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Numerical and Experimental study of Louvered Fin Heat Exchangers and Increasing the Heat Transfer capacity by Geometrical and Flow parameters using CFD

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Abstract: Louvered fin heat exchanger is a type of compact Heat exchanger that consists of a stack of alternate flat plates called parting sheets and corrugated fins, both being brazed together as a block. Streams exchange heat by flowing along the passages made by the fins between the parting sheets. Separating plates act as the primary heat transfer surfaces and the appendages known as fins act as the secondary heat transfer surfaces intimately bonded to the primary surface. Aluminium is the most commonly used material and stainless steel is employed in high pressure and high temperature applications. CFD Simulation results show an excellent flow phenomenon with the basis of stability and accuracy. Results show the best combination of the angle for optimum pressure drop and heat transfer rate. In current study the temperature drop is increase with increase in louver angle, turbulent is high near to the winglet. As the velocity of air is increase the temperature drop is decreased. We found that when louvered angle, velocity, pressure, Temperatures are the best combination of the angle for optimum pressure drop and heat transfer rate.

Key words: Louvered Fin Heat Exchanger, Louvered angle, Numerical Simulation, CFD, Experimental Analysis, Fluent , etc.

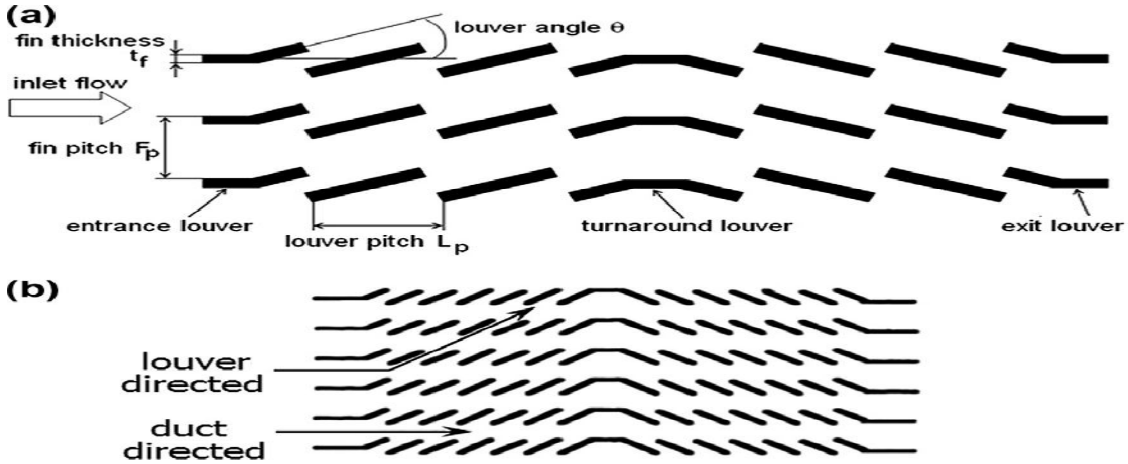
I. INTRODUCTION

A fin is a surface that extends from an object to increase the rate of heat transfer to or from the environment by increasing convection. The amount of conduction, convection, or radiation of

An object determines the amount of heat it transfers. Increasing the temperature difference between the object and the environment, increasing the convection heat transfer coefficient, or increasing the surface area of the object increases the heat transfer. Sometimes it is not economical or it is not feasible to change the first two options. Adding a fin to an object, however, increases the surface area and can sometimes be an economical solution to heat transfer problems.

A. Louver Fin

The space and mass constraints imposed by the transportation industry demand the use of compact finned heat exchangers to meet various cooling duty requirements. Louvered-fin geometries have been a popular technique to augment fin heat transfer incompact heat exchangers, such as shown in Figure 1.1. While it is clear that louvers provide benefits in terms of increased cooling capacity, the flow mechanisms responsible for louver performance are still not completely understood. Several theories to explain louvered-fin flow behaviour have been proposed. Some investigators contend that louvers simply serve as flow tabulators, disturbing the air flow path and thereby increasing fluid mixing. Others believe louvers align the airflow in the louver direction creating a series of miniature flat plates with heat transfer typical of flat plate boundary layers. The complexity of the flow and the difficulty in constructing a large array of test samples has limited louvered-fin flow modelling efforts. The highly competitive nature of the transportation industry has also made it difficult to obtain this information from the open literature.



1 (a) Louver array with geometrical parameters; (b) duct vs. louver-directed flow.

B. Types of louver Fins.

1) Super High Density Fin

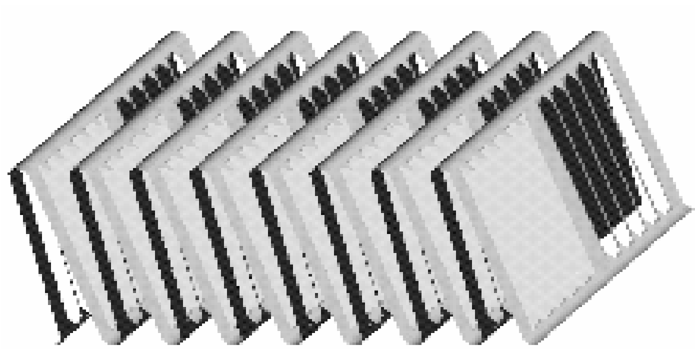


Figure 2. Super High Density Fin

C. Applications

1) High Efficiency Heat Exchangers
2) Automotive Radiators
3) Heater Cores
4) Combo-Cooler
5) Charge Air Coolers
6) Computer Heat-Sinks

