International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 10 **Issue:** II **Month of publication:** February 2022

DOI: https://doi.org/10.22214/ijraset.2022.40230

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 10 Issue II Feb 2022- Available at www.ijraset.com

Review: Enhancement of Heat Transfer through Modification in Fins

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Abstract: Overheating and excessive increase in the temperature of the compressors body causes thermal loading on the compressors surfaces. The life of the compressor mainly depends upon the abrupt change in the thermal stresses and the pressure stress induced in the body. The life of the compressor can be successfully improved and optimized by working on the compressor body. Specifically speaking the compressors fin areas is the heat affected area. Change in small cross section area can significantly change the convective heat transfer. This paper focuses on providing economical methods which are optimized and easily implementable solutions in the existing manufacturing setup. The above techniques are implemented on compressor head body. All possible attempts are made to change the cross section and the shape of the heat transfer areas so that maximized heat transfer reached in the operating process. The implementation of the optimize techniques is carried out by analyzing different cross sections such as straight, trapezoidal and parabolic. The scope of revising the strategies ultimately helps to increase productivity, efficiency, pointing to increase the profit. The only aim to propose the solution is to optimize the heat transfer rate by the change in the design
Keywords: Heat Transfer, Fins, Compressor, Cross section, efficiency

I. INTRODUCTION

Compressor becomes almost an integral part of the mechanical industry and many other commercial applications. The compressed air is used in many other applications such as the Mechatronics system where high amount of high pressurized air is required. The electrical energy is not only used for increasing the pressure of the fluid or the gas, but there is simultaneous increase of the temperature of the fluid as well. In most case the heat is removed by some passive means since the temperature is not high as the IC engines. Still the increase of the temperature is quite enough for creating the temperature patterns which increases the thermal loading and the thermal stresses. This generated temperature stresses as well as the flow induced stresses are quite enough for the defining the overall effective operating life of the compressor. This removal of the heat transfer becomes an essential issue while designing the compressor body. The distribution of the heat is totally taken care by the fin design that is present on the outer surface of the compressor body. The only aim that is related while designing is to increase the maximum surface area so that the heat is dissipated through the fins. The convective heat transfer is enhanced by addition of the fins. Similarly, if the change in the flow from laminar to turbulent is focused in that scenario there is effective mixing of the hot and cold air removes heat quickly

II. LITERATURE REVIEW

Towards setting up an ideal design, **Shivdas Kharche et al. [1]** has reported the possible attempts can be made in cross section areas of the fin. There are two case analyzed for plotting the optimized heat transfer in case of fins. In case I normal testing is done on a rectangular cross section which is also called as the single flow chimney pattern figure 1 shows the details for the same, similarly in case II a notch is made in a rectangular section. The rectangular notch is present at the centre of one of the edges, which will in turn create a "c" section for the analysis figure 2 shows the notched fin.

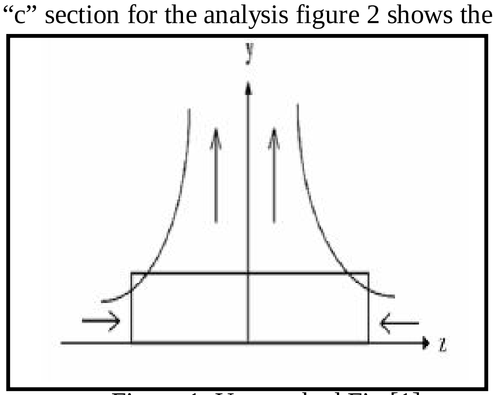

Figure 1: Un-notched Fin [1]

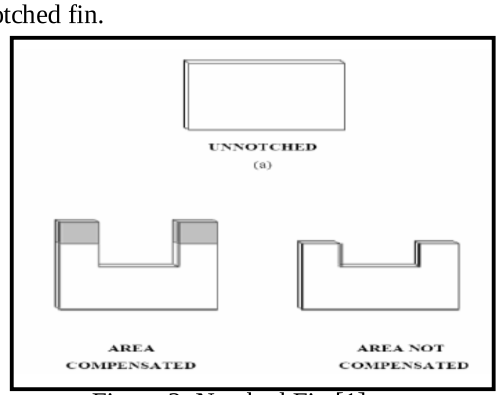

Figure 2: Notched Fin [1]

The author finally reveals about the results about the test carried for the above design parameters which are as follows, the heat transfer is increased by increasing the height(H) of the fin and decreasing the length(L) of the fin. H/L ratio is responsible for the increasing the heat transfer rate. Figure 3 shows the comparative results for heat transfer coefficients for both processes.

