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A Literature Review on Use of Nanofluids in Refrigeration Systems

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Abstract*: In the present scenario, refrigeration and air conditioning are essential equipment for comfort living of human being. The focus of the researcher is to increase the cooling capacity and developed an energy efficient refrigeration system. So the attempt is made to use nanofluid in refrigeration systems to enhance the cooling capacity and reduce power consumption. Nanofluids are obtained by dispersing solid nanoparticles (diameter<100nm) made of metal oxides, metals, nanotubes etc. in common fluids such as water, glycol, oils, and refrigerants. The mixture of nanoparticles and pure refrigerants are called nanorefrigerants. In this paper, the basic, history of nanofluids, production techniques, preparation methods, thermophysical properties and performance characteristics of nanorefrigerants have been reviewed.

***Keywords*: nanofluids, nanorefrigerants, refrigeration systems, thermophysical properties, performance characteristics.**

I. INTRODUCTION

Refrigerants are extensively used in refrigeration and air conditioning systems in domestic, commercial buildings, industries and automotive. Refrigerants are the working medium which evaporates by taking the heat from the space that is to be cooled, thus producing the cooling effect. Refrigerant development throughout the history, took place due to different reasons, such as safety, stability, durability, economic or environmental issues, thus giving rise to new research and equipment improvement in terms of safety and efficiency.

In India, about 80% of the domestic refrigerators use R134a as the refrigerant due to its excellent thermodynamic and thermophysical properties. But, It must be phased out soon according to Kyoto protocol due to its high global warming potential (GWP) of 1300. From the environmental, ecological and health point of view, it is important to find some better substitute for HFC refrigerants. Refrigerators are identified as major energy consuming domestic appliance in the household environment.

Rapid industrialization has led to unprecedented growth, development and technological advancement across the globe. It has also given rise to new concerns of an energy crisis. Thermal systems like refrigerators and air conditioners consume a large amount of electric power. So, an avenue of developing energy efficient refrigeration and air conditioning systems with nature- friendly refrigerants is a current need.

The rapid advances in nanotechnology have led to emerging of new generation heat transfer fluids called nanofluids. Nanofluids are prepared by suspending nano-sized particles (1-100nm) in conventional fluids and have higher thermal conductivity than the base fluids. Nanofluids have the following characteristics compared to the normal solid-liquid suspensions.

1) higher heat transfer between the particles and fluids due to the high surface area of the particles
2) better dispersion stability with predominant Brownian motion
3) reduces particle clogging
4) reduced pumping power as compared to the base fluid to obtain equivalent heat transfer.

Based on the applications, nanoparticles the most common the new generation nanoparticles are ceramics, which are best split into metal oxide ceramics, such as titanium, zinc, aluminum and iron oxides.

II. HISTORY OF NANOFLUIDS

The idea of dispersing metallic particles into fields to enhance the thermal conductivity of fluids was first proposed by Maxwell (1873) considering that solids have high thermal conductivity than liquids. Earlier studies used mill metric or micrometric solid particles but this kind of fluids have major problems like tendency to deposit clogging, erosion, surface abrasion and high pressure-drop, etc. The use of nanofluids is to get more potential to overcome these problems.

Masuda et al., (1993) was measured the thermal conductivity of 13 nm Al_2O_3–water and 27 nm TiO_2–water. They found that when 4.3% volume fraction Al_2O_3 and TiO_2 nanoparticles were added to water, the fluid thermal conductivity increased by 32% and 11%,

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respectively, compared with pure water. This report was the first one on nanopowder and has thus served as a foundation for further fluid thermal conductivity studies.

Choi (1995) was introduced a new concept by mixing nanoparticles of sized 1-100nm into liquids to improve their thermal conductivity and called it as nanofluids. The purpose of the development of nanofluids is to enhance the heat transfer performance of various heat transfer fluids and lately, this concept has been extended to the refrigerants as well.

III. PRODUCTION TECHNIQUE OF NANOFLUIDS

Nanoparticles can be produced from mechanical attrition, pyrolysis, gas condensation, chemical precipitation. Methods like dc plasma jet, dc arc plasma, radio frequency induction plasmas, chemical synthesis, gamma rays and laser ablation are used. Inert-gas condensation is frequently used to make nanoparticles from metals with low melting points. The first need is to obtain a stable and homogenous colloidal solution for successful reproduction of properties and interpretation of experimental data.

The techniques applied to this purpose are:

1) Single-step method: In this case, synthesis and dispersion of nanoparticles into the fluid take place simultaneously.

2) Two-step method: Nanoparticles powder is put into the base fluids and physically dispersed by strong mechanical stirring,

low or high energy ultrasounds, ball milling, high-pressure homogenization (Fedele et al., 2010), thus obtaining nanofluids with different particle/fluid combinations. This technique is suitable for the dispersion of oxide nanoparticles, while it is less effective for metal nanoparticles, because of their greater tendency to create agglomerates with negative effects on the physical properties.

IV. EFFECT OF THERMOPHYSICAL PROPERTIES

The thermophysical properties are important to measure the effectiveness of a nanofluid. The thermal conductivity, viscosity, density, specific heat and latent heat are some of the most important thermophysical properties of a fluid.

A. Thermal Conductivity

To determine the heat transfer rate of a nanorefrigerant, it is important to know its thermal conductivity. Peng et al., (2009) experimentally measured the thermal conductivity of a nanorefrigerant and proposed a model to predict the thermal conductivity. The authors also investigated that with an increase in nanoparticle concentration, the thermal conductivity increases sharply. Mahbubul et al., (2013) observed the effect of volume concentration and temperature on Al2O3/R141b nanorefrigerant.