D. Three Dimensional Computational domin and Delta winglet position

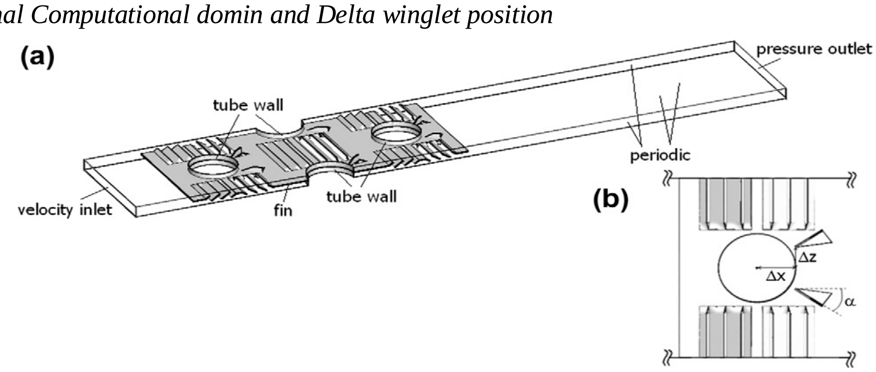


Figure:3(a) Three-dimensional computational domain and (b) top view showing the delta winglet position**.**

1) *Radiator:* Radiators are heat exchangers used to transfer thermal energy from one medium to another for the drive of cooling and heating. The common of radiators are constructed to function in automobiles, buildings, and electronics. The radiator is always a source of heat to its environs, although this may be for either the drive of heating these environs, or for cooling the fluid or coolant supplied to it, as for engine cooling. Despite the name, radiators generally transfer the bulk of their heat via convection, not by thermal radiation, though the term "convector" is used more narrowly; see radiation and convection, below. The Roman hypocaust, a type of radiator for building space heating, was described in 15 AD. The heating radiator was invented by Franz San Galli, a Polish-born Russian businessman living in St. Petersburg, between 1855 and 1857.
2) *Radiator (engine cooling):*Radiators are used for cooling internal combustion engines, mainly in automobiles but also in piston-engineaircraft, railway locomotives, motorcycles, stationary generating plant or any similar use of such an engine.Internal combustion engines are often cooled by circulating a liquid called *engine coolant* through the engine block, where it is heated, then through a radiator where it loses heat to the atmosphere, and then returned to the engine. Engine coolant is usually water-based, but may also be oil. It is common to employ a water pump to force the engine coolant to circulate, and also for an axial fan to force air through the radiator

E. Radiation VS. Convection

In practice, the term "radiator" refers to any of a number of devices in which a fluid circulates through exposed pipes (often with fins or other means of increasing surface area), notwithstanding that such devices tend to transfer heat mainly by convection and might reasonably be called convectors.

The term convection heater or *convector* refers to a class of devices in which the source of heat is not directly visible. As domestic safety and the supply from water heaters keeps temperatures relatively low, radiation is inefficient in comparison to convection.

F. Pin fin heat sink and pin fin arrangement

A pin fin heat sink having mixed geometry pin fin arrangements is presented. The mixed geometry pin fin arrangement are designed to optimize the positive attributes of each individual pin fin geometry to provide a low cost overall system and provide better system performance in high flow rate systems. In an exemplary embodiment, the pin fin heat sink comprises a base surface having a plurality of pin fins perpendicular to and protruding there from. The plurality of pin fins actually comprises a plurality of pin fins having a first arrangement and a plurality of pin fins having a second arrangement. The second arrangement pin fins are intended to streamline any turbulence created by the first arrangement pin fins which are located upstream of the second arrangement pin fins. Preferably, the first arrangement comprises substantially circular shaped pin fins and the second arrangement comprises extensively elliptical shaped pin fins.

G. Compound Heat Exchanger

Companies of heat exchangers are continuously searching for new and better designs. A promising approach is to combine known enhancement techniques, resulting in so-called compound heat exchangers. In this paper the air-side of a round-tube heat exchanger with louvered fins and delta winglet vortex generators is studied. The contribution of five important design parameters to the thermal hydraulic performance of the compound heat exchanger was numerically investigated. Knowing which parameters have the biggest influence is important for the optimization. To limit the number of simulations, the Taguchi method was used. At high inlet velocities the performance is mainly determined by the louvers, while at lower inlet velocities also the delta winglet geometry has a significant contribution. To validate the simulations, an aluminium compound heat exchanger was made and tested in a wind tunnel. This validation experiment showed that there is an acceptable match between the numerical results and measurements.