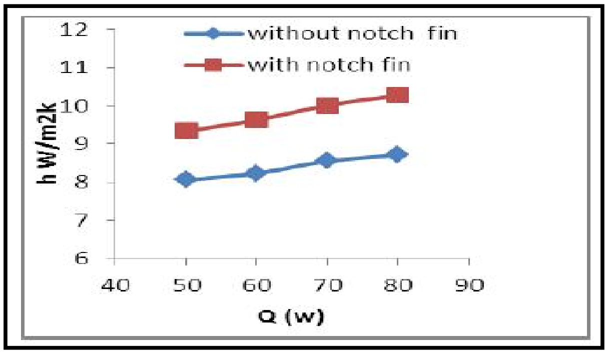

Figure 3: Comparison of heat transfer coefficients for without notch and notch fin [1]

Further P. Raghupati and Dr. Sivakumar [2] explains about thickness to length ratio to be taken for an ideal design for optimization of the heat transfer rate through the compressor body. In the test carried by the author the number of fins in the test are taken are constant. These are 10 in numbers. The alteration for maximum heat transfer is obtained by the change in the thickness to length ratio. Depending on the economical aspect of the material thickness lies between 2-3 mm. Necessary length for maximum heat transfer is found out by physical testing for different lengths.

The author carried out 2 tests for 3mm thickness keeping the length of the fins as 45mm and 49 mm respectively. Another test of 3.5mm thickness was carried out on 47mm length. The results shows that temperature difference obtained for 3 mm thickness is 345K and 343K for 45 and 49mm respectively, similarly 345K is obtained for 3.5mm thickness. The results are tabulated in table no 1 [2]

Table 1: Comparison of maximum heat transfer for different thickness [2]

Trial No.	No. of fins (N)	Thickness of fins (T, in mm)	Length of fins (L, in mm)	Max. temperature obtained (in K)
Existi ng	10	3	45	345
1	10	3.5	47	345
2	10	3	49	343
3	10	2.5	51	342

Mohammad Mashud et al. [3] have discussed much more on the keeping cylindrical fin as the base fin. Some minor changes are brought in act on the cylindrical profile which will be responsible increase in the heat transfer through the compressor body. The analysis for heat transfer is carried out on a plain cylindrical fin, circular cylindrical fin and threaded cylindrical fin. The diameter of the cylindrical fin is 20mm with a length of 150mm. Convective heat loss reduces sharply as pressure is decreased. It is because as the pressure inside the pressure reduction chamber is reduced, a low-density situation arises. In low-density circumstances the mean free path of the gas molecules is large enough, and as density reduces this distance increases. The larger this distance becomes, the greater the distance required to communicate the temperature of a hot surface to a as in contact with it. This means, it cannot be assumed that the layer or air in the immediate neighbourhood of the surface of the fin will not have the same temperature as the heated surface. This causes a considerable reduction in convective heat transfer coefficient, h [3]

From this experimental study it has been found that the grooved radiating fin loses approximately 1.23 times greater heat per unit area, compared to the threaded pin fin, and 2.17 times greater heat per unit area, compared solid to the solid pin fin at a pressure lower than atmospheric pressure. As pressure decreases heat loss reduces and contribution of radiation heat transfer on total heat loss increases. [3]

Fengming Wang, Jingzhou Zhang et al. [4] made an experiment setup for acquiring the maximum heat transfer characteristics in a rectangular fin. The test was carried on family of similar cross section such as a circular fin, elliptical fin and dropped shape fin. The diameter of the circular fin is 6mm, the major and minor axis of the ellipse are 4.24mm and 2.12mm respectively(drop-A). Lastly the dropped fin has 4.6, 4.2 and 3.8 as the minor axis(drop-B); similarly, is having 8.5, 9.2 and 10.1 as the major diameter(drop-C).

