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:

International Journal for Research in Applied Science & Engineering Technology (IJRASET)

Experimental Investigation of Heat Transfer Enhancement Using U-Cut Semicircular Ring Turbulators in Double Pipe Heat Exchanger

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Abstract- Heat enhancement techniques are being utilized for many decades by evaluating different parameters of heat exchangers. Various types of configuration of heat exchanger are analyzed so far with various types of mechanical turbulators. After exploring various research works on types of turbulators used in heat exchanger an attempt has been made by using a modified setup that has not been implemented yet. The work presented here focuses on heat transfer augmentation by means of Semicircular ring turbulators with U-Cut on its periphery by inserting them in inner tube of concentric pipe heat exchanger. It's aimed to prove that, when a turbulators (the enhancement device) is inserted inside a pipe, the obstruction hence experienced by fluid flow causes a major change in flow pattern, its behavior and properties. In the current work the concept of pitch variation is introduced, which is defined as the horizontal distance between two consecutive turbulators. It describes that, the lesser is the pitch the more are the turbulators that can be inserted in inner pipe of double pipe heat exchanger and hence more will be the friction factor that will occur.
Keywords- Double pipe Heat Exchanger, UCSRT (U-Cut semicircular ring turbulators), friction factor, Thermal performance, Heat Augmentation, Nusselt Number, Reynolds number, Prandtl number, Specific heat.

I. INTRODUCTION

A heat exchanger as its name suggests is a device used to exchange heat (enthalpy) between two or more fluids at different temperature may be in direct contact or in contact through some solid surface. There are generally no external heat or work interaction in heat exchangers. Typical applications involving heat exchange are cooling tower in thermal plant, radiators in automobile Condensers, evaporators in milk processing plant etc. Main factor facilitating the heat transfer is temperature gradient including certainty that heat transfer occurs from high temperature to low temperature. Heat transfer basically occurs by three modes of heat transfer; conduction, convection and radiation. But role of radiation is insignificant in heat exchangers.Heat exchangers are classified according to heat exchange mode into direct contact type, regenerative and recuperative type. From above types recuperative are most commonly used heat exchanger. Designing a heat exchanger which can suit most of application with minimum limitation is very difficult but important. There are always has limitation like compact size, power requirement, rate of heat flow, etc. So enhancement of heat transfer using active heat enhancement techniques to achieve high performance of heat exchangers leads to high initial investment. So far no work is reported on study of semicircular disc type turbulators with u cut on its periphery. So it is a new design based on ring type turbulators. This research focused on overcoming the limitation in the ring type turbulators by improving heat transfer at the cost of lesser pressure drop.

II. LITERATURE REVIEW

Heat exchangers are commonly used to transfer heat between two fluids due to temperature gradient. In present world these equipments are one of most important parts of industries, air conditioning system cooling tower in thermal power plant and lot of other application. Among all type of heat exchanger recuperative type is most important. In this type of configuration fluids at different temperature are separated by surface and heat transfer occurs through this surface. [1].Augmentation techniques use baffles on heated surface to increase the heat transfer area and to enhance turbulence. Reverse flow is created due to these baffles because flow is separated and attached frequently. Recently lots of techniques are used to enhance heat transfer. Thus in this paper focus on studying the behavior of perforated turbulators keeping the pressure drop to a minimum.[2]A set of experiment to investigate the turbulent flow and heat transfer behavior in a double pipe counter water flow heat exchanger with inserted semicircular disc baffles on the opposite distances from the outer surface of the length of the inner tube. Epoxy resin is used to fix