II. LITERATURE

As per Cristian[1] a whole heat exchanger with a hydraulic diameter of 2.3mm is tested, which is a mini channel heat exchanger according to the Kandlikar classification. This is a louvered fin and flat tube heat exchanger currently used in car cooling systems, also known as radiator. A glycol–water mixture (60/40 in volume) circulates through the tubes at flows ranging from 100 to 7800l/h and at a supply temperature of 90°C. This fluid is cooled with ambient air at a temperature of 20°C and at frontal air velocities varying between 0.5 and 7m/s. The thermo hydraulic performance of the heat exchanger is compared with the classical correlations given in the literature for the heat transfer and the friction factor calculation. On the glycol–water side the heat exchanger is characterized for Reynolds numbers from 30 to 8000. A first comparison is carried out with the correlations available in the literature with a purely predictive model by obtaining a predictive value with a systematic under prediction lower than 10%. In a second step a semi-empirical model is considered to identify the experimental heat transfer coefficients for this application. Henk Huisseune[2] Louvered fin and round tube heat exchangers are widely used in air conditioning devices and heat pumps. In this study the effect of punching delta winglet vortex generators into the louvered fin surface in the near wake region of each tube was numerically investigated using computational fluid dynamics (CFD). The delta winglets serve to reduce the size of the tube wakes. They cause three important mechanisms of heat transfer enhancement. First, due to the swirling motion of the generated vortices, hot air is removed from the tube wake to the mainstream regions and vice versa. Second, the induced wall-normal flow locally thins the boundary layer, which also enhances the heat transfer. Third, the size of the wake zones is reduced because the flow separation from the tube surface is delayed. This also results in a reduced form drag of the tube surface. The net core pressure drop, however, increases when adding delta winglets to the louvered fins because of increased friction and flow blockage. For the same heat duty and pumping power, the louvered fin heat exchanger with delta winglets is more compact than when no delta winglets are present. Henk Huisseune[3] Manufacturers of heat exchangers are continuously searching for new and better designs. A promising approach is to combine known enhancement techniques, resulting in so-called compound heat exchangers. In this paper the air-side of a round-tube heat exchanger with louvered fins and delta winglet vortex generators is studied. The contribution of five important design parameters to the thermal hydraulic performance of the compound heat exchanger was numerically investigated. Knowing which parameters have the biggest influence is important for the optimization. To limit the number of simulations, the Taguchi method was used. At high inlet velocities the performance is mainly determined by the louvers, while at lower inlet velocities also the delta winglet geometry has a significant contribution. To validate the simulations, an aluminium compound heat exchanger was made and tested in a wind tunnel. This validation experiment showed that there is an acceptable match between the numerical results and measurements. Guilherme [4] Experimental work was conducted to compare the thermal–hydraulic performances of cross-flow micro-channel condensers using louvered fins and metal foams as extended surfaces. Three copper foam surfaces with pore densities of 10 and 20 pores per inch (PPI) and porosities of 89.3 and 94.7%, and three aluminium louvered fins with lengths of 27 and 32 mm (in the flow direction) and heights of 5 and 7.5 mm were evaluated. The experiments were carried out in a closed loop wind-tunnel calorimeter equipped with a R-600a refrigeration loop. A condensing temperature of 45 °C was used in all tests, with face velocities ranging from 2.1 to 7.7 m/s. A comparison based on the thermal conductance and air-side pumping power showed that the surfaces enhanced with louvered fins performed better than the metal foams under all conditions investigated Kyoungmin [5] Frosting experiments were conducted on surface-treated (hydrophilic, hydrophobic, and dual) louvered-fin heat exchangers with varying fin pitches, and the frosting behaviour of the rows was investigated in terms of the experimental conditions. In the early stage of experiments, three of these surface-treated heat exchangers exhibited the highest heat transfer rate at 16 FPI (fins per inch), in particular, the hydrophobic unit had the smallest reduction in the heat transfer rate during the latter stage due to the frost-retardation effect. Hence, the hydrophobic unit had the largest overall heat transfer rate. For the hydrophilic and dual-treated heat exchangers, the first row (front side) showed more active frost growth than the second row (rear side), and thus the leading-edge effect was demonstrated in these two heat exchangers. By contrast, with the hydrophobic heat exchanger, the leading-edge effect was not observed when the refrigerant temperature was higher than −10°C, or the airflow rate was higher. The ratio of remained water after defrosting was the highest for the hydrophobic unit, but this unit still showed the highest overall heat transfer rate during the repeated frosting and defrosting experiments cycle, due to frost retardation.

III. PROBLEM FORMULATION

We found a lot of researches are going on in the field of heat transfer through fin. It consists of micro fin and macro fin of different types. In many literatures we found the review on different type of fine like rectangular fin, trapezoidal fin, parabolic fin, pin fin, offset fin etc. and also we got the work done by H. Husseune. [7] on the louver fin which is very important in heat transfer enhancement. We have decided to work on this reference. As it has been reported that the best parameter it had taken is the combination of louver angle, height ratio of the delta winglet, angle of attack of the delta winglet vortex generator, delta winglet aspect ratio and fin pitch(**). We have taken all the parameters except louver angle as constant as in the reference paper [7]. The detail of geometry taken for the test and simulation are explained in following chapters. The louver fin and the testing setup will be done in GEI industry. Also simulation of the component is to be done and results compared.

** F_p(mm) – fin pitch

$\Theta(^o)$ - louver angle

α^o - angle of attack of the delta winglet vortex generator(°)

h* - height ratio

Λ - delta winglet aspect ratio

IV. METHODOLOGY

A. *Experimental set up*

The test was carried out at GEI industry, Bhopal. Wind tunnel of rectangular shape was used to perform the test on louver assembly in the test rig. The condition of the air is at normal temperature and pressure as given in the reference [7].The dimension of the setup for the experimentation is as follows:- Linear length in the direction of the flow is 200 mm. It consists of 10 tubes along the complete length. The lateral length of the arrangement is taken as 160 mm. The flow is perpendicular in this direction and the sides are completely fixed for the flow of the air through the channel of the wind tunnel duct. The height of the fin is taken as 50 mm, the arrangement is kept plates of louver fin placed over each other total 10 stripes are taken in this direction one will take 3.8 mm. overall the value of the arrangement is 200mm X 160mm X 50mm. this is arranged in the wind tunnel for the testing air is allowed to pass through this space only.