Conclusion can be made as follows, the more streamlined drop-shaped pin fins are better at delaying or suppressing separation when a flow passes through them, which reduces the aerodynamic penalty compared to circular pin fins. Similarly heat transfer characteristics shows that heat transfer enhancement of drop-shaped pin fins is weaker than that of circular pin fins. The reduction in average Nusselt number between the drop-shaped and circular pins was about 24% for drop-A, 26% for drop-B, and 27% for drop.

Mehendi Ehteshum et al. [5] has explained the effects of perforation on the rectangular fin body. The aim in making perforation is to increase the area, so that maximum heat transfer can be possible. Table no 2 explains about the detail and different possible construction features made on a rectangular fin.

Table 2: Fin array data [5]

Type	No. of fins, n	No of perforations, N	Dia. of perforation, d_p (mm)	Length, l (mm)	Width, w (mm)	Height, h_f (mm)	Channel width, w_{ch} (mm)	Fin width, t (mm)	Fin height, h_t (mm)	Total surface area, A_s (mm^2)	Base area, A_b (mm^2)	Mass (gm)
(a)	4	0	0	34	32	15	3	5.75	9	4742.0	1088	36.6
(b)	4	1	2	34	32	15	3	5.75	9	5571.4	1088	35.5
(c)	4	2	2	34	32	15	3	5.75	9	6400.8	1088	34.3
(d)	4	1	3	34	32	15	3	5.75	9	5967.2	1088	34.0
(e)	4	2	3	34	32	15	3	5.75	9	7192.4	1088	31.4

Further the results show that heat transfer coefficient rate is significantly increased with fin having higher diameter over fin having smaller diameter i.e. fin having diameter 3mm has higher heat transfer coefficient than fin having 2mm diameter. Nusselt number which is a dimension less number also shows results on the similar basis as that of the heat transfer coefficient. Finally, to conclude increase in Reynolds number increases both the heat transfer coefficient and Nusselt number as well decreases the thermal resistance. Solid fin has maximum thermal resistance than perforated fin. The value of the thermal resistance decrease as the diameter of the perforation goes on increasing.

S M Wange et al. [6] has focused on the notch creation which makes an attempt to increase heat transfer. The fin array consists of number of fins fixed to the base plate by using aluminum welding operation.

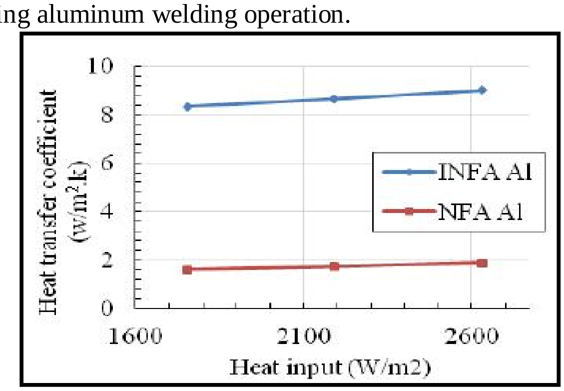

Figure 4: Heat Transfer Coefficient for Fin Arrays [6]

Figure 4 shows that effect of heat input on heat transfer coefficient for inverted notch fin array and normal fin array. The value of Lc for without notch fins is 0.0585 m and for notch fins the value of Lc 0.03234 m. The heat transfer coefficient is value of h is depends upon the ratio Nu/Lc. The heat transfer coefficient is directly proportional to Nusselt number. The value of Nu is affected as Lc is increase or decrease. In notch fins the value of Lc is less than without notch fins. Hence the value of h is more in notch fins than without notch fins. It is observed that more temperature difference in notch fins hence ultimately increase the value of heat transfer coefficient.

