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Experimental Analysis of the Latent Heat Storage System (LHS) Using Paraffin Wax as Phase Change Material

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Abstract: An experimental study using paraffin wax as a phase change material (PCM) was performed to analyse thermal physiognomies on the latent heat storage system (LHS). The use of phase change materials through latent heat storage is an unusual approach to maintaining thermal energy. There is the advantage of considerably high energy storage and the uniform temperature of the storage process. Tube & shell type heat exchanger (HE) has been used in this experimentation. Water circulates in tubes and around the tube's paraffin wax as phase change material is filled. The focus is on heating (charging) and cooling (discharging) of PCM (paraffin wax), which is the melting and solidifying of paraffin wax. The temperature distribution in paraffin is studied consistent with the various flow rates of the warmth transfer fluid.
Keywords: Paraffin wax, PCM, Tube in Shell Type Heat Exchanger, HTF, Latent Heat Storage.

I. INTRODUCTION

Due to the rise of energy costs, buildings energy consumption has attended to decrease within the past decades. This gives a golden opportunity for developing innovative renewable technologies that are more adapted to recent buildings with low energy demand. So, the primary challenge is to manage non-simultaneous availability of heat source or sink and therefore energy demand of buildings. Hence, different technologies dedicated to energy storage are developed recently; one among them is that the use of phase change materials (PCM). These materials are considered because they exhibit a better heat storage capacity than sensible storages and a to unable phase change temperature consistent with their composition. There are three forms of thermal energy storage process, namely sensible heat storage, latent heat storage and thermo-chemical storage. Latent heat storage materials that are used to store thermal energy through change of state are referred to as phase change materials (PCMs). Latent heat-based TESs (LHTESs) show advantages of high storage density and fractional temperature swing. As an example, for the equivalent amount of stored thermal energy, an ice storage unit would require 8 times less volume as compared to a typical water storage unit storing with 10°C temperature change. Furthermore, the extensive variety of PCM‟s phase change temperatures make it possible to tailor each of the precise applications with suitable working conditions.

Nevertheless, only limited result shows in making high capacity and high thermal storage/extraction rated systems. One major issue with use of PCMs is that the heat transfer difficulty in charging and discharging of thermal energy. A typical thermal conductivity of PCM is wwithin the range between 0.2W/m-K and 0.7W/m-K. Advanced design of heat exchangers and accurate numerical evaluation may shed light to high performing TES systems. In parallel, sub cooling and phase separation properties as well as inflammability and corrosion issues are other technical bottlenecks to be overcome.

Shell and tube type HE is the better encouraging equipment as latent heat storage system because it serves high efficiency for a minimum volume is different from other materials in the way that it can absorb or release a multiple amount of latent heat when changing phase. The use of the abundant source solar thermal energy and hot waste streams available in industries has attracted the scientific community to serve attractive solutions for the issue on energy conservation and storage/retrieval. Thermal energy often stored in the form of sensible heat in which the temperature of the storage material varies with the amount of energy stored. Water or rock are often the simplest example. Alternatively thermal energy is often stored as heat of transformation during which energy is stored when a substance changes from one phase to a different by either melting or freezing. The temperature of the substance remains constant during phase transition. Of the two latent heat thermal energy storage technique has proved to be a far better engineering option because of its various advantages like large energy storage for a given volume, uniform energy storage/supply, compactness, etc.

Table I: THERMO- PHYSICAL PROPERTIES of COMMERCIAL GRADE PARAFFIN WAX

Melting temperature of the PCM	54.32 °C
Latent heat of fusion	184.48 kJ/kg
Density of the PCM (Liquid phase)	775 kg/m^3
Density of the PCM (Solid phase)	833.60 kg/m^3
Specific heat of the PCM (Solid phase)	2.384 kJ/kg °C
Specific heat of the PCM (Liquid phase)	2.44k J/kg °C
Thermal Conductivity	0.15 W/m°K
Viscosity	6.3 X10^{-3}
Kinematic Viscosity	8.31 X10-5 m^2/sec
Prandtl Number	1001.23
Thermal Expansion Coefficient	7.14 X 10-3 /°C

II. PROBLEM STATEMENT

Population of world is increasing every day, therefore demand for energy increasing. Temperature of earth is increasing, because ofgreenhouse effect. Increase in pollution is caused due to emission of toxic gases, refrigerant such as HFC, CFC, etc.

