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Investigation of Thermal Performance of Heat Pipe Heat Exchanger for Waste Heat Recovery

Nikhil R. Deshmukh[1], Jitendra A. Hole[2]
[1, 2]Mechanical Engineering Department, Savitribai Phule Pune University

Abstract: The waste heat recuperation by heat pipes are plainly acknowledged as a great method for sparing vitality and keeping the a worldwide temperature alteration. This paper contain the literature review of the application of heat pipe heat exchangers for the waste heat recovery that is really focused on the vitality sparing and the improvement of productivity of HPHE. The test examinations comprise of aerial warmth exchanger furnished with thirty warmth channels are accused of the refined water as the working liquid. The stream design comprised of a solitary pass on the evaporator and condenser areas. The warmth funnels were made of the stainless steel, estimated 900 mm long and was introduced in an amazed game plan. The targets of detailed trial examination were dissect the impact of gulf temperature 100 °C and air mass stream rates (0.0625-0.25 kg/s) on the warm execution of HPHE. The paper was analyzed to support future works. This review provides additional information of the design of HPHE with optimum condition for waste heat recovery.

Keywords: Air mass flow rate, air-to-air, efficiency, heat pipe, heat transfer rate, waste heat recovery.

I. INTRODUCTION

The heat pipe is firstly introduced by Gaugler in 1942.The heat pipe is best method of recovery of waste heat, an excellent way of saving energy and prevent global warming. A heat pipe heat exchanger (HPHE) is used as air-to-air heat recovery device in both industrial and commercial applications. Heat pipe heat exchanger for heat recovery equipment is aimed for recovering sensible heat and they are recommended for system in which inlet and return air should not be mixed such as surgery rooms in hospitals, chemical and biological laboratories. The upsides of utilizing heat pipes over regular techniques is that expansive amounts of warmth can be transported through a little traverse a significant separation with no extra power contribution to the system,(expect for the fans to drive the airstreams) together with straightforwardness of outline and simplicity of make. Efforts have successfully developed a series of heat pipes equipment, such as heat pipes gas exchangers, heat pipes steam generators, high-temperature heat pipes hot air furnaces, and Also, heat pipe heat exchangers are suitable for energy recovery in air conditioning systems in tropical countries where incoming fresh air at high temperature could be precooled by the cold exhaust air stream before it enters the refrigeration equipment.

The new type of heat pipe heat exchanger designed and applied to recover waste heat for dyeing and printing industry. The heat pipe heat exchanger has a large boiling chamber. The condensed water falling down due to gravity. Three month after applying it can save 15% natural gas without any blockage of the gas side channel [1]. A specially designed cleaning device used to clean the heat exchange tubes and enhance the heat transfer rate of device which is used steel industry for waste heat recovery the result is that heat transfer rate, heat transfer coefficient, effectiveness, and exergy efficiency were improved [2]. Air-to-water warm exchanger display with six wickless warmth funnels accused of water and two pass stream designs are staggered. The outcomes are higher warmth exchange rate as higher delta temperature and higher mass stream rates and most extreme viability is 29% is gotten [3]. Examine the different attributes of a warmth pipe warm exchanger used to recuperate the waste warmth in slag cooling process in steel industry. The primary parameters of warmth pipe warm exchanger are tentatively and in addition hypothetically. The outcomes are warm exchange proportion and warmth exchange coefficient increment with increment in mass stream rates [4].The heat pipe heat exchanger for waste heat recovery is better way of saving energy and preventing global warming. The application of heat pipe heat exchangers for heat recovery that is focused on the saving and enhancement of the conventional heat pipe, two phase closed thermosyphon and oscillating heat pipe heat exchanger. The design of heat pipe heat exchangers with optimum condition in waste heat recovery [5]. The heat pipe heat exchanger particularly gas to gas is compared with the conventional heat exchangers. In that both quality and cost of industrial heat pipe heat exchanger is improved. Also calculated air to air thermosyphon based heat exchanger using ε-NTU method [6]. The design, manufacture and testing of an innovative flat heat pipe heat exchanger for waste heat recovery. The rate of heat recovery is up to 5 kW. The design to recover heat by radiation from hot steel rods during the manufacturing of cooling process [7][11]. The pump driven circle warm pipe utilized for vitality recuperation for depletes air to decrease outside air taking care of vitality utilization of aerating and cooling frameworks. Impact of working liquid, mass stream rate, warm trading region and confronting air speed on warm exchange limit, temperature viability and coefficient of execution were examined [8].The pump driven circle warm pipe utilized for vitality recuperation for deplete air to decrease outside air taking care of vitality utilization of aerating and cooling frameworks. Impact of working liquid, mass stream rate, warm trading region and confronting air speed on warm exchange limit, temperature viability and coefficient of execution were examined [8].The thermal performance of single pass cross flow on air side and two flow passes on the water side heat pipe heat exchanger is calculated by using CFD Modelling [9]. In this physical-mathematical modelling of heat transfer in the air-to-air heat exchanger with a periodical change in the air flow for room ventilation. This model is used for optimization of operation and construction parameters for heat exchanger [10]. The open-cell metal froth filled plate warm exchanger is utilized for second rate squander warm. This is utilized for squander warm recuperation through warmth trade and thermoelectric power age. The high warmth trade proficiency of 83.56% amongst hot and cool water accomplished [11]. Nomenclature