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ISSN: 2321-9653
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these inserts. In his research he uses these rings at different pitches and then investigates various factor like heat transfer and Nusselt number and friction coefficient. [3] Circular tube equipped with perforated twisted tape insert with different porosities (R_p) are used in experimental investigations. The examination was conducted for the turbulent flow regime i.e. Re 7200-49800 using air as working fluid under uniform wall heat flux boundary condition. As far as influence of porosity is concerned, the presence of strong swirl intensity causes more efficient interruption of boundary layer along the flow path; thus at 4.5% value of porosity and at Re 7525; a maximum performance of 59% was achieved.[4]Study the presence of twisted tape inserts in double pipe heat exchanger for two different test sections having different relative pitches. For the specified value of Reynolds Number; heat transfer rate was found to be higher for lower twist ratio since the turbulent intensity and flow length was higher at lower value of twist ratio.[5]Find experimental results for heat transfer and pressure drop for the case when two three start spirally corrugated tubes were combined with five twisted tape inserts with different relative pitches. In Re: 3000-60000; the heat transfer and pressure drop was obtained significantly higher compared to smooth tube under same operating conditions. The isothermal friction coefficient showed a falling trend for straight and swirl flow when the relative pitch decreases.[6]To experimentally determined thermo-hydraulic performance experimentally for 75 starts spirally start grooved tube with twisted tape inserts. The results indicated that the direction of twist (clockwise and anticlockwise) affects the thermo-hydraulic performance for all kinds of flow regimes.[7]

III. EXPERIMENTAL APPARATUS AND PROCEDURE

The parts of setup showed in the line diagram Fig. 1 and actual setup Fig. 2.respectively. It consist of basically two concentric tubes of which inner tube has ID=2.15cm and OD=2.45cm and outer tube has ID=4.5cm OD=5c.m respectively. Inner pipe made of copper and outer pipe made of GI. Test section length for Heat transfer is 4.232 m and test section length for measuring pressure drop is 4.34m. It consist of two rotameters one for cold water side range 0-1500 LPH and one for hot water side range 0-2000 LPH. Four RTD pt-100 and Four Chip Sensors = 0 – 100 degree Celsius are installed in setup for different temperature reading. Readings of temperature were noted down from multi-point digital temperature indicators. Hot Water Reservoir (Mild Steel) of 260 liters capacity , Outlet Cold Water Reservoir of 260 liters capacity and Inlet Cold Water Reservoir 600 liters capacity are installed with setup. Circulation Pipes of PVC are used. Kirloskar Motor of 0.5 HP is used on cold water side and Crompton Greeves Motor of 1HP on hot waterside. Hot water tank has four 2KW heaters installed in it that can maintain a maximum constant temperature of 75 degree Celsius. Inner pipe (smooth) of copper, of 4m length and its U-bend is of 0.232m length, Outer pipe is made up of G.I. and is approximately equal in length to that of inner pipe.