He FaJiang et al. [7] has explained about the physical setup and analysis done on the on various fin structures. The author and the team has perform the complete analysis on design of experiments (DOE). Figure 5 explains model for which the design of experiments are performed. He has done 13 parameters with 2 layers. Table 3 show the same.

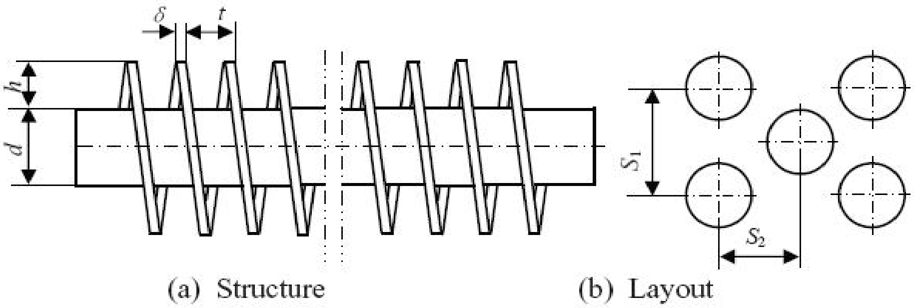

Figure 5: Structure and layout of Fined Tube [7]

Table 3: Structure Parameters of Spiral Finned Tube [7]

No.	Tube Dia. d(mm)	Fin Pitch t(mm)	Fin Thk. δ (mm)	Fin Height h(mm)	Trans. Tube Pitch S_1(mm)	Long. Tube Pitch S_2(mm)
1	32	7	1.5	13	80	80
2	32	10	1.5	13	80	80
3	32	13	1.5	13	80	80
4	32	16	1.5	13	80	80
5	32	13	1.5	7	80	80
6	32	13	1.5	10	80	80
7	32	13	1.5	16	80	80
8	32	13	1.5	10	64	80
9	32	13	1.5	10	92	80
10	32	13	1.5	10	106	80
11	32	13	1.5	13	80	64
12	32	13	1.5	13	80	92
13	32	13	1.5	13	80	106

Further the author still to find the relationship of heat transfer and the flowing resistance with the fin height. The parameters that are use are as follows Heat transfer Nu number and flowing resistance Eu number relations with Re number (Re=5×103~5.5×104) and fin pitch t under constant tube diameter (d=32mm), fin thickness (δ =1.5mm),fin height (h=13mm), transverse tube pitch S1=80mm(S1/d=2.5), longitudinal tube pitch S2=80mm(S2/d=2.5). Figure 6 shows the Nu number relations with Re and fin height h Similarly figure 7 shows the relationship between Eu number relations with Re and fin height h

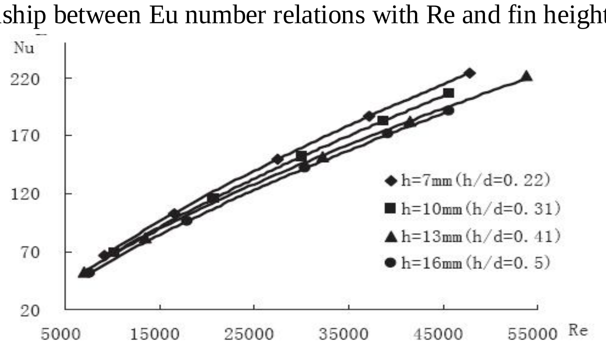

Figure 6: Nu number relations with *Re* and fin height *h* [7]