A. Abbreviations

HPHE heat pipe heat exchanger
NTU number of heat transfer units

B. Symbols

g gravity
Q heat transfer rate (kW)
T temperature °C
Tei inlet temperature of evaporator °C
Teo outlet temperature of evaporator °C
Tci inlet temperature of condenser °C
Tco outlet temperature of condenser °C

C. Greek letters

ε heat exchanger effectiveness
Subscript
c condenser
e evaporator
in inlet
out outlet

II. EXPERIMENTAL APPARATUS AND METHODS

A. Experimental apparatus

To Study the warmth exchange execution of heat pipe heat exchanger and decide the effectiveness of heat pipe heat exchanger at various mass stream rates at 100 °C channel temperature. The device comprised of HPHE, air radiators, blowers, heat pipes, channels, test sensors, surface sensors, temperatures pointers, stream control valve, and so forth. The schematic graph as appeared in Fig. 1.

As indicated by Fig. 1, the hot air disregards the at base side of evaporator area from right half of HPHE and streams out left hand side. Also, cool air enters goes at top side of condenser segment from left side to right side.

There are 30 heat pipes in the HPHE, orchestrated as 6 sections, with amazed triangular course of action. The appropriation of warmth channels are appeared in Fig. 2.

The warmth pipe made of stainless steel, of the outer distance across is 25.4 mm, thickness 1.2 mm and aggregate length is 900 mm. The lengths of the evaporator segment, adiabatic segment and buildup segment are 425 mm, 50 mm, 425 mm, separately.

The two finishes of warmth funnels are fixed firmly and the filling measure of working liquid (refined water) is 30% of warmth pipe volume. The gadget comprises of two blowers which are associated with conduits of evaporator segment and condenser side of area. The warming gadget made out of ten electric air radiators of 10 kW of length 400 mm and estimated by K write sensors.