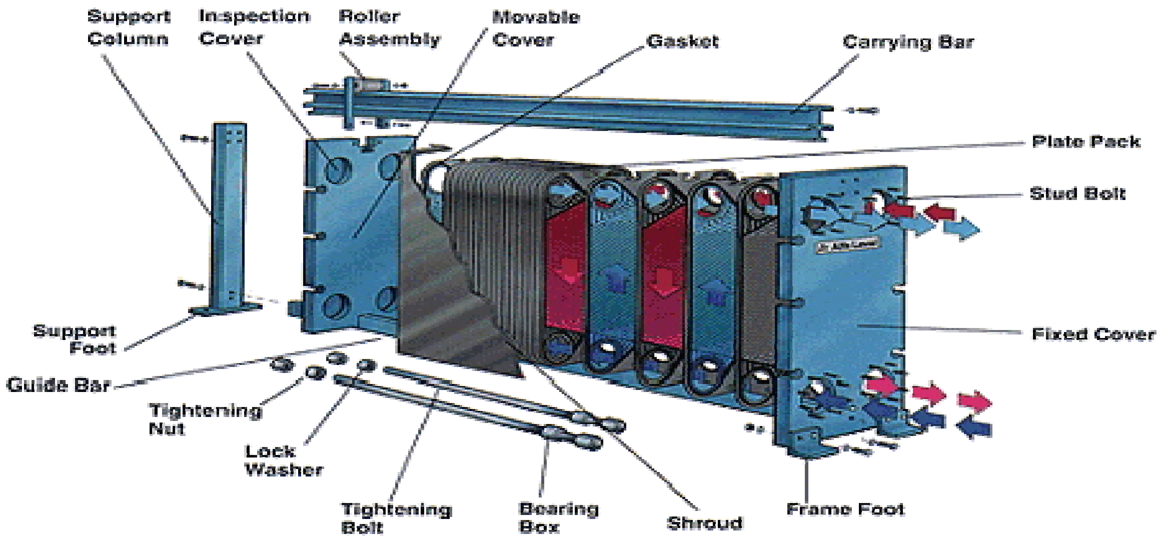


Figure 4 Experimental Set-up

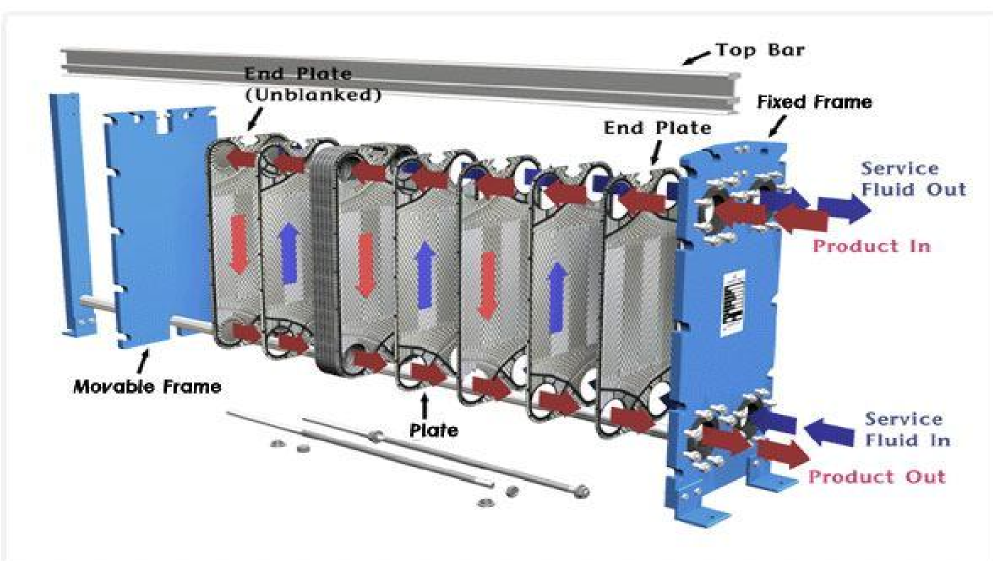


Figure 5 Exploded view

B. *CAD Modelling*

The CAD Model is completed in NX 7.5 as shown in the following fig.

Dimension are taken as according to the reference taken from the literature survey, the CAD is prepared for all the cases discussed and the dimension in table below this represent the dimension of the proto-type made for testing and validation.

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Sr. No	F_p(mm)	Θ^o	α^o	h*	Λ
1	1.71	28	35	0.9	2.0

Fp(mm) – fin pitch
Θ(o) - louver angle
αo - angle of attack of the delta winglet vortex generator(°)
h* - height ratio
Λ - delta winglet aspect ratio

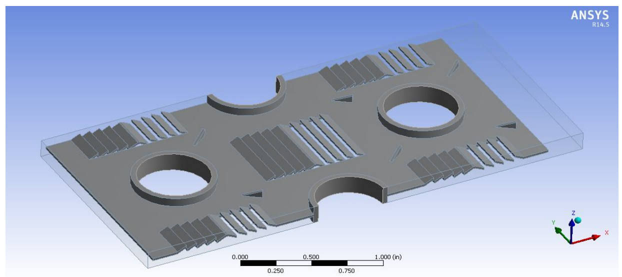


Fig 6 . Shows the CAD model prepared

The above fig shows the CAD model of Louver fin with air domain the fin is modelled as we had assumption that for the section we are analyzing the fin due to limitation of the Hardware we have. It is modelled in CAD software. To define the geometric detail of the domain we modelled the CAD. This is the isometric view of the modelled in CAD.

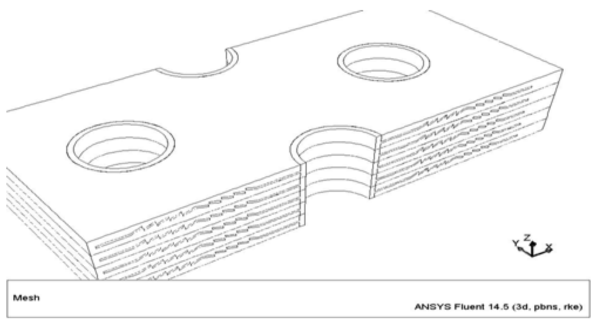


Fig.7 shows the periodic representation of the Fin domain

C. Meshing

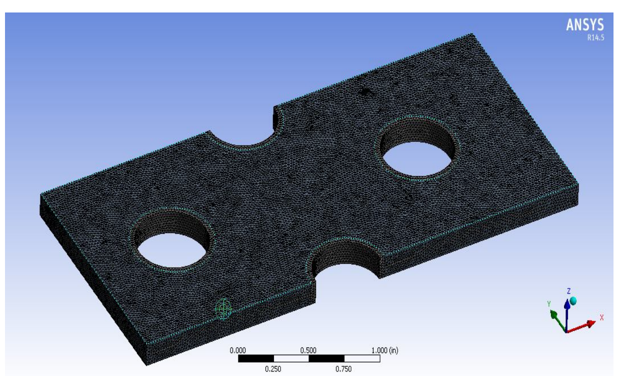


Fig. 8 shows the mesh representation of the Fin and air domain

The fig above show the meshed isometric view of the louver fin only. The view represent the detail captured is proper or not.

D. Mesh detail for all the models in the model

Nodes 144227

Element 603999

In the above tabular pattern the detail of mesh i.e. element and node are of complete domain

E. Material property

1) Air

Density (Kg/m3) 1.225

Specific Heat (j/Kg-k) 1006.43

Thermal Conductivity (w/m-k) 0.0242

Viscosity (Kg/m-s) 1.7894e-5

F. Aluminium

Density (Kg/m3) 2719

Specific Heat (j/Kg-k) 871

Thermal Conductivity (w/m-k) 202.4

The above properties are considers for the calculation of the Thermo-hydraulic problem for the following formulation of the CFD.