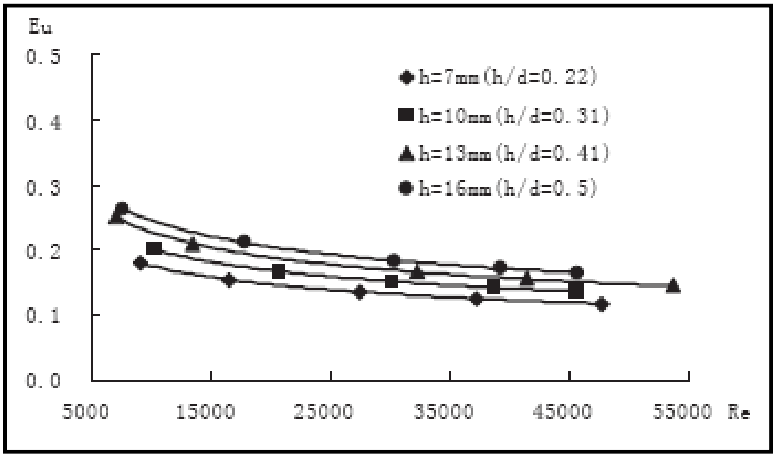

Figure 7: Relationship between *Eu* number relations with *Re* and fin height *h* [7]

The author speaks about the effect of transfer pitch on the heat transfer and the flowing resistance. Figure 8 shows the graphical plot for the Nu number relations with Re and transverse tube pitch S1, similarly figure 9 shows the plot Eu number relations with Re and transverse tube pitch S1.

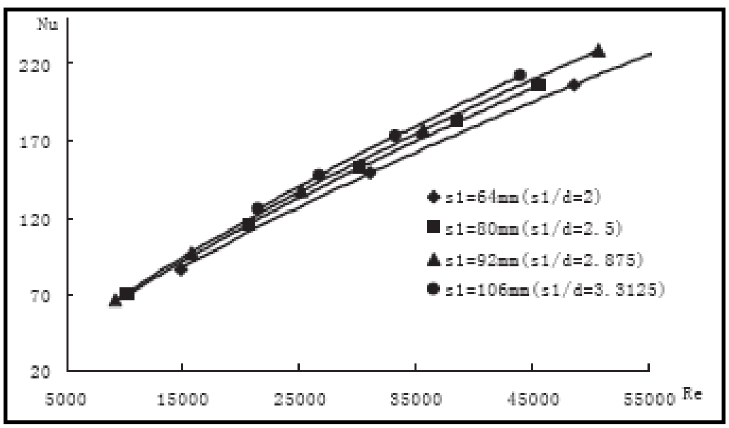

Figure 8: *Nu* number relations with *Re* and transverse tube pitch S_1 [7]

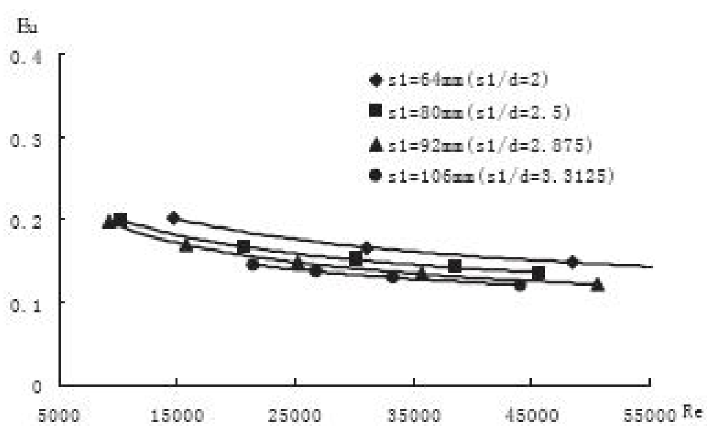

Figure 9: *Eu* number relations with *Re* and transverse tube pitch S_1 [7]

Esmail M.A. Mokheimer [8] has investigated the performance of annular fins of different profiles which are subjected to locally variable heat transfer coefficients. The working performance is measured in terms of the efficiency of the fin, which is further a function of the ambient temperature and the geometry of the fin. The overall performance is obtained is measured from the curves which are plotted called as the "fin efficiency curves" the author further reveals about the calculations and the performance is based upon the constant heat transfer coefficient.

If the natural heat transfer coefficients dominates the constant heat transfer coefficient at that times local heat transfer coefficient are been used for such cases. The aim in using the local heat transfer coefficient is that it is the function of the local temperature. The results that have obtained are for various annular profiles having cross section such as rectangular, triangular, concave parabolic and convex parabolic

Finally to conclude the author says the deviation between the fin efficiency calculated based on constant heat transfer coefficient and that calculated based on variable heat transfer coefficient increases with both the dimensionless parameter m and the radius ratio of the fin. The use of the present results obtained for heat transfer equipment that involve annular fins subject to natural convection heat transfer mode would result in a considerable reduction in the extended surface area and hence a significant reduction in the weight and size of the heat transfer equipment.