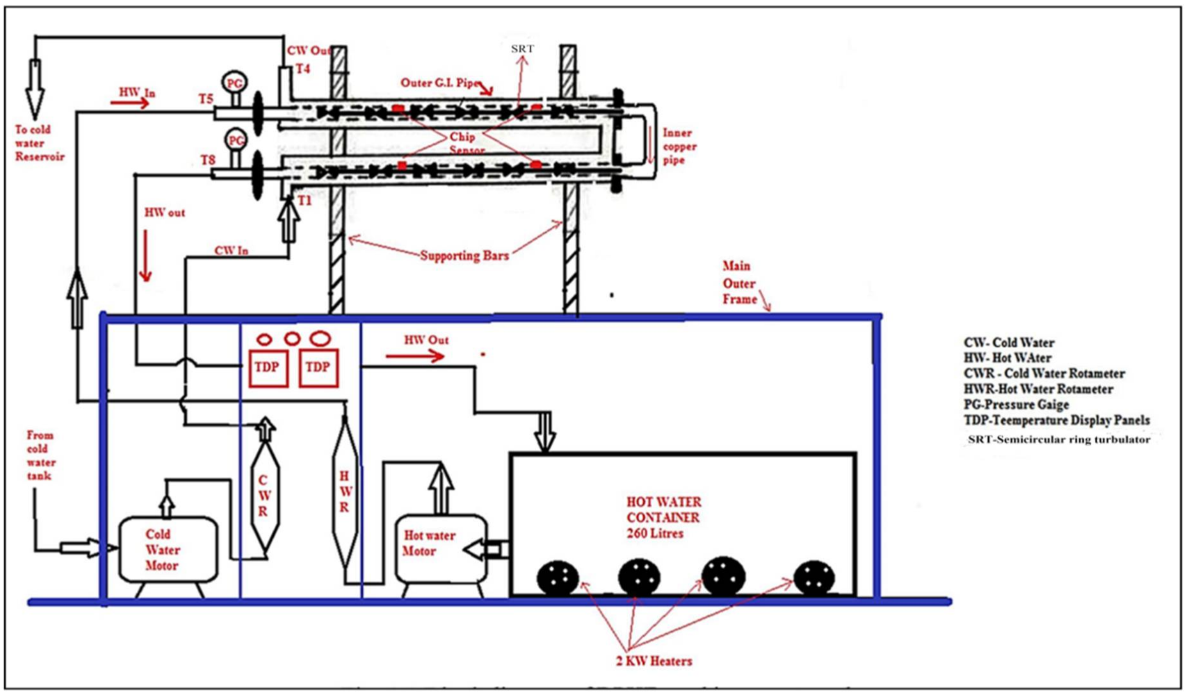

Fig1. Conceptual Diagram of Setup

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ISSN: 2321-9653
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Fig2. Actual diagram of setup

IV. DATA REDUCTION

A. Friction Factor Calculation

1) Darcy-Weisbach Friction Factor: $\lambda = \dfrac{(\Delta P/L)*D}{(\rho V^2/2)}$

2) Blasius Equation: $\lambda = \dfrac{0.316}{Re^{0.25}}$

3) Colburn's Equation: $\lambda = \dfrac{0.046}{Re^{0.2}}$

B. Heat Transfer Calculations

1) Dittus-Boelter Equation: $Nu_{PT,Theo} = 0.023 * Re^{0.8} * Pr^{0.4}$; for $Re > 10^4$

2) Sieder-Tate Equation: $Nu_{PT,Theo} = 0.023 * Re^{0.8} * Pr^{0.4} * (\underline{\mu/\mu s})^{0.14}$; for $Re > 10^4$

$(\underline{\mu/\mu s})^{0.14}$ is known as viscosity correction factor and falls very close to 1, hence is taken unity for all calculations.

C. Thermal Performance Calculations

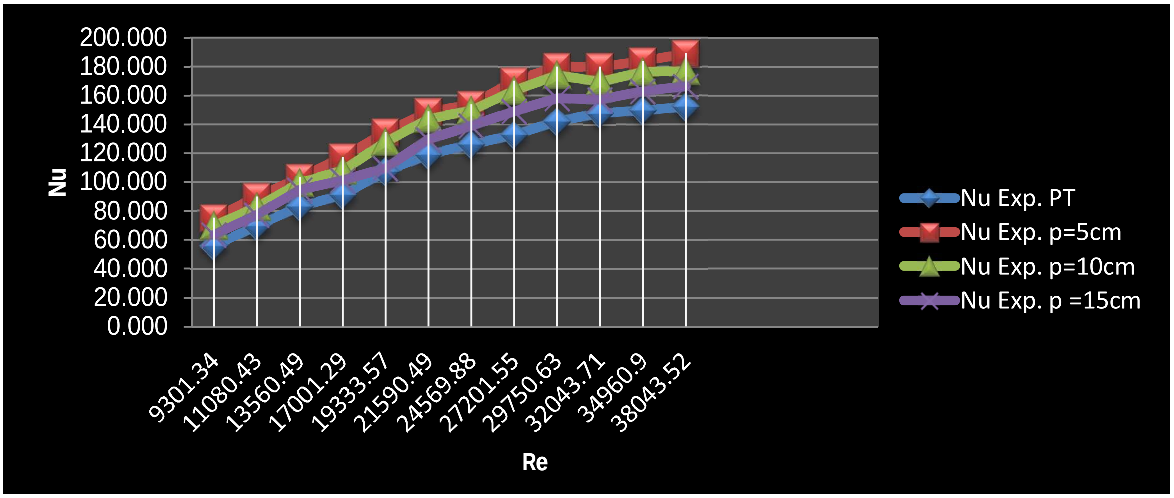
At Constant Pumping Power

1) $(\lambda * Re^3)_{PT} = (\lambda * Re^3)_T$ 2) $\eta = \dfrac{\left(\frac{Nu_T}{Nu_{PT}}\right)}{\left(\frac{\lambda_T}{\lambda_{PT}}\right)^{0.333}}$

