iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 4 **Issue:** VII **Month of publication:** July 2016

DOI:

Volume 4 Issue VII, July 2016
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

Experimental Investigation of Heat Transfer in Heat Exchanger Using Different Geometry of Inserts

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Abstract: The investigation of heat transfer coefficient and friction factor in a single tube heat exchanger with different geometry of inserts has been presented experimentally. The experimentally obtained data for different cases is compared with the data obtained for smooth tube. The experimental analysis has been made and results were obtained for the Reynolds's number ranging from 3000 to 18000.
Keywords: Heat transfer, Heat exchanger, Enhancement techniques, twisted tape

I. INTRODUCTION

Heat exchangers have several industrial and engineering applications. The design of heat exchanger is quite complicated as it needs exact analysis of heat transfer rate and pressure drop and the major challenge is to make the equipment compact. The heat transfer enhancement is the technique used for improving the heat transfer rate by increasing the effective surface area. Heat transfer enhancement technology is being very widely adapted in heat exchanger used for various process applications like refrigeration, automotives, process industry, chemical industry etc.

The twisted tape (without and with perforation) also called as swirl flow device, increases the heat transfer rate by disturbing the viscous and thermal boundary layer but in the process pumping power may increase significantly and ultimately the pumping cost becomes high. This paper presents the heat transfer coefficient and friction factor characteristic for smooth tube, smooth tube with aluminum tape, smooth tube with perforated aluminum tape, smooth tube with twisted tape and smooth tube with perforated twisted tape.

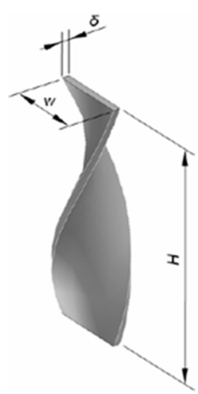
II. ABOUT EXPERIMENTAL SET-UP

Fig.1shows the experimental setup from front side. The smooth tube and tube with different insert is used in the experimental set up. The tube material used is copper. The length of tube used is 900 mm and tube diameter is 21 mm with 1.25 mm thickness. In this experiment water is used as a working fluid. Fluid is flowing in only one direction. Rotameter is used for measuring the flow rate of water. The range of rotameter is 0-10 LPM. Thermocouples are used for measuring temperature at the inlet of tubes. The uniform heat flux wire type heater is fabricated from nicrome wire. This wire is connected in series with dimmer stat in order to supply the same amount of heat to nicrome wire. The heat is provided on 900 mm length of tube and other side is unheated as well as insulated. Commercial glass wool insulation is used on external surface to prevent the heat leakage due to convection and radiation. The heated test section is 900 mm long. For wall temperature measurement, five thermocouples are used at different place of heating surface. Moreover, one thermocouple is placed inlet and one thermocouple is placed at outlet to measure the inlet and outlet bulk temperatures, respectively. Manometer is used to measure the pressure drop within the tested tube. The mass flow rate of water is controlled with the help of valve. One valve is used to control the mass flow rate of water by opening and closing of valve knob and readings are taken at various mass flow rate of water.

III. ABOUT THE INSERTS

The insert used for the experiment are plane and twisted aluminum tape with and without perforation. The aluminum twisted tapes was chosen for its wide availability and low cost. Each aluminum tape originally measured 900 mm long and 18 mm wide.

Thickness, δ = 1 mm



Tape Width, w = 18 mm
Twist Pitch, H = 5.24 cm
Perforation pitch, p = 5.24 cm

IV. EXPERIMENTAL PROCEDURE

After complete the fabrication of the experimental setup. Firstly I fill the water tank by using the tap water and then start the water pump. Set the current and voltage range in ammeter and voltmeter respectively so that it gives the uniform heat flux to the tube at wall temperature range of 40^0C to 45^0C. And now with setting the flow rate of the working fluid at 2 lpm, 4 lpm, 6 lpm, 8 lpm and 10 lpm.

The setup would be run continuously till the steady state achieve. After achieving the steady states I take the reading of temperature at the inlet and outlet of tube without using any inserts i.e. smooth tube. And also take the reading of tube surface wall temperatures by using digital temperature controller. Take the reading of pressure drop across the test tube section by using the U-tube manometer. The experimental procedure repeated with changing the valve of the inlet working fluid at different flow rate, till the steady state is achieved. After achieving steady state in smooth tube the same experimental procedure is repeated for different inserts which are as follows:

Volume 4 Issue VII, July 2016
ISSN: 2321-9653

In first phase, simple plane aluminum tape insert is used in tube and this test sectioned is compared with smooth tube. The systematic view of plane aluminum tape used in this investigation is given in fig.3

Fig.2 Smooth Tube

Fig.3 Smooth Tube with plane aluminum tape

In second phase, plane aluminum tape with perforation insert is used in tube and this test sectioned is compared with smooth tube and tube with plane aluminum tape without perforation. The systematic view of aluminum tape with perforation is used in this investigation is given in fig.4.

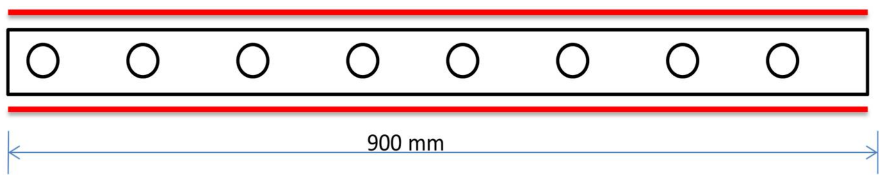


Fig.4 Smooth tube with plane aluminum tape with perforation

In third phase, twisted aluminum tape without perforation insert is used in tube and this test sectioned is compared with smooth tube, tube with aluminum tape and aluminum tape with perforation. The systematic view of tube with twisted aluminum tape is used in this investigation is given in fig.5.

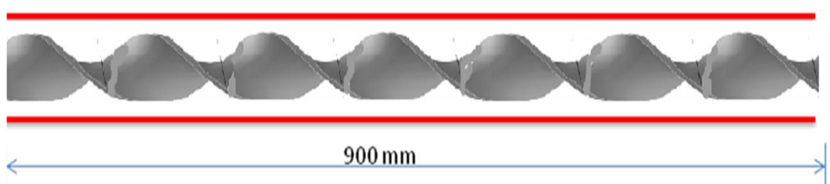


Fig: 3.5 Smooth tube with twisted aluminum tape without perforation

In fourth phase, twisted aluminum tape with perforation insert is used in tube and this test sectioned is compared with smooth tube, tube with aluminum tape, aluminum tape with perforation and twisted aluminum tape. The systematic view of tube with twisted aluminum tape with perforation is used in this investigation is given in fig,6

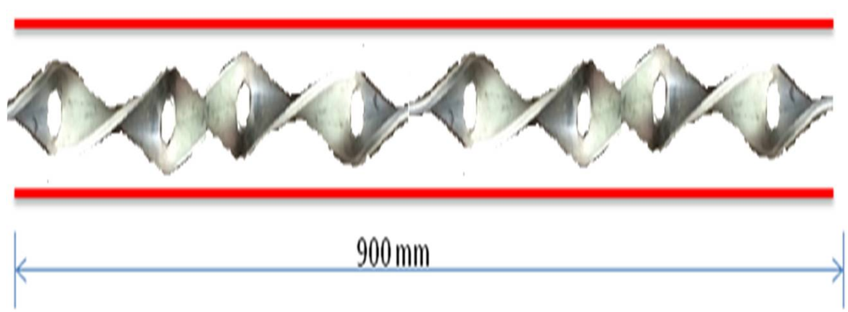


Fig.6 Smooth tube with twisted aluminum tape with perforation

Volume 4 Issue VII, July 2016
ISSN: 2321-9653
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A. Friction Factor Calculation

The pressure drop was determined from the differences in the level of manometer fluid. The fully developed friction factor was calculated from the following equation:

$(\Delta P) = \rho \times g \times h$

$F = (\Delta P \times 2 \times D) / (l \times \rho \times v^2)$

where ΔP is the pressure drop over length of 900 mm.

B. Heat Transfer Calculation

The heat transfer rate in the test section was calculated using.

$Q = m \times Cp \times (To - Ti)$

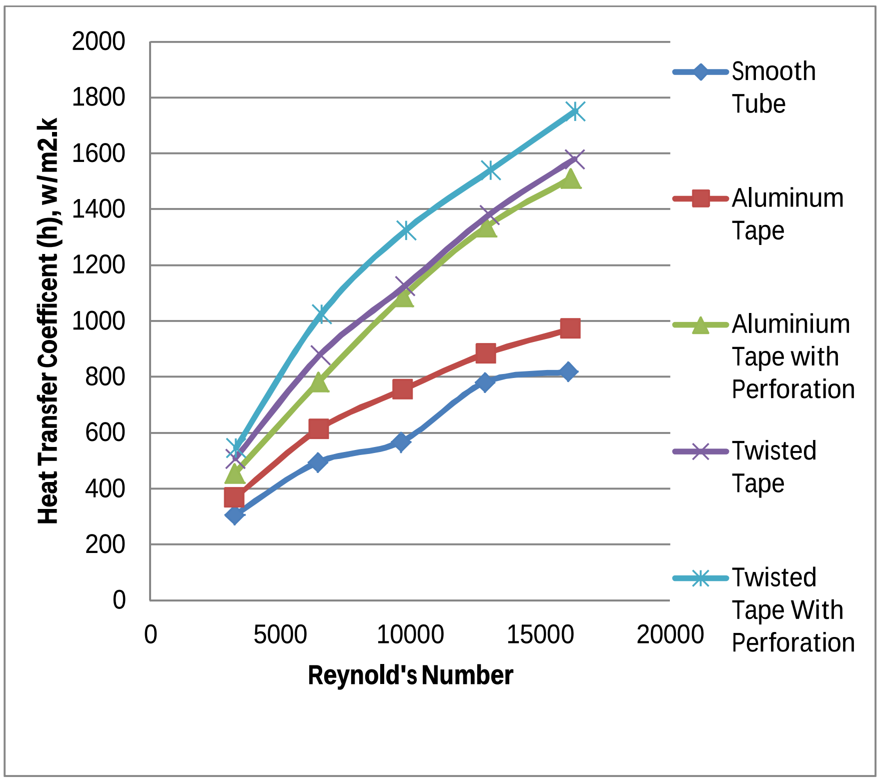
$Q = h \times As \times (Tw - Tb)$

The nusselt number is calculated from the equation

$Nu = hD / k$

V. RESULT AND DISCUSSION

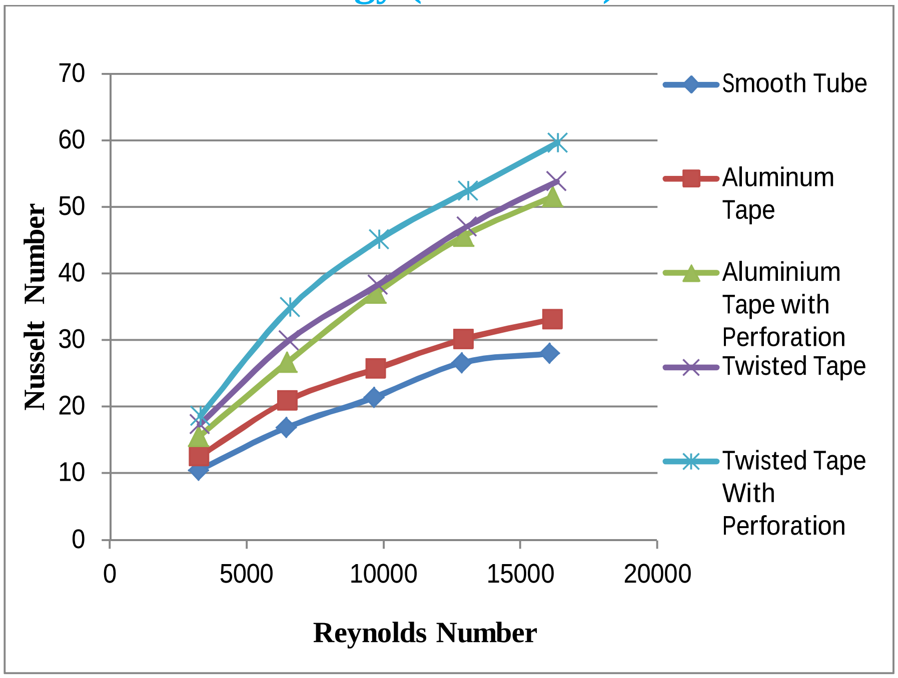
The experimentation was carried out with the smooth tube without and with using Aluminum Twisted Tape with and without Perforation inserts in Passive heat transfer enhancement methods. Heat transfer coefficient and friction factors are calculated for all cases. Parameters were plotted for Reynolds no. and mass flow rate. Following graphs are plotted to compare the performance of different inserts used in tube.



Gr.1 Heat transfer coefficient Vs Reynolds Number

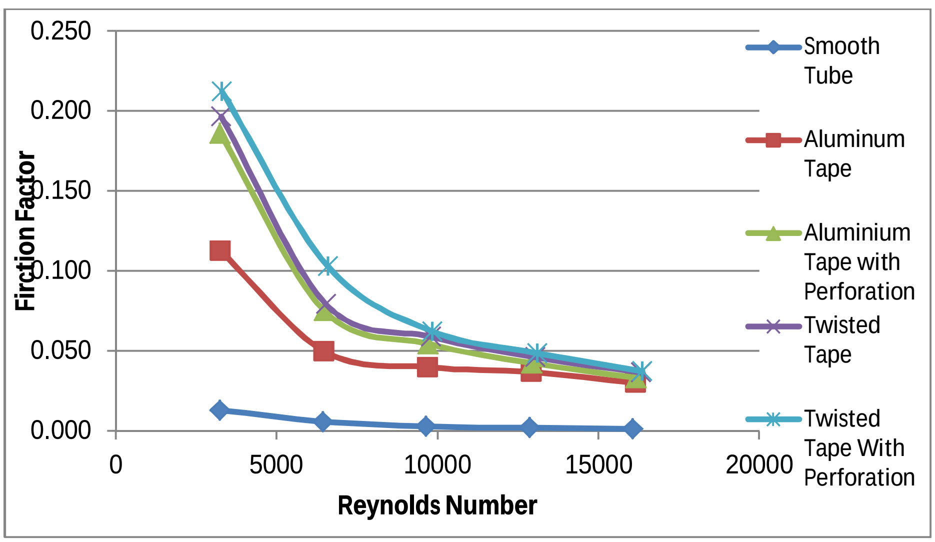
From the Gr.1, it is observed that the heat transfer coefficient increases with increase in Reynolds number. As Reynolds number increases, the water flow will cause more turbulence, so due to which the heat transfer rate will increase. From the Gr.1 it is observed that the tube without using any insert gives less heat transfer coefficient than with the use aluminum tape, tape with perforation, twisted tape and twisted tape with perforation. Twisted tape with perforation insert create more turbulence in tube which increases the heat transfer coefficient. Twisted tape with perforation insert gives maximum value of heat transfer coefficient as compared to aluminum tape, tape with perforation, twisted tape and to the smooth tube respectively.

Volume 4 Issue VII, July 2016
ISSN: 2321-9653



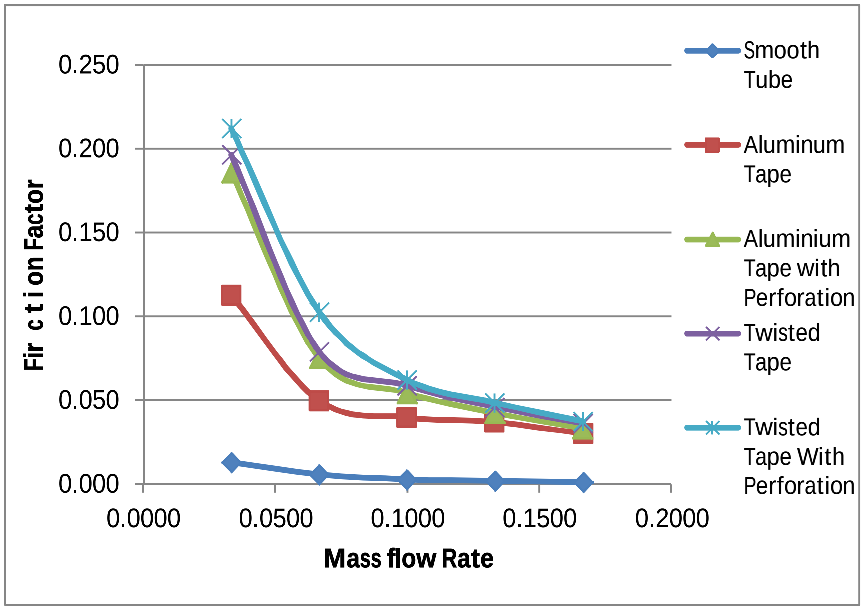
Gr.2 Nusselt Number Vs Reynolds Number

From the Gr.2, it is observed that there is increase in Nusselt number with Reynolds number. As Reynolds number increases the water flow will cause more turbulence due to which heat transfer rate will increase. As heat transfer coefficient is directly proportional to Nusselt number, $Nu=hD_h/K$ i.e increase in heat transfer coefficient increases the Nusselt number. It is observed that maximum Nusselt number is obtained for twisted tape with perforation insert as compared to aluminum tape without and with perforation and aluminum twisted tape inserts. Minimum Nusselt number is obtained for smooth tube without using any inserts type.



Gr.3 Friction factor Vs Reynolds Number

From the Gr.3 it is observed that as Reynolds number increases there is decrease in friction factor is observed. This is because friction factor is inversely proportional to the velocity. So as velocity increases (i.e. Reynolds number increases) friction factor will decrease. From Gr.3, it is observed that least friction factor is obtained in smooth tube without using any inserts. In a tube with aluminum twisted tape with perforation insert give maximum frication factor because pressure drop is maximum in tube. In a tube with aluminum twisted tape with perforation insert give maximum frication factor followed by aluminum twisted tape, aluminum tape with perforation, tape without perforation and lest friction factor is obtained in smooth tube.



Gr.4 Friction factor Vs Mass Flow Rate

From the Gr.4 it is observed that as mass flow rate increases there is decrease in friction factor is observed. This is because friction factor is inversely proportional to the velocity. So as velocity increases (i.e. Reynolds number increases) friction factor will decrease. From Gr.4, it is observed that least friction factor is obtained in smooth tube without using any inserts.

VI. CONCLUSION

Experimental investigations have been carried out in the circular tube to study the effect of aluminum tape without and with perforation and aluminum twisted tape without and with perforation inserts on heat transfer enhancement, friction factor. From the graphs plotted, following conclusions are made.

The heat transfer in tube with aluminum twisted tape with perforation insert is found to be more as compared to smooth tube i.e. without using any inserts. The increase in heat transfer coefficient of water 52.05 % higher for aluminum twisted tape with perforation insert, 45.74 % aluminum twisted tape without perforation insert, 42.58 % for aluminum tape with perforation insert and 17.33 % aluminum tape without perforation insert over when no inserts is use in tube. The increase in heat transfer occurs because more turbulence is generated within the tube by using different shaped of inserts as compared to without using inserts.

Friction factor reduces as the Reynolds number increases. This is because with increase in Reynolds number velocity increases and as friction factor is inversely proportional to velocity it decreases. This friction factor found to be maximum in aluminum twisted tape with perforation inserts followed by aluminum twisted tape without peroration, aluminum tape with perforation, aluminum tape without perforation and lest friction factor is obtained in smooth tube.

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Volume 4 Issue VII, July 2016
ISSN: 2321-9653

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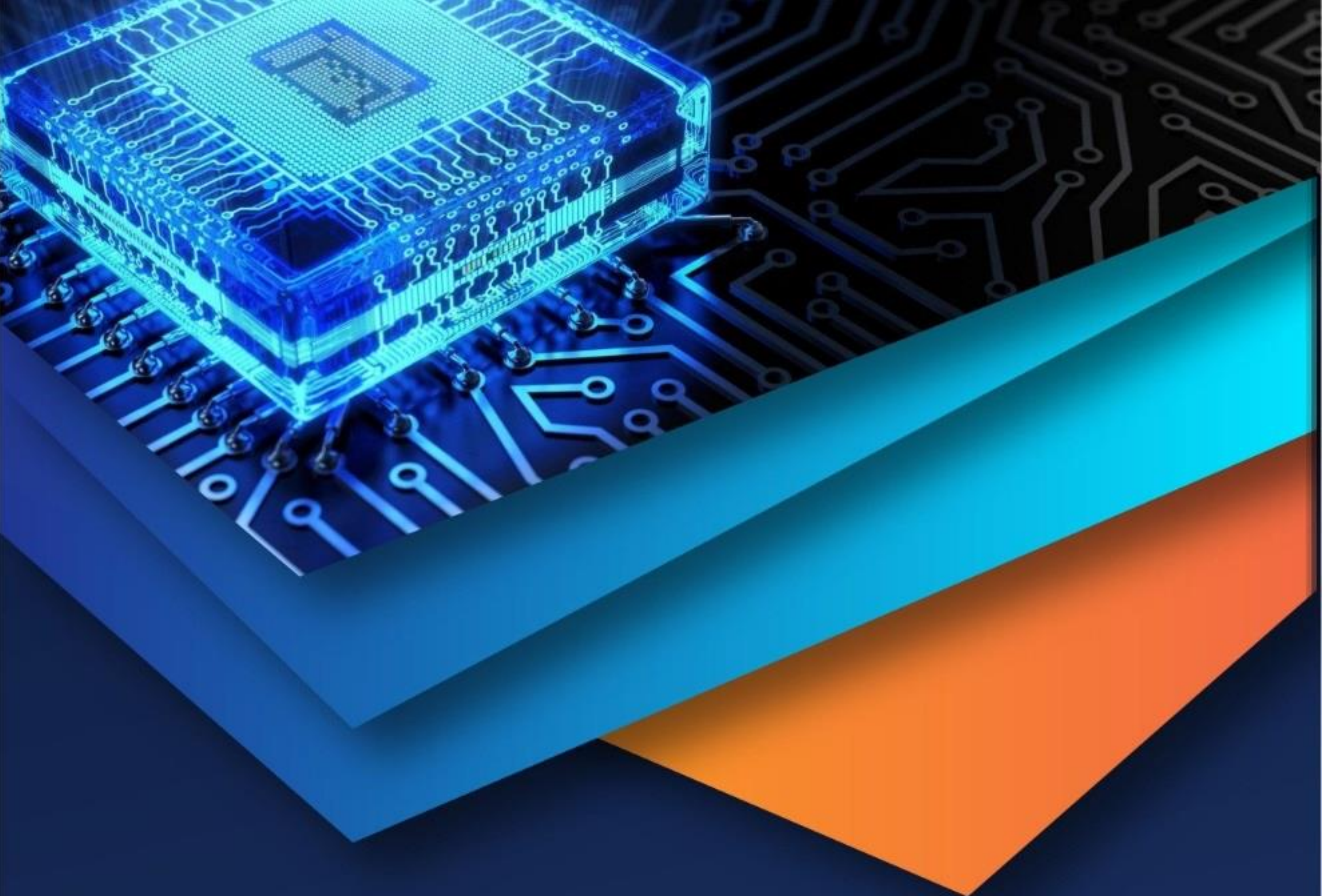

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