S. H. Barhatte, M. R. Chopade [9] has experimentally proved that increasing the area of heat transfer will definitely help in increase the heat transfer rate. The author reveal about the ideal of developing a triangular not at the base of the fin base. The idea behind doing is to increase the overall heat dissipating area. The author says about the shape of the triangle that should be constructed is also important. The ratio of height of the triangle to the base of the triangle called as the aspect ratio is also of importance.

Further the he has performed some test by changing the aspect ratios. Table 4 gives the details for the same, it also explains about the value of heat transfer "h" for both the experimental and the computational method. The triangular notch having the aspect ratio of 1.266 has the maximum value of the heat transfer, for aspect ratio 1.266 the corresponding value of h is 6.545 experimental and 6.423 computationally. These both value of heat transfer is having the maximum value among the group.

Table 4: Experimental and Computational Values of *h* [9]

SET	Aspect Ratio	Experimental Value of h	Computational Value of h
SET 0	Unnotched	6.495	5.691
SET 1	0.866	6.505	6.078
SET 2	1.000	6.517	6.097
SET 3	1.333	6.532	6.152
SET 4	1.266	6.545	6.423
SET 5	1.400	6.494	6.137

Sikindar Baba.Md et al. [10] has explained some techniques that help in the increasing the heat transfer rate by increasing the surface area. The amount of the surface area determines the amount of conduction, convection and radiation that is transmitted through the body. Increasing the temperature difference the object (fin) and the environment increase the convection heat transfer coefficient.

The author has performed some experimental test and found out some results based on test performed. Table 5 explains about the temperature difference between the base of the fin and the tip of the fin. Further he has computed the temperature which lies between the outer surface and inner surface and which is measured along the length of the inter cooler. The temperature difference between those two surfaces is very litter since the thickness is 3mm and the thermal conductivity is very high. The analysis shows that in the case of triangular shape fins the heat transfer id more and optimized one since the area of heat transfer is increased and material cost is also reduced. If actual results are plotted heat transfer rate is increased by 3.39%.

Table 5: Comparison of Base, Centre line and Tip temperatures ofthe fins [9]

Fin	Temperature at fin base	Temperature at centre of fin	Temperature at fin tip
1st fin	77.3 °C	76.933 °C	76.089 °C
2nd fin	76.0 °C	75.6434 °C	74.823 °C
3rd fin	76.6 °C	76.2387 °C	75.408 °C
4th fin	75.1 °C	74.7504 °C	73.946 °C
5th fin	75.6 °C	75.2465 °C	74.433 °C
6th fin	76.6 °C	76.2387 °C	75.407 °C
7th fin	76.7 °C	76.3380 °C	75.505 °C
8th fin	76.8 °C	76.4372 °C	75.602 °C
9th fin	78.2 °C	77.8263 °C	76.966 °C
10th fin	77.4 °C	77.0325 °C	76.187 °C
11th fin	76.5 °C	76.1395 °C	75.310 °C
12th fin	77.9 °C	77.5286 °C	76.674 °C
13th fin	76.9 °C	76.5364 °C	75.7 °C
14th fin	75.9 °C	75.5442 °C	74.725 °C
15th fin	77.7 °C	77.3302 °C	76.47 °C
16th fin	75.5 °C	75.1472 °C	74.335 °C
17th fin	73.2 °C	72.8651 °C	72.094 °C
18th fin	74.0 °C	73.6589 °C	72.874 °C
19th fin	73.6 °C	73.2620 °C	72.484 °C
20th fin	70.0 °C	69.6900 °C	68.976 °C

III.CONCLUSION

The compressors head body which is mounted on the compressor is just been mounted on the body for the purpose removal of the heat from the body and transferring it to the environment. The design which is made may not be an optimized one. The heat carrying capacity may be lower than its feasible actual capacity. An attempt is made in terms of the change in some design parameters or combination of design parameters which will increase in heat transfer coefficient

