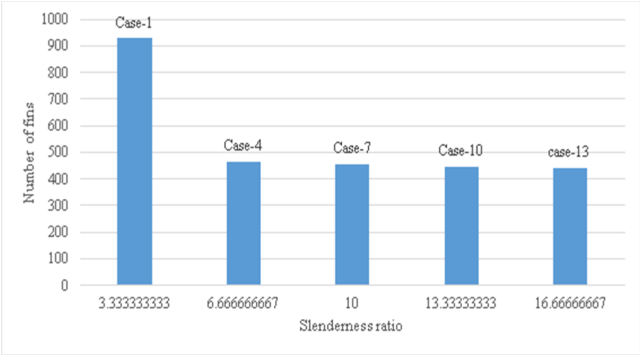

Fig. 6 Slenderness ratio vs number of fins for pin fin diameter of 0.0015 m.

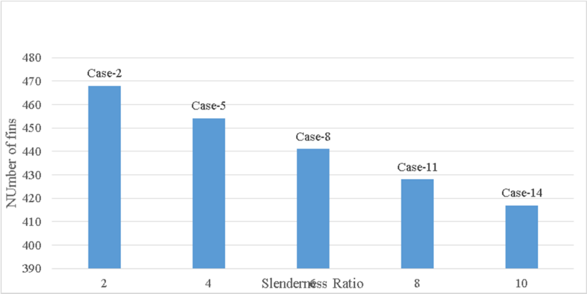

Fig. 7. Slenderness ratio vs number of fins for pin fin diameter of 0.0025 m.

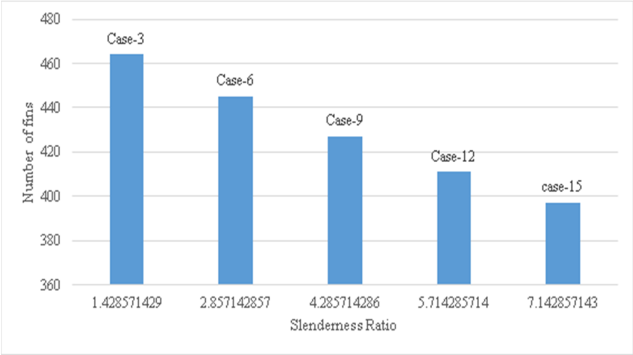

Fig. 8 Slenderness ratio vs number of fins for pin fin diameter of 0.0035 m.

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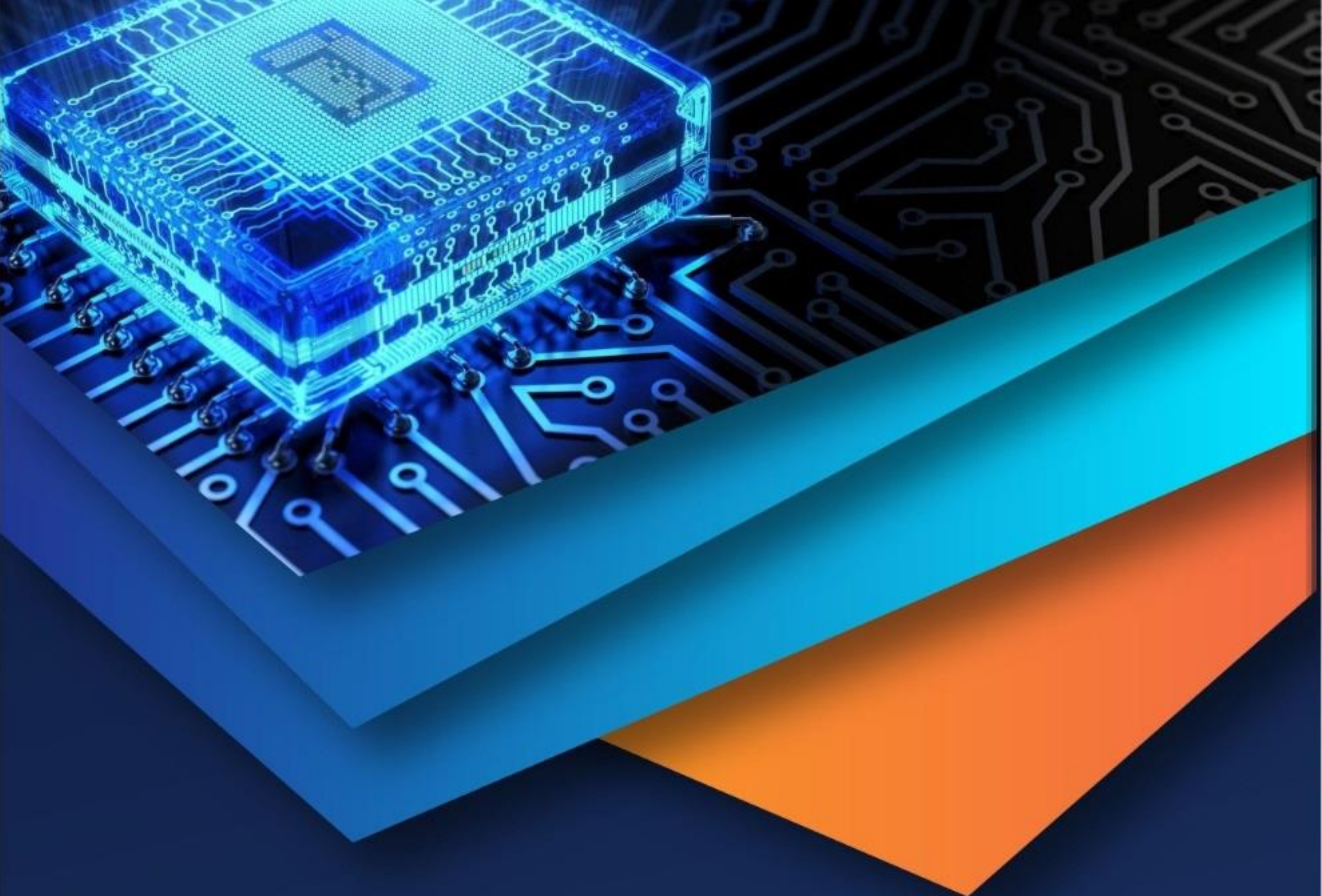
REFERENCES

[1] ICICI Direct Research, "BAJAJ ELECTRONICS (BAJELE)," icicidirect.com, September 2013.

[2] A.Dewan, P.Patro, I. Khan, and P. Mahanta The effect of fin spacing and material on the performance of heat sink with circular fins, July 2009,

[3] Rasselo Moitsheki and Charis Harley, "Steady thermal analysis of two dimensional cylindrical pin fin with non-constant base temperature,", vol. 2013, Hindwai Publication Corporation, June 2011.

[4] Akshay Andhare and Samer Khan, "Analytical Investigation on temperature Distribution of high wattage white light lamp", IJSTR Volume 4 - Issue 3, March 2015- ISSN 2277-8616



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