G. Solver details method from

Viscous

Realizable K-ε

Enhanced Wall function

H. Boundary condition

The following are the boundary condition

I. Velocity at inlet

Velocity Magnitude .3 m/s , 1.26 m/s and 2.69 m/s

Operating pressure 1 atm

Turbulent Intensity (%) 2

Turbulent Viscosity Ratio 2

Initial temperature of air 293 as in the time of experiment

J. Outlet condition

Pressure outlet

Operating pressure 1 atm

Backflow Turbulent Intensity (%) 2

Backflow Turbulent Viscosity Ration 2

Backflow Total Temperature of air 293

V. RESULTS & DISCUSSION

A. Experimental Results

Pressure droop according to the flow velocity with different angle of the louver:-

Velocity (m/s)	0.3	1.26	2.69
Pressure (Pa)	2.75	20.13	88.67

Temperature reading on the test setup of the louver fin of different angle at the exit of the flow reading is taken after the air is coming out from the fin.

Velocity (m/s)	0.3	1.26	2.69
Temperature (k)	321	315	312

B. Result from simulation

Case SL. No.	Parameter 1 Louver angle O(°)	Parameter 2 Velocity (m/s)	Pressure (Pa)	Temperature (k)
case 1	24	0.3	1.86	321.66
case 2	24	1.26	16.01	315.91
case 3	24	2.69	64.19	312.45
case 4	26	0.3	2.01	321.78
Case 5	26	1.26	19.01	315.11
case 6	26	2.69	66.29	312.74
case 7	28	0.3	2.01	321.84
case 8	28	1.26	18.60	315.91
case 9	28	2.69	81.96	312.71
case 10	30	0.3	2.14	321.99
case 11	30	1.26	21.08	317.10
case 12	30	2.69	72.09	312.88
case 13	32	0.3	1.71	322.99
case 14	32	1.26	17.42	317.61
case 15	32	2.69	68.84	312.30

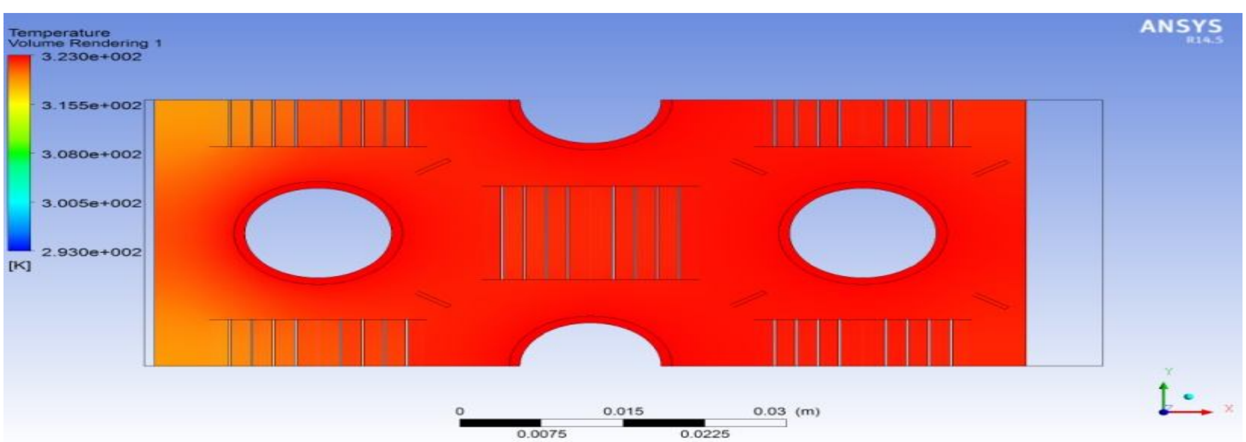
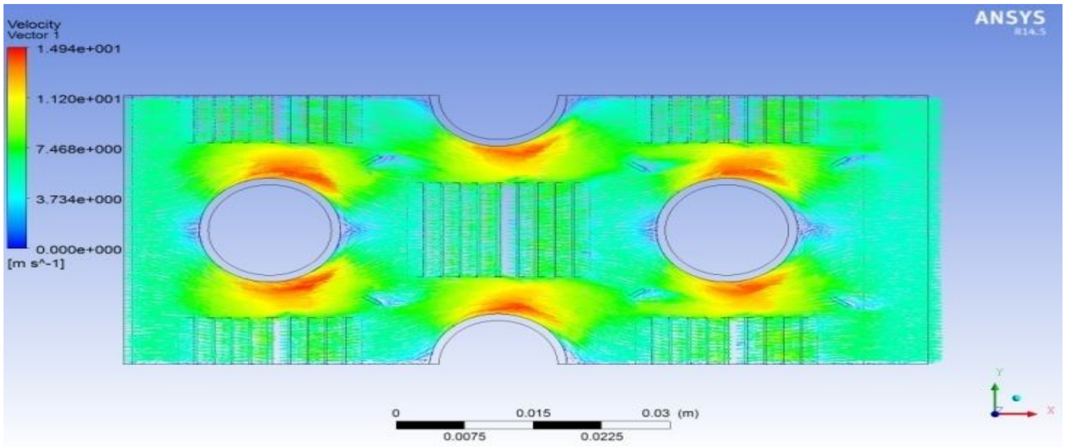


Fig. 9 shows the temperature distribution of air in the case no 13

The above fig shows the temperature distribution of air over the louvered fin as shown in the fig temperature maximum all over the place at the rate of 322.99 k.



Fig, 10 shows the velocity distribution of air in the case no 13

The above fig show the vector plot for the louver fin segment the maximum velocity is near the tube i.e.14.9 m/s, the air is flowing through the louver fin with lower velocity and it provides the mixing of the air through louver it reduces the temperature of the air flowing in between the fines. Average velocity is around 8 m/s as from the above fig we are dying to the values.