There will be problem of energy crisis, due to shortage of non- renewable energy sources.

Thus, gap between the global energy supply and demand has increase, so reaching to a thermally and cost efficientt thermal energy storage system has received a considerable attention among researchers.

In order to supply heating and cooling effect electricity could also be costly. Efficiency of storage devices isn't more enough, to extend efficiency we haveuse PCM.

III. OBJECTIVES

A. The main objective of this project is to analyse the heat transfer rate in a PCM heat exchanger.
B. To investigate the charging characteristics of the PCM under various conditions.
C. The study also analyses the societal effects that more efficient heat storage might have.
D. To carefully assess, through theoretical modelling as well as measurements of PCM Heat Exchanger in real applications.
E. To store energy and supply it whenever requires.

IV. METHODOLOGY

Usually experimentation is done over shell & tube type heater exchanger for its performance improvement. For this experiment, a potential survey was conducted over use of PCM which uses this energy. Qualitative data was obtained from this survey. After analysis of this data, actual problem was found on which research is to be done. Further the problem regarding PCM was defined.

An actual model was made for this research. Testing of model includes numerical experimental analysis & Computational fluid dynamics simulation. The result obtained after experimentation and simulation is further discussed, analyzed and conclusion is recorded.

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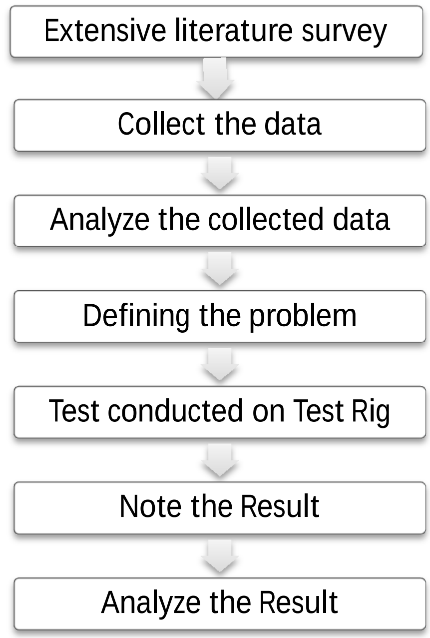

Fig 1: Methodology

V. LITERATURE REVIEW

Yue Hu, Per Kvols Heiselberg et. al. This paper presents a new window application for pre-cooling of ventilation air using a PCM heat exchanger. In summer, the PCM heat exchanger is discharged by night ventilation, and recharged by high temperature ambient air in pre-cooling mode. The design and optimization processes of the heat exchanger are conducted by means of numerical modelling, which is verified by full-scale experiments. The nonlinear properties and hysteresis of PCM are set in the model. The hysteresis of PCM used in the model is slightly overvalued by DSC measurement, but the deviation from the experiment lies within a reasonable range.[1]

S. Bakhshipour, M.S. Valipour, Y. Pahamli et. al. This paper includes Parametric analysis of domestic refrigerators using PCM heat exchanger in the present study, numerical simulation of refrigeration cycle incorporated with a PCM heat exchanger is carried out. To this end, the refrigeration cycle without PCM has been simulated and then, the performance coefficients of the refrigerator in either with and without PCM are evaluated.[2]

Jaume Gasia, Marc Martin, Luisa F. Cabeza et. al. By referring this paper we understood Latent heat thermal energy storage (LHTES) using phase change materials (PCM) is an effective way of storing thermal energy because of its high energy storage density and the nearly isothermal melting and solidification processes at the phase change transition temperature of the PCM. Studied the feasibility of storing latent heat with liquid crystals by performing different techniques such as polarized light microscopy, Differential Scanning Calorimetry (DSC), Thermo Gravimetric Analysis (TGA), and rheological measurements. They found that these materials showed promising results despite the fact that further investigations were required. [3]