V. RESULTS AND DISCUSSION

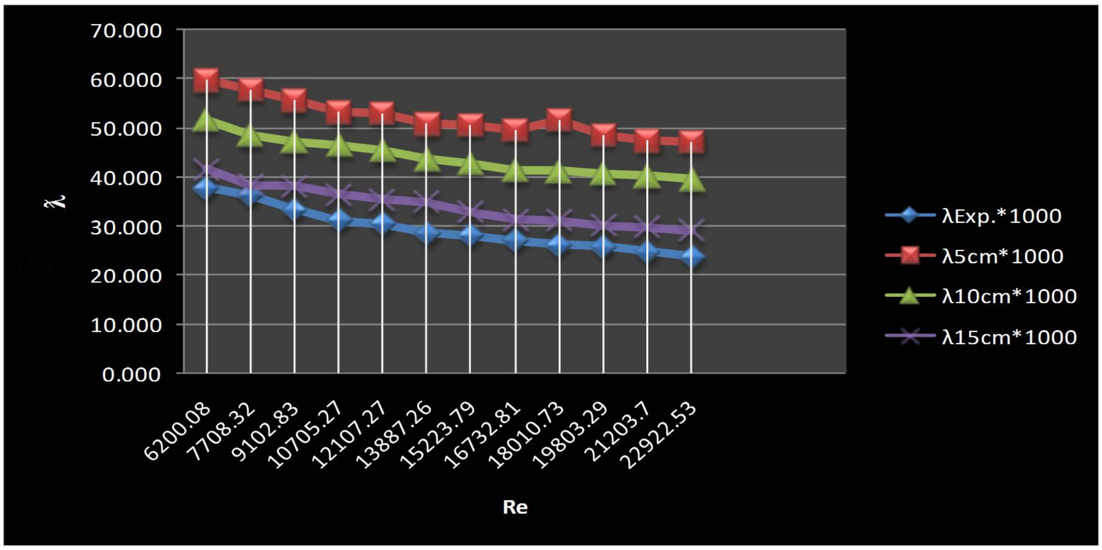
A. Effect of Pitch on HTE for UCSDT with Plain Tube, Pitch P=15cm, 10cm

When UCSRT with different pitches (P =5cm, 10cm and 15cm) were inserted in internal copper tube of double pipe heat exchanger, it exhibited different trends when the graph between the obtained experimental values of Nusselt number and Reynolds number was plotted, which is depicted in Fig. below While analyzing the graph it was clear that the rate of heat transfer was significantly enhanced when the plain tube and tube with UCSRT with various pitches were compared for a given fixed value of Reynolds number. Maximum heat transfer occurs for pitch 5 cm.