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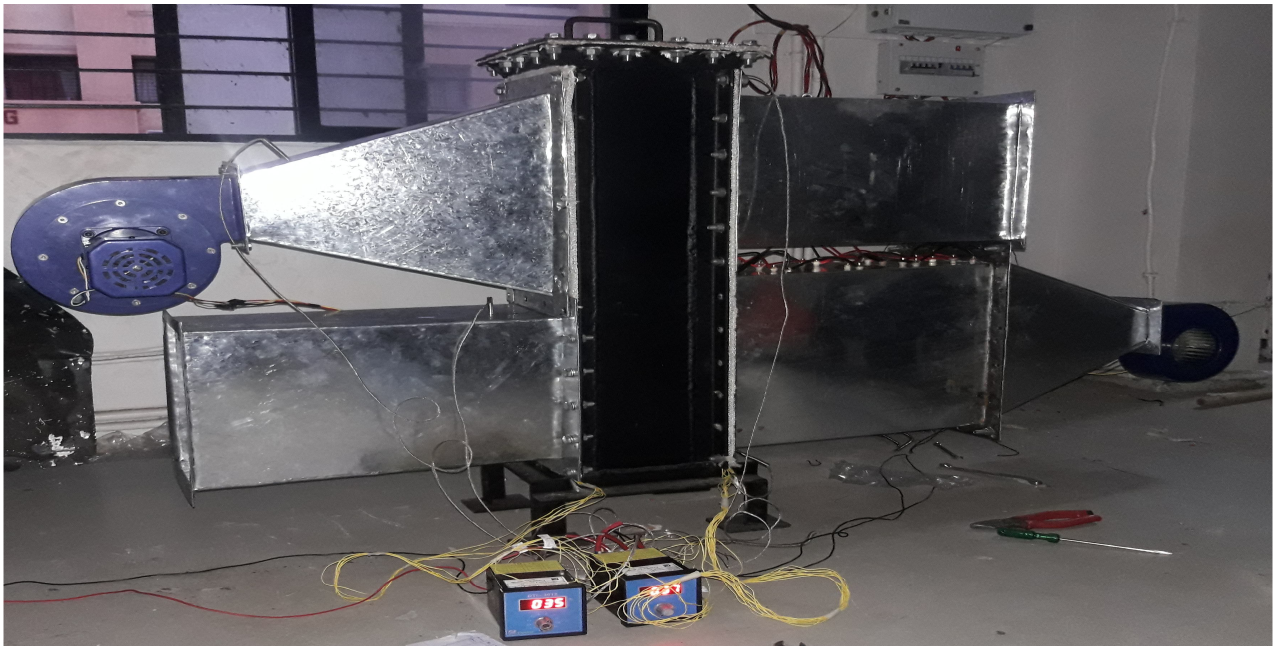

Fig.1 Schematic diagram of the experimental apparatus.

B Experimental Design

With a specific end goal to evaluate the execution and decide the ideal working state of HPHE for gas cooling application in industry, heat exchange rate, productivity are estimated by variety of condenser bay mass stream rates. The ideal states of HPHE can be resolved. It is appeared in Fig. 1 squander warmth of hot wind streams through the vanishing area of HPHE to discharge warm. In this procedure temperature of air is 100 °C steady amid exploratory process. The frosty wind streams over the condenser segment of HPHE and its temperature is 28 °C. Comparing the thickness of air 1.2 kg/m3 and its particular warmth limit is 1.005 kJ/(kg °k) in display examine. The managing estimation of mass stream rate from 0.0625 kg/s to 0.25 kg/s. The temperature pointers are utilized to record the all temperatures over various mass stream rates. At the point when framework is steady in trial condition 16 sets of readings of information are recorded constantly and clear deviations are expelled. The normal qualities are taken for the last exploratory information of working condition.

In analyze the hot wind stream rate is consistent, the chilly wind stream is shift and the estimations of gulf and outlet temperatures are recorded. In light of this, the HPHE framework execution parameters are examined, and the ideal working states of framework are resolved.

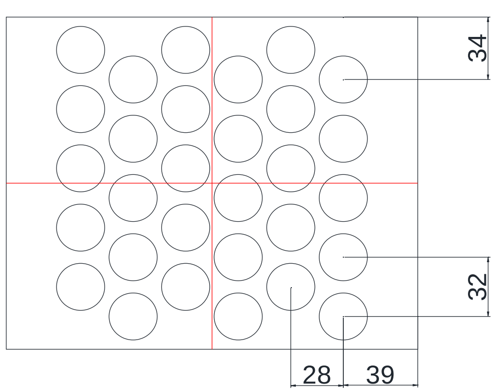

Fig. 2 Schematic diagram of distribution of heat pipes

III. RESULTS AND DISCUSSIONS

A plot of the temperatures versus the mass flow rates was created to ensure the result was consistent. Fig.3 shows the temperature of the flow at the inlets and outlets of the evaporator and condenser sections of the heat exchanger. It can be observed that the duty of the heat exchanger increases at higher mass flow rates shown by the greater difference in temperature in the evaporator section as well as condenser section both side of mass flow rates. A similar trend was observed by H. Mroue *et.al* [3].