Zeshan Abbas, Khurram Shahzad, Saeed Jamal et. al. They performed experimental study on Latent Heat Storage system (LHS). Aim of this study was to analyse thermal physiognomies. They also introduced energy crisis that would occur in future. Therefore, we have to develop renewable energy methods to deal with energy crisis. Paraffin wax is a good PCM for energy storage in latent heat storage system. It has a suitable transition temperature range of 50-60°C and a relatively high latent heat of 206 kJ/kg.[4]

VI. EXPERIMENTATION

It consists of heat exchanger with paraffin wax as PCM, insulation cover, piping, pump, frame, flow meter, and temperature sensor etc. Pictures of experimental setup, construction detail are shown in fig. (a).

In experiment the temperature distributions of fluid and the wax in the Heat Exchanger for two different flow rates are recorded during heating and cooling processes. During the heating process the fluid at high temperature is circulated through the heat exchanger continuously.

Fig 2: Experimental Setup

A. Equations

1) $\eta = Q_S/Q_A$
2) $QS = M_w * C_{pw} * T$
3) $QA = M_{pcm} * Cp_{pcm} * \Delta T + M_{pcm} * L_{pcm}$

Where,

Q_s = Heat stored
Q_a = Heat available
M_w = Mass of Fluid (HTF)
Cp_w = Specific Heat of Fluid (HTF)
M_{pcm} = Mass of PCM
Cp_{pcm} = Specific Heat of PCM
L_{pcm} = Latent Heat of PCM

B. Observation Tables

Table 2: Reading of Axial Temperature with Time During Charging Mode with Avg. Flow Rate Of 20 L/Hr

TIME (sec)	PCM (°C)	HTF (°C)
0	32	70
15	45	55
30	50	54
45	55	53
60	59	52
75	60	52
90	62	51

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Table 3: Reading of Axial Temperature with Time During Charging Mode with Avg. Flow Rate Of 15 L/Hr

TIME (sec)	PCM (˚C)	HTF (˚C)
0	32	72
15	40	62
30	46	62
45	50	62
60	54	62
75	57	62
90	59	61

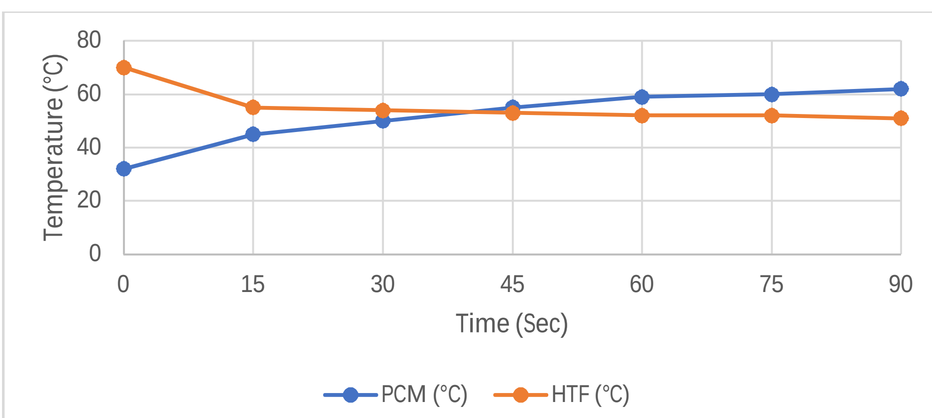
Table 4: Reading of Axial Temperature with Time During Discharging Mode with Average Flow Rate Of 20 L/Hr

TIME (sec)	PCM (˚C)	HTF (˚C)
0	62	35
15	50	44
30	45	42
45	40	42
60	38	40
75	30	37
90	28	37

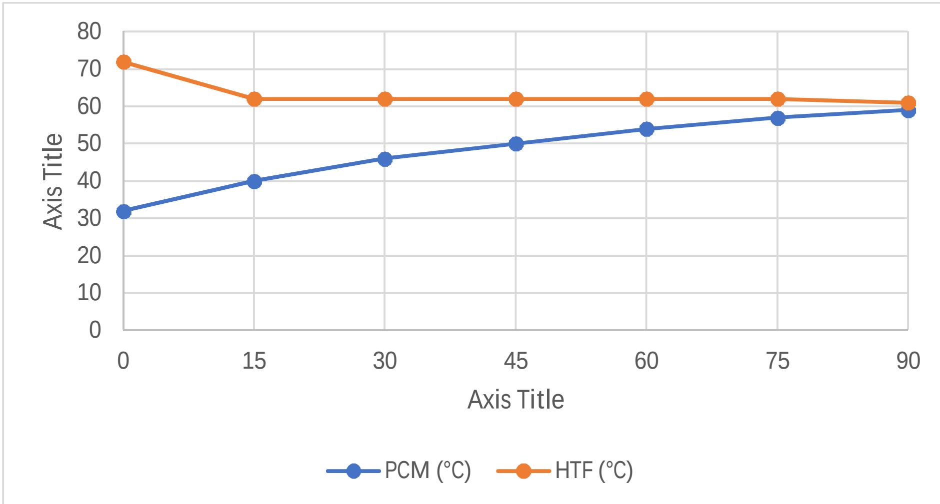
Table 5: Reading of Axial Temperature with Time During Discharging Mode with Average Flow Rate Of 15 L/Hr

TIME (sec)	PCM (˚C)	HTF (˚C)
0	58	32
15	55	50
30	50	48
45	48	42
60	42	40
75	40	38
90	38	35

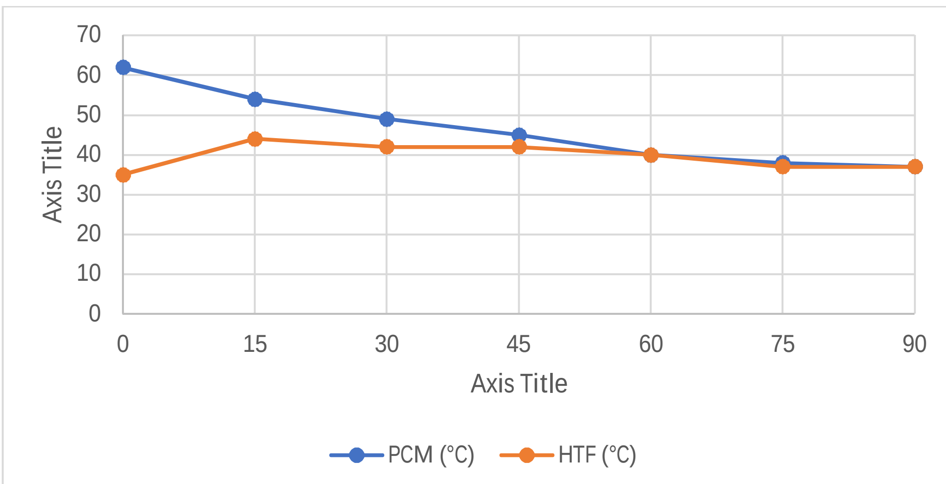
C. Graphical Analysis



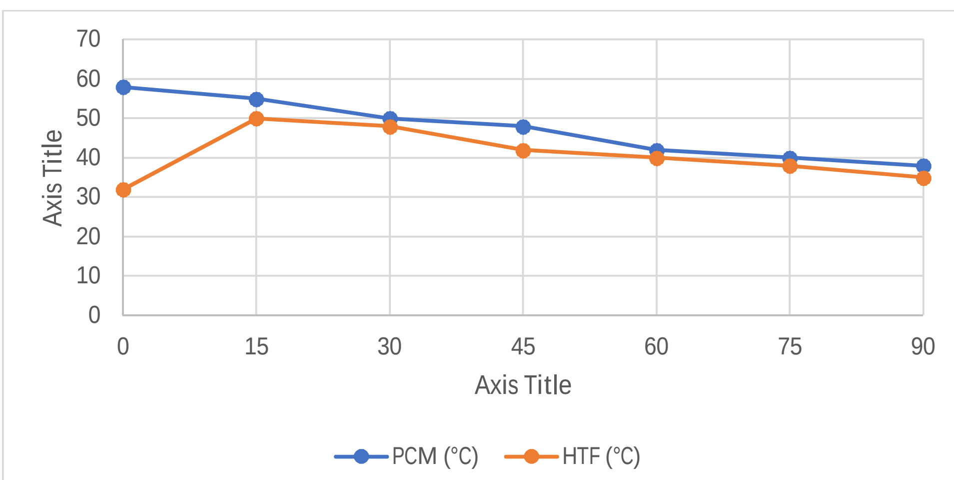
Graph 1: Variation of inlet & outlet temperature with time during charging mode with avg. flow rate of 20 L/hr



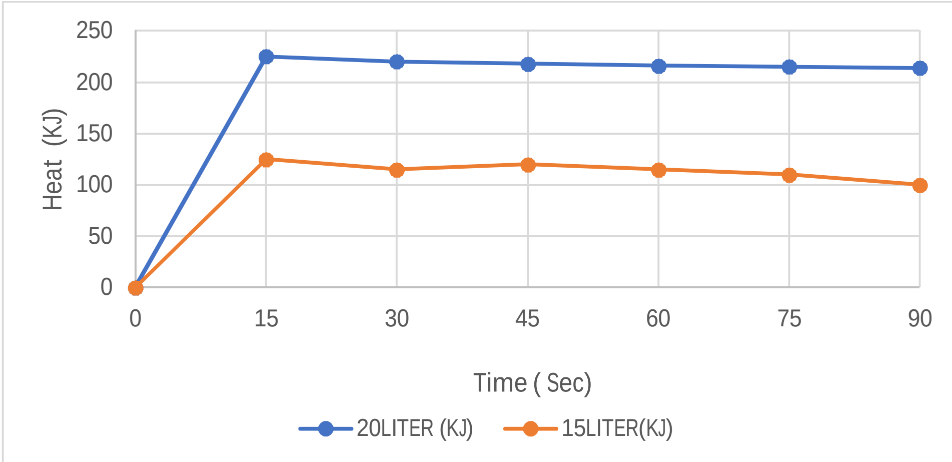
Graph 2: Variation of inlet & outlet temperature with time during charging mode with avg. flow rate of 15 L/hr



Graph 3: Variation of inlet & outlet temperature with time during discharging mode with avg. flow rate of 20 L/hr



Graph 4: Variation of inlet & outlet temperature with time during discharging mode with avg. flow rate of 15 L/hr



Graph 5: Heat Stored for flow rate of 20 & 15 L/hr

VII. RESULT

After Analysis of thermal physiognomies of paraffin wax as PCM, we get following Experimental Results,

A. Capacity of heat stored during charging for flow rate of 20 & 15 L/hr is 220KJ & 120 KJ resp. although for discharging at 20 & 15 L/hr heat stored is 140 KJ & 60 KJ resp.
B. For Experiment we get efficiency as 62% for 20 LPH & 50% for 15 LPH of flow rate. Which means efficiency increases with increase in flow rate.

VIII. CONCLUSION

The experimental results show the feasibility of using PCM as storage media in heat recovery systems. Latent heat storage (LHS) system with PCM is often successfully used for recovery and reuse of waste heat. When the rate of flow is higher the efficiency of the setup increasing. To optimize the performance of the heat exchanger loss of energy should be kept as low as possible. Experiment with flow rate 20lph gives better efficiency than with 15lph flow rate.

IX. ACKNOWLEDGMENT

I would like to thank my guide Dr. Nihar Walimbe & co-guide Prof. Maheshwar Chamnali for their expert guidance. Also, Shraddha Engineering where the model was prepared and experiments were conducted with help of Mr. Vijay Pawar Head/ Owner of company. I would also thank Prof. Prashant Wavhal for helping in simulation work using Ansys software.

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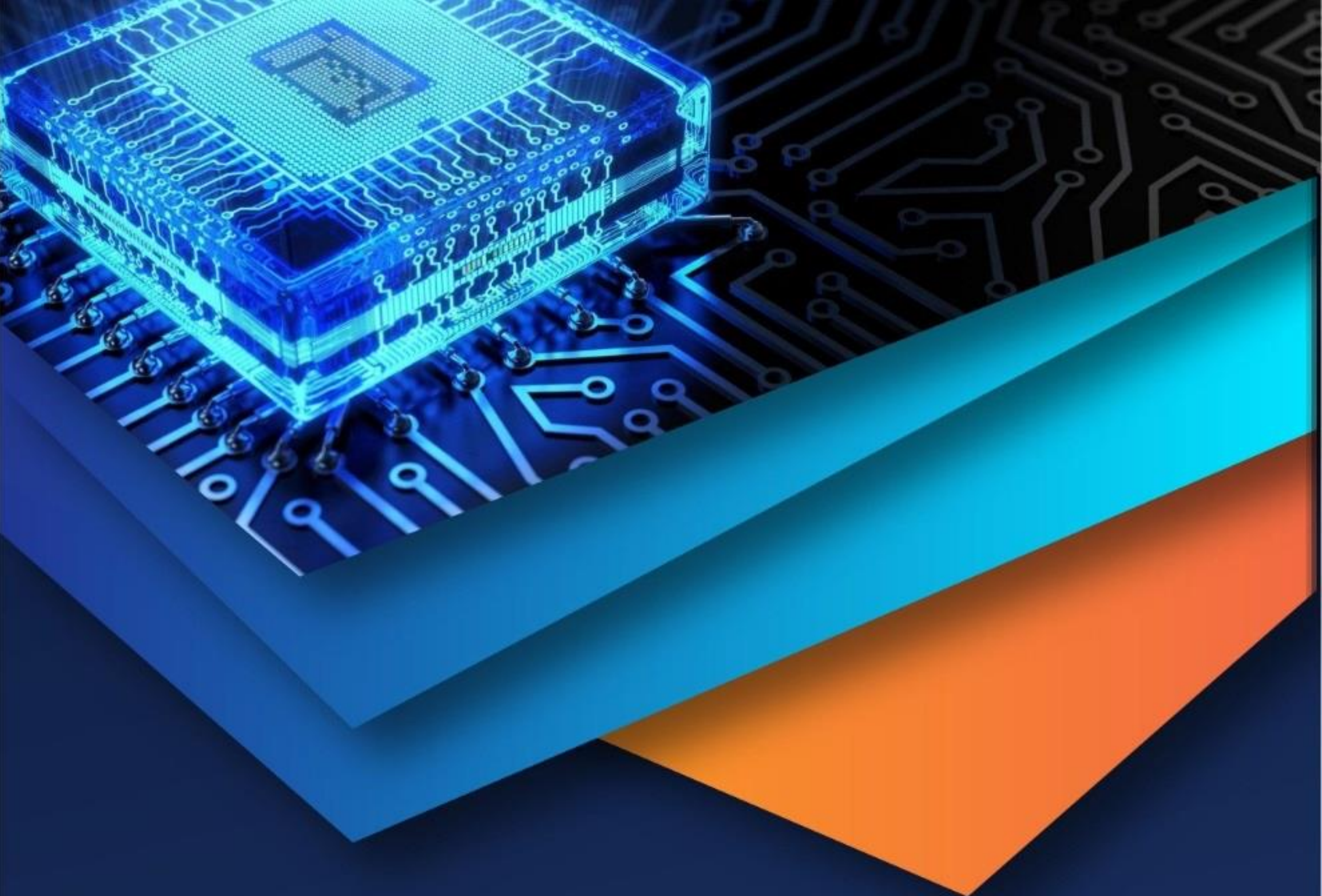

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