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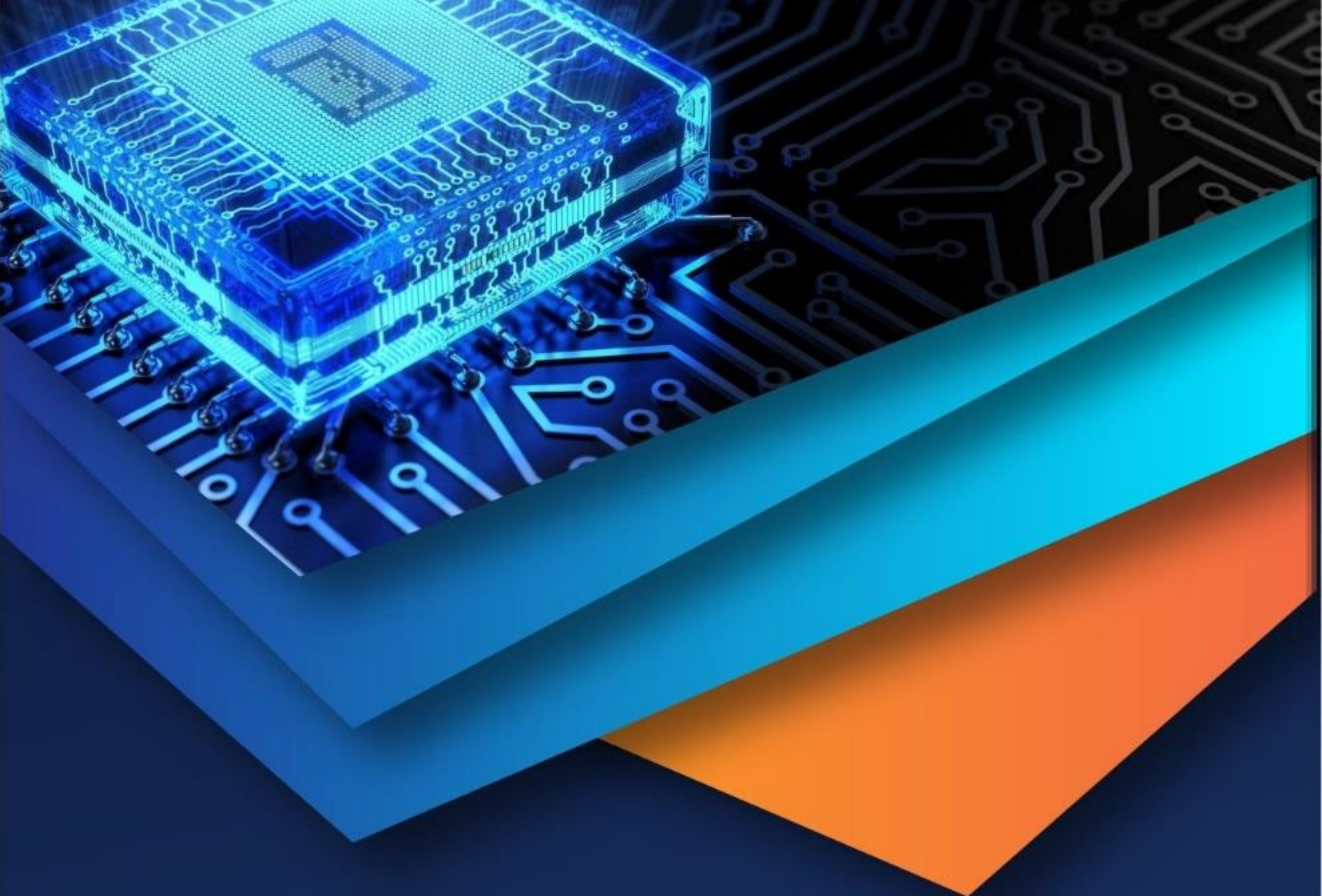

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