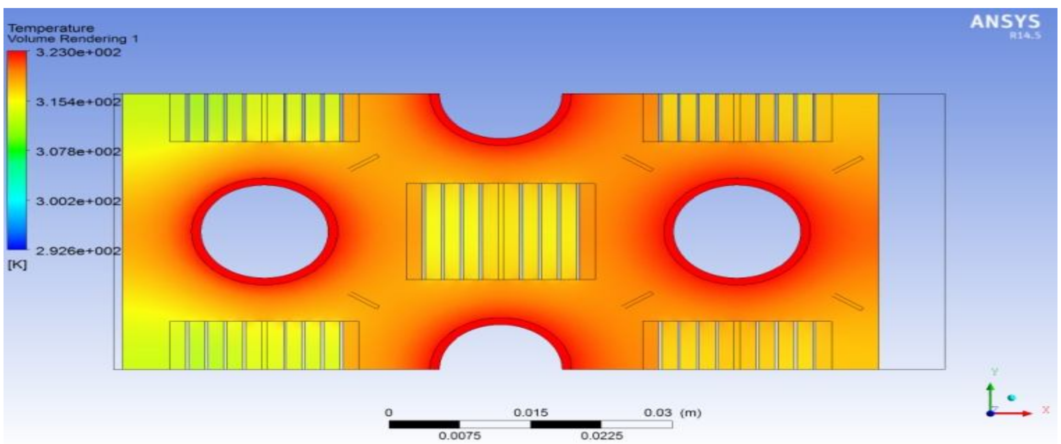
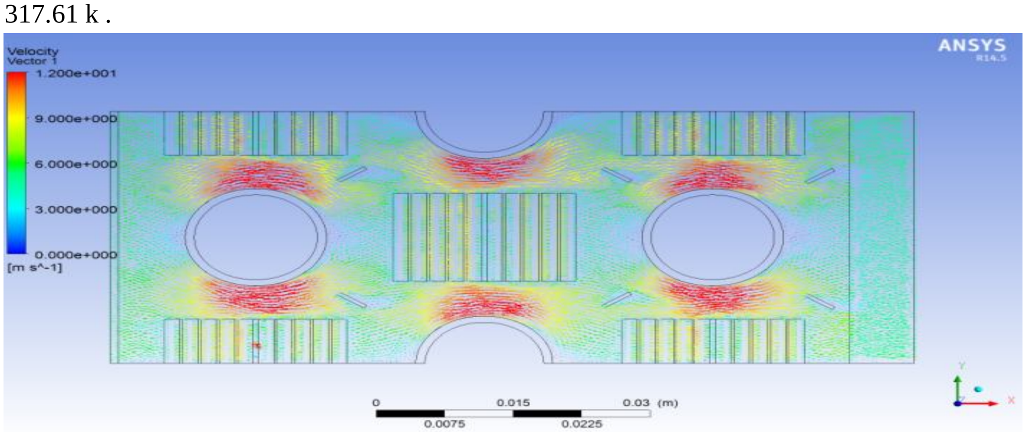


Fig. 11 shows the temperature distribution of air in the case no 14

The above fig shows the temperature distribution of air over the louvered fin as shown in the fig temperature maximum all over the place at the rate of 317.61 k .



Fig, 12 shows the velocity distribution of air in the case no 14

The above fig show the vector plot for the louver fin segment the maximum velocity is near the tube i.e.12 m/s, the air is flowing through the louver fin with lower velocity and it provides the mixing of the air through louver it reduces the temperature of the air flowing in between the fines. Average velocity is around 6.5 m/s as from the above fig we are dying to the values.

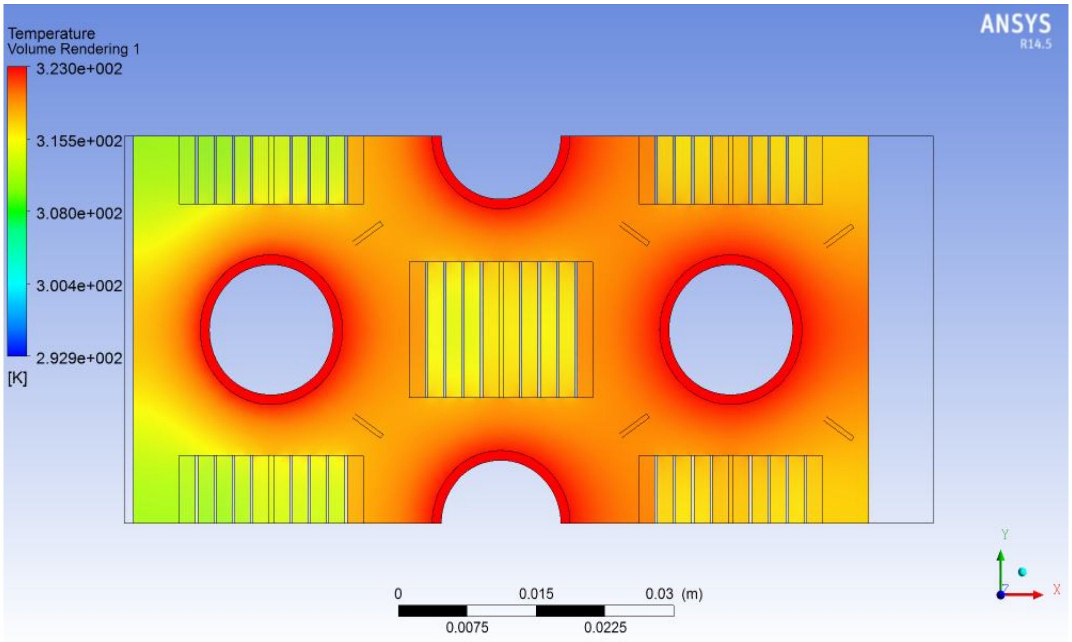
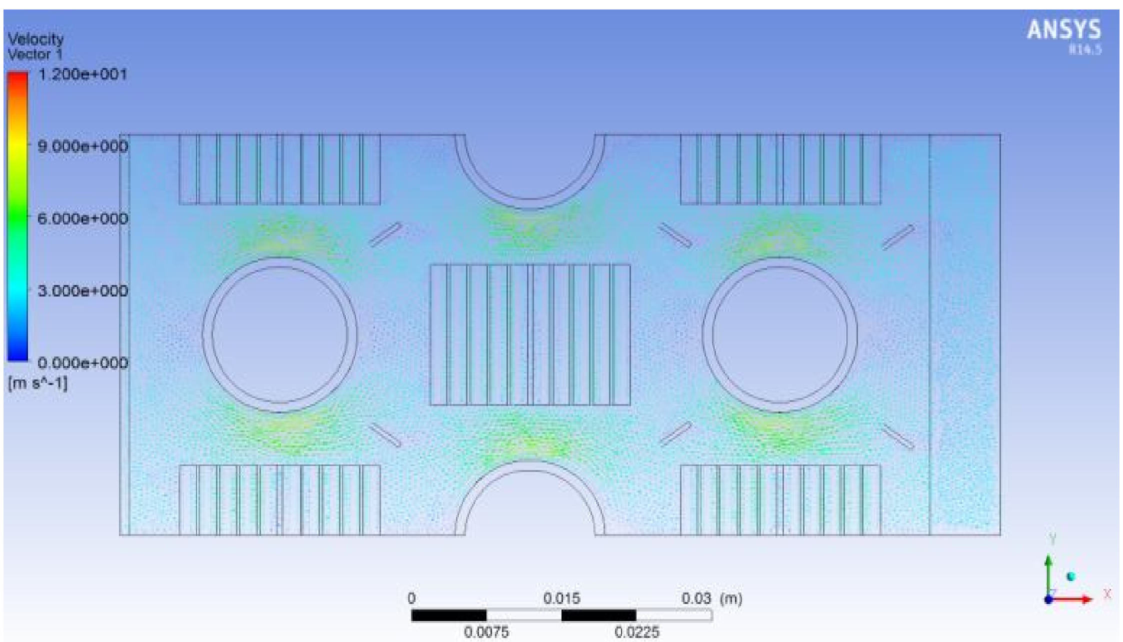