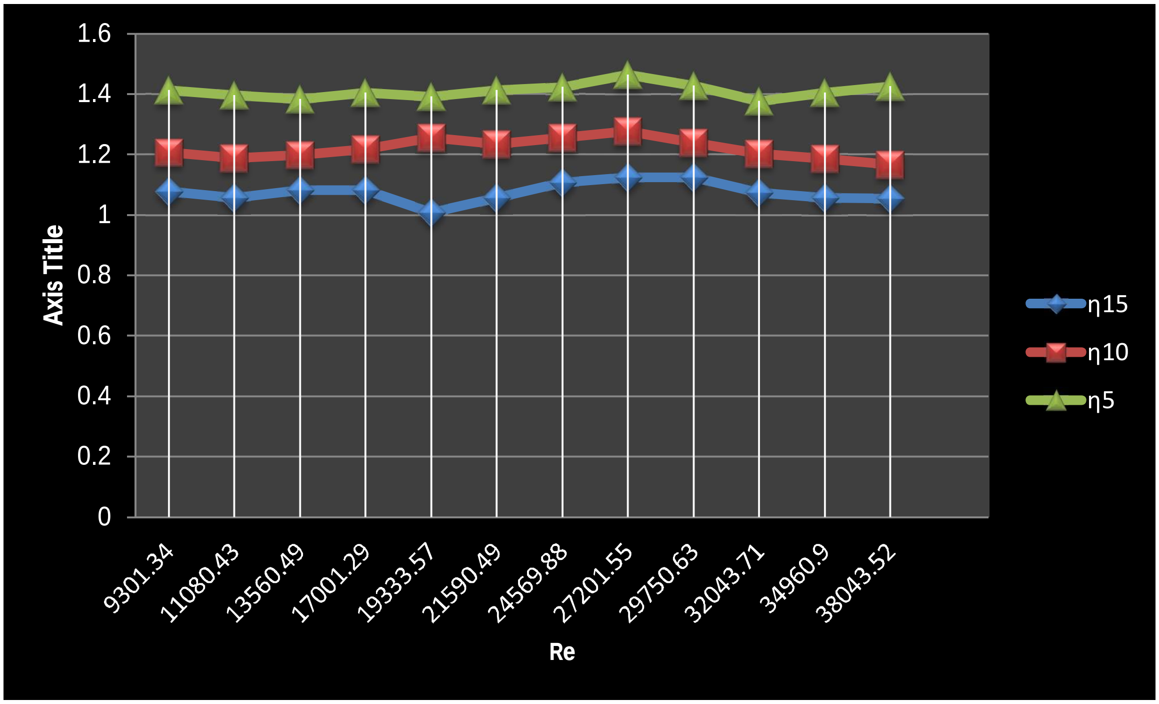
B. Friction factor comparison of UCSDT and Plain tube; (λ vs Re)

Experiments were performed under unvarying or constant conditions of heat flux for measuring the effect of inserting UCSRT of different pitches viz. 5cm, 10cm and 15cm. To obtain the friction factor and to plot the trend followed, calculations were made when friction factor varied with the varying Reynolds number. The results hence obtained were compared with that obtained while using plain inner copper tube. In Fig. the trend indicates an increment in friction factor with a decrease in UCSRT pitches. The reason behind this phenomenon was that the less is the distance between two consecutive UCSRTs' the more are the UCSRTs' that can be mounted on the cylindrical rod and hence inserted in inner copper tube, consequently causing more obstruction to the hot water stream. Maximum friction factor occurs with pith 5cm.



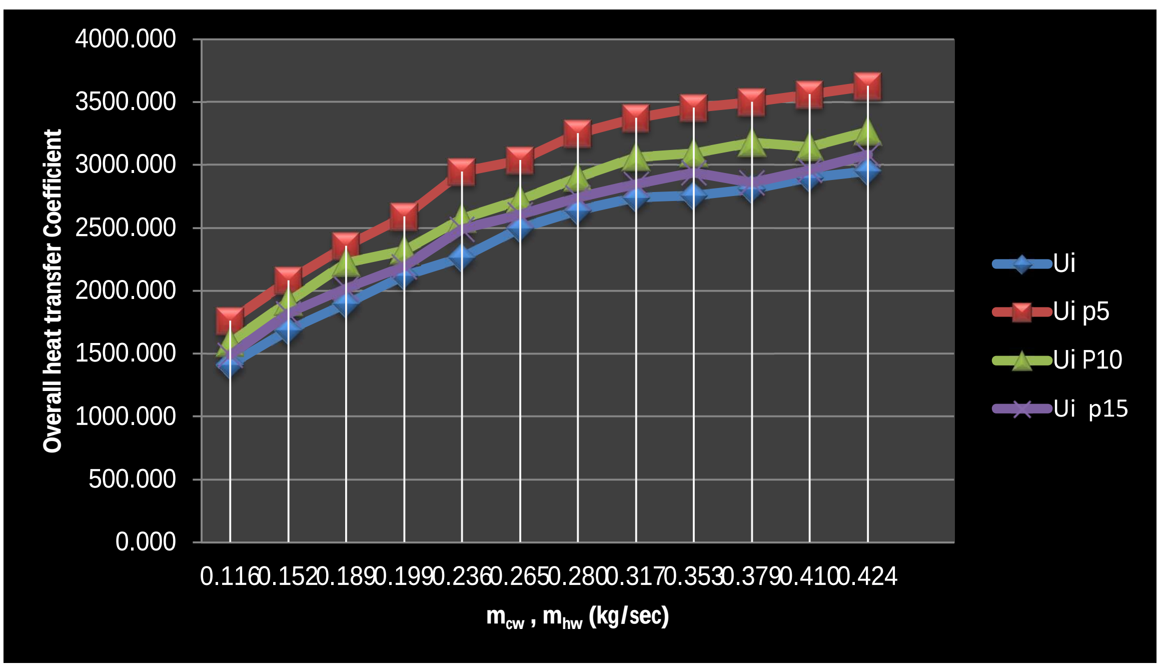
C. Thermal Performance Factor

At this stage, experimentation involved UCSRT with varying pitches, which includes an augmentation of heat transfer rate, though with a simultaneous increment in friction factor with decrease in pitch. The criteria of decreasing pitches comes at a price, that is, every extra turbulators inserted cause an extra resistance to flowing water and hence leading to an increment in friction factor. The more is the obstruction caused the more will be the effort required by pump to sustain a constant mass flow rate and hence more will be the pumping power required which at a certain level proves to be uneconomical. Consequently, a mutual agreement or an optimum state has to be concluded between the effectiveness of UCSRT in heat transfer augmentation and the increase in friction factor it causes.



D. Overall Heat Transfer Coefficient

At same mass flow rate of hot water and cold water, overall heat transfer coefficient increases linearly as can be seen in graph below. This figure also concludes that overall heat transfer coefficient for UCSRT with pitch P=5cm maximum.



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VI. CONCLUSIONS

The experiment for augmentation of heat transfer is successfully performed with UCSRT arrangement in double pipe heat exchanger and heat transfer (Nusselt no) is enhanced by 56 to 173.25 % Friction factor is increased maximum of 59.7 % for UCSRT pitch 5cm vis-à-vis plain tube. Overall heat transfer coefficient is maximum for pitch 5 cm and its value is 3629.278. However, thermal performance factor gives maximum value 1.463 for UCSRT pitch 5cm. The Nusselts number was found to be increased when UCSRT with pitches P=15cm, 10cm and 5cm were inserted in inner plain tube of double pipe heat exchanger, vis-à-vis plain tube as the Reynolds no. increased. Nusselt no. is maximum for pitch P=5cm.Friction factor and pressure drop characteristics were also studied and evaluated. It revealed that, with an increment in UCSRT pitch friction factor and pressure drop increases. UCSRT offers a maximum of 41.63%, 51.7% and 59.7% friction factor with 15cm, 10cm and 5cm respectively, vis-à-vis friction factor generated by plain tube. However, friction factor and pressure drop following decreasing trend with increase in Reynolds number.

VII. ACKNOWLEDGMENT

I would like to express my sincere regards, appreciation and thanks to my ME Thesis Supervisors **Prof. Gurjeet Singh,** Assistant Professor, Mechanical Engineering Department, PEC University of Technology, Chandigarh for both constant guide and giving me an chance to perform my dissertation into a complete form. They always provided me the generous guidance and constant encouragement when any difficulties arise by giving valuable time, advice and cooperation. It has been a great pleasure and honor to work with them.I am also thankful to my teachers and other staff members of department, who has been very helpful during my course work. I am also thankful to my family and fellow students of master of engineering, for their wholehearted support, encouragement and cooperation, which helped me, lot during my Thesis work to overcome uncertainties and difficulties. Last, but not the least, I bow in gratitude to the almighty whose grace enabled me to complete this project.

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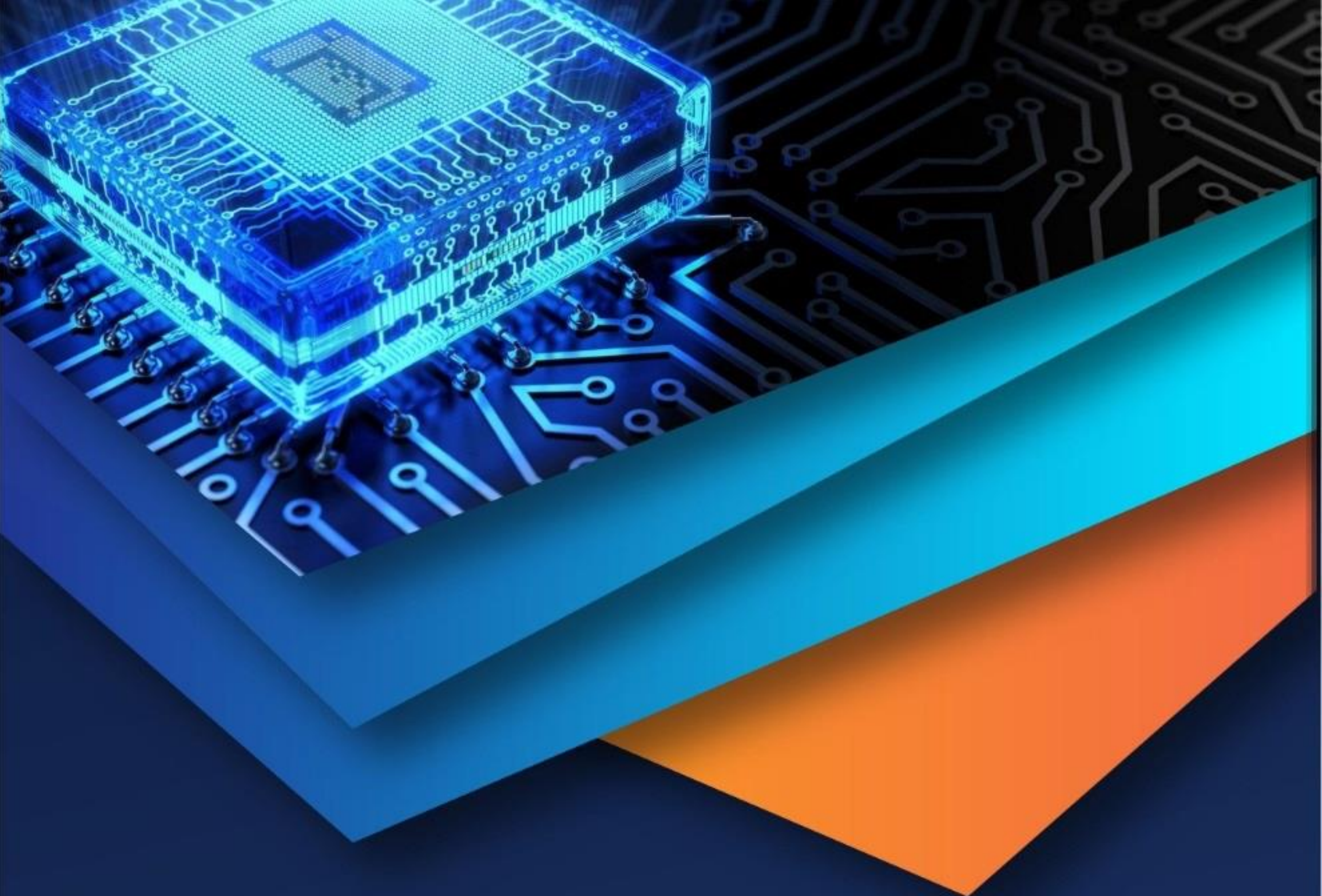

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