The proficiency of the test unit was likewise decided by the distinctive delta conditions and is shown in Fig. 4. The chart demonstrates a decent upward pattern for various stream rates and temperature for 100 °C. This is caused by an adequate heat being consumed by the pipe, causing regularities in the bubbling administration which brings about better execution. At higher mass stream rates the proficiency is higher as the pipe has consumed the heat in the stream Fig. 4 also illustrates how the efficiency increases with the as increase in the mass flow rate. Increasing the air mass flow rate results in an increase in the temperature change of cold side and therefore an increase in the efficiency of the heat exchanger. The maximum efficiency achieved was 89.28% at 0.1875 kg/s, 100 °C. Efficiency of test unit was when lower mass flow rates result in lower efficiency.

Fig. 5 shows the variation of temperature along the heat pipes were recorded for four different mass flow rates at 10 kW heat input. The maximum temperature was recorded at Te2 in evaporator section at different mass flow rates while in condenser section the temperature increases towards the end as air flow through the condenser section it absorb heat continuously hence the heat gaining capacity of air reduces towards the end of condenser section leads to increase the temperature in the condenser. Then a similar trend was observed for all four mass flow rates.

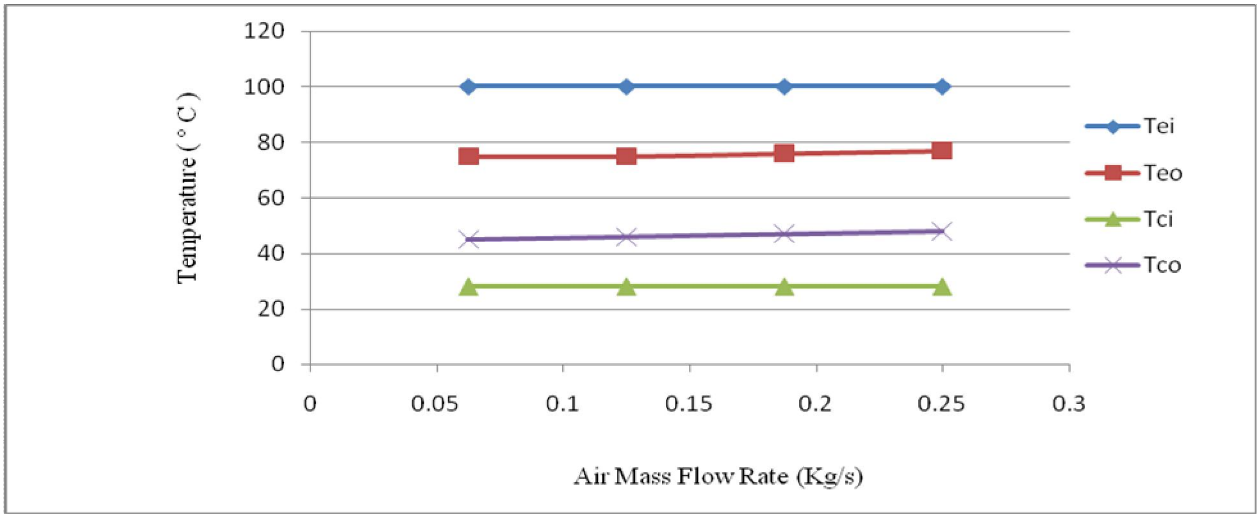

Fig. 3 Temperature distribution of heat exchanger for 100 °C inlet temperature

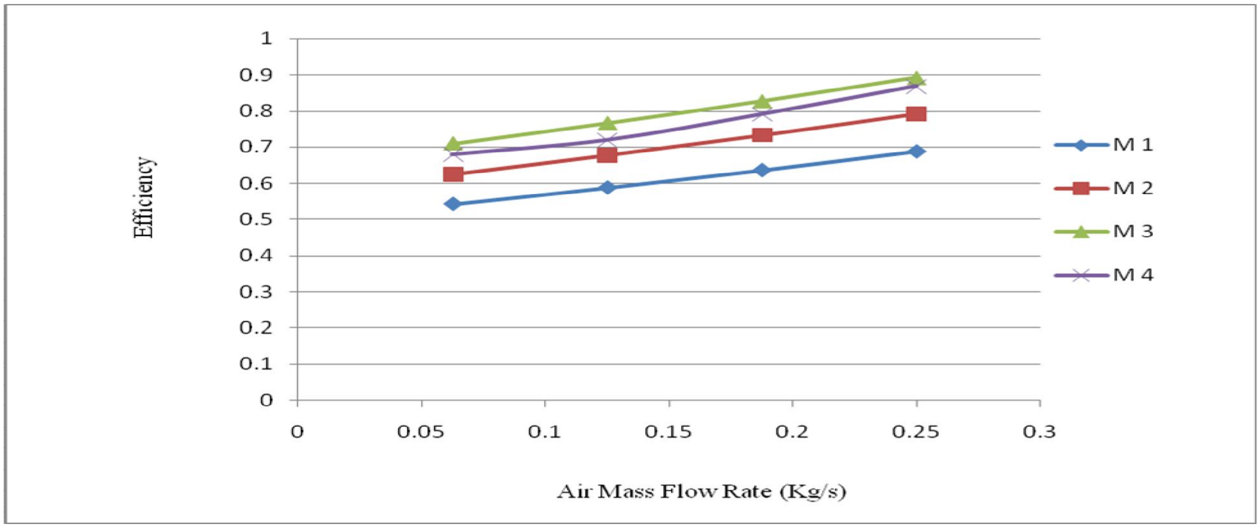

Fig. 4 Efficiency of heat exchanger for 100 °C inlet temperature

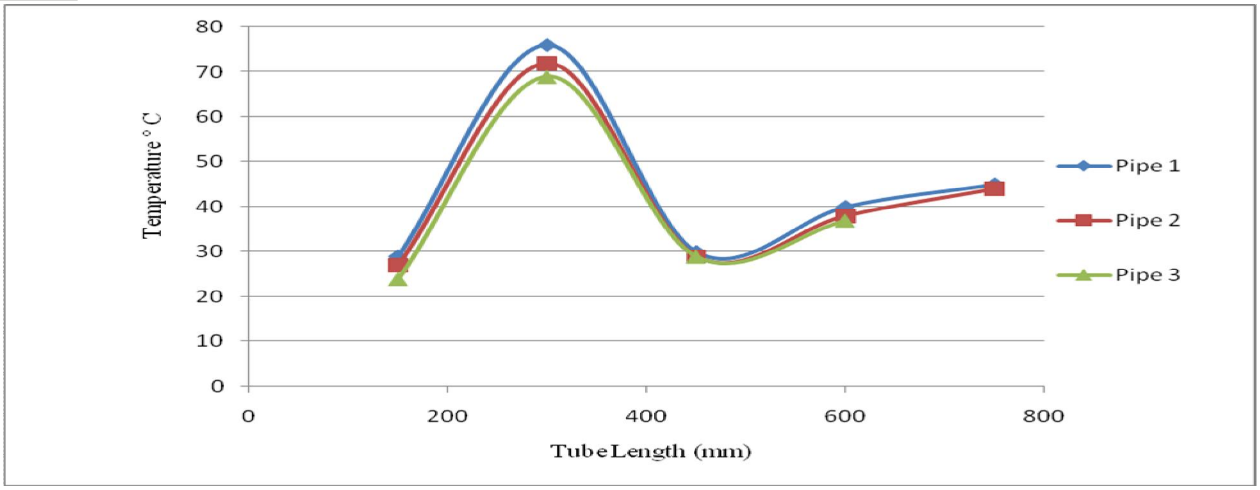

Fig. 5 Temperature of heat pipe according to inlet condition (ṁ=0.1875 Kg/s)

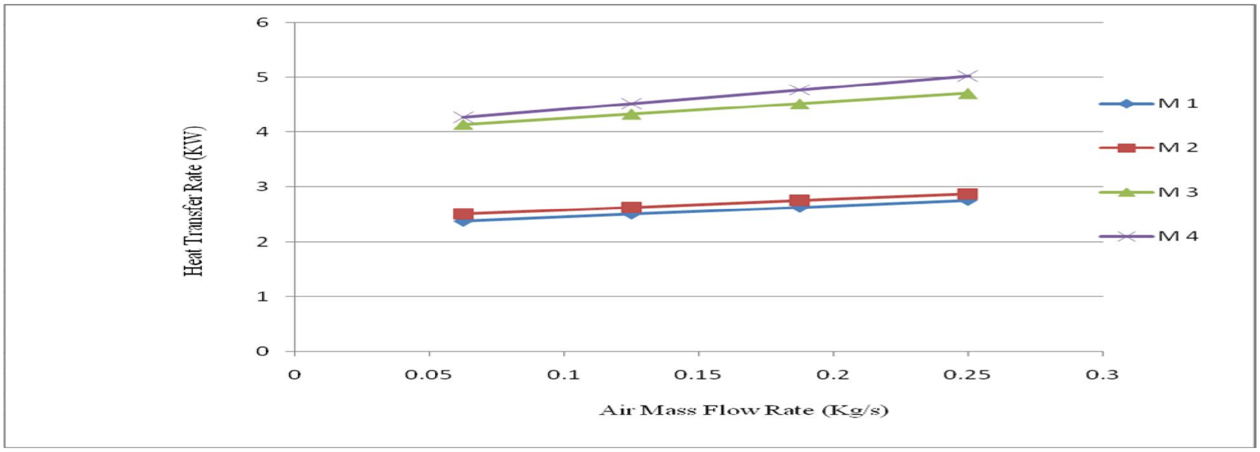

Fig.6 Heat transfer rate for different flow rates at 100 °C air at inlet temperature

Fig.6 a plot show the heat transfer rate versus air mass flow rates across heat pipes at different inlet conditions. Total heat transfer rate taking into account for different mass flow rates at 100 °C inlet condition. Likewise, increasing the mass flow rate increases the overall turbulence, also having the effect of increasing the overall heat transfer rate. Heat transfer rate is lower as mass flow rate is lower. A similar trend was observed by H. Mroue et.al [3].

IV. CONCLUSION

In this paper new sort of heat pipe heat exchanger aerial has been proposed and effectively done, its warm execution examined by mix of a few systems including heat exchange rates and proficiency. The outcomes were broke down utilizing articulations from late writing survey utilized as a part of trial, for example, factor mass stream rates and gulf temperatures stays consistent. The following conclusions were obtained by experimental Results:

A. The higher heat transfer was achieved at higher mass flow rates.
B. The efficiency was to be directly proportional to mass flow rates.
C. The maximum efficiency 89.28% was achieved at higher mass flow rates and inlet temperature was 100 °C.
D. To improve efficiency heated air which was obtained evaporator outlet again recirculates to evaporator inlet. This application used for clean as well as dirty gas cooling process for waste heat recovery.
E. To modify the surface and dimensions of heat pipes.
F. The theoretical work, optimization of structure and enhancement of heat transfer of HPHE should be paid more attention in the future research. Moreover, further investigation on automatic control and regulation of waste heat recovery is also needed.

G. The waste heat recuperation is an exhaustive capacity and vitality sparing potential, due to the open absence of adequate learning and comprehension of framework. Government divisions, look into organizations building and specialized people cooperate to advance the innovation improvement for stainless steel and advantageous life.

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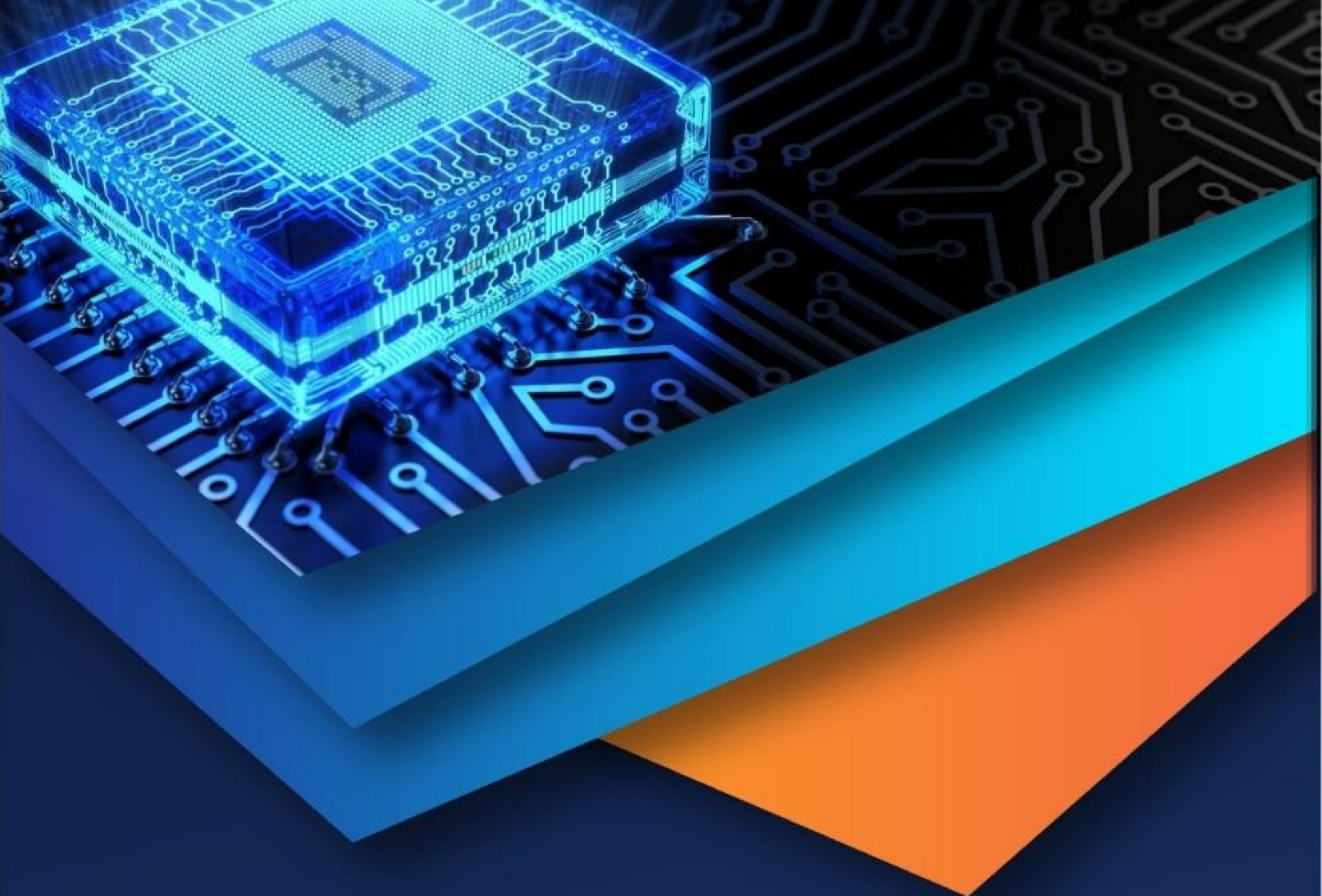

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