Fig. 13 shows the temparature distribution of air in the case no 15

The above fig shows the temperature distribution of air over the louvered fin as shown in the fig temperature maximum all over the place at the rate of 312.30 k .



Fig, 14 shows the velocity distribution of air in the case no 15

The above fig show the vector plot for the louver fin segment the maximum velocity is near the tube i.e.12 m/s, the air is flowing through the louver fin with lower velocity and it provides the mixing of the air through louver it reduces the temperature of the air flowing in between the fines. Average velocity is around 6 m/s as from the above fig we are dying to the values

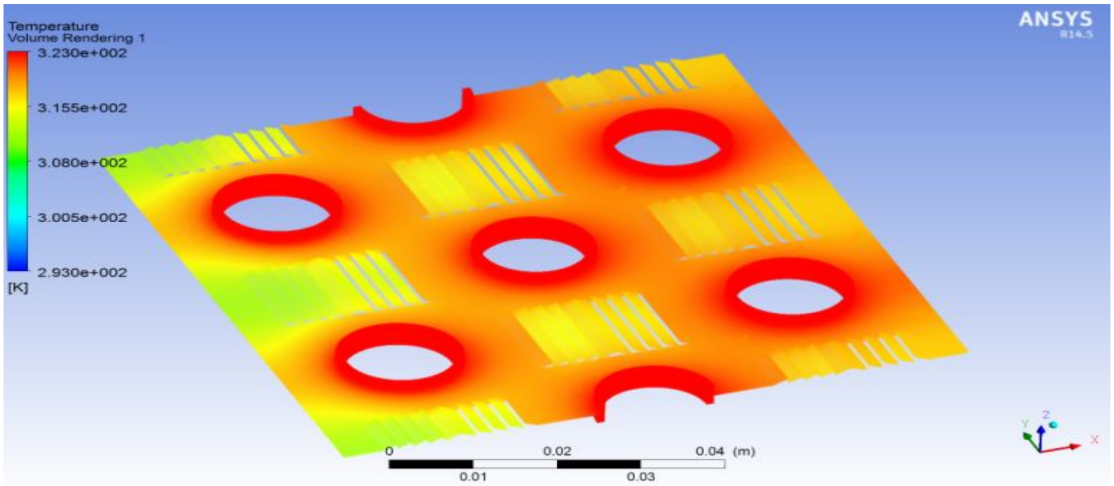


Fig. 15 shows the temperature distribution of air in the complete entity

The above fig shows the temperature contour in the direction of the flow the red colour indicate the high temperature of the pipes and followed by the colour indicated in the scale given in the left corner of the

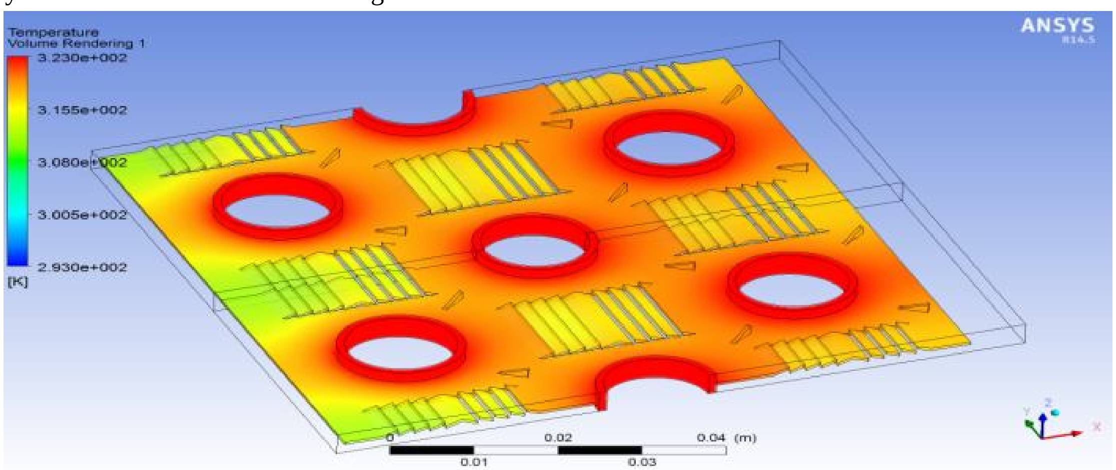
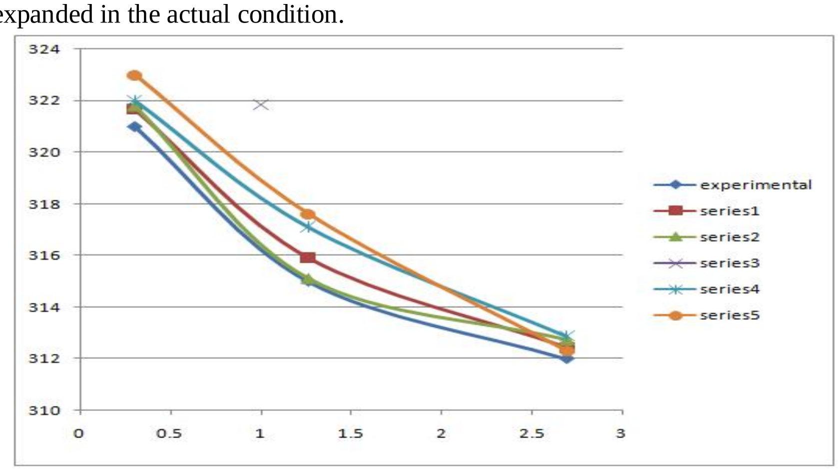


Fig. 16 shows the velocity distribution of air in the complete entity

The above fig shows the temperature contours in the direction of the flow the red colour indicate the high temperature of the tubes and followed by the colour indicated in the scale given in the left top corner of the image. The result is expanded as the periodic boundary condition is expanded in the actual condition.



Graph 1 shows the temperature-velocity results of the louver fin for Experimental and Simulation cases

V. CONCLUSION

As we had discusses in the previous chapter for the comparison of the experimental and simulation, we got the conclusion of that the results are satisfactory in simulation as compared to the experimental results. With the continuation of this we are studied as discussed in the methodology. We got the best combination of the angle for optimum pressure drop and heat transfer rate. As in the study we seen the temperature drop is increase with increase in louver angle, turbulent is high near to the winglet. As the velocity of air is increase the temperature drop is decreased and it is highest in series 5 then subsequently in the series 4 series 3 series 2 and series 1. From this we are found the list is in series 5.

We are found that when louvered angle ,velocity , pressure, temperatures are the best combination of the angle for optimum pressure drop and heat transfer rate.

Louver angle ϴ(°)	Velocity (m/s)	Pressure (Pa)	Temperature (k)
32	0.3	1.71	322.99
32	1.26	17.42	317.61
32	2.69	68.84	312.30

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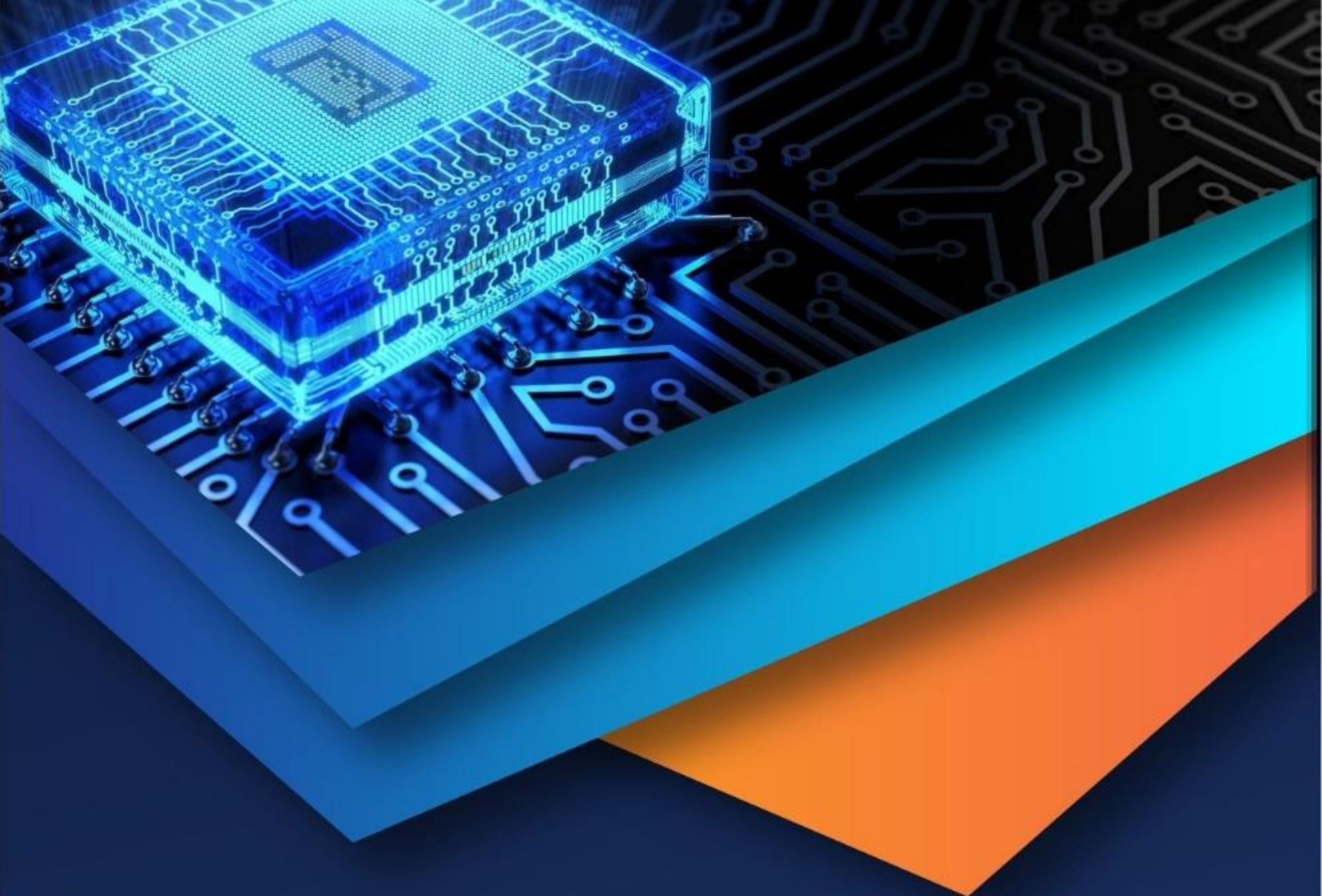

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TOGETHER WE REACH THE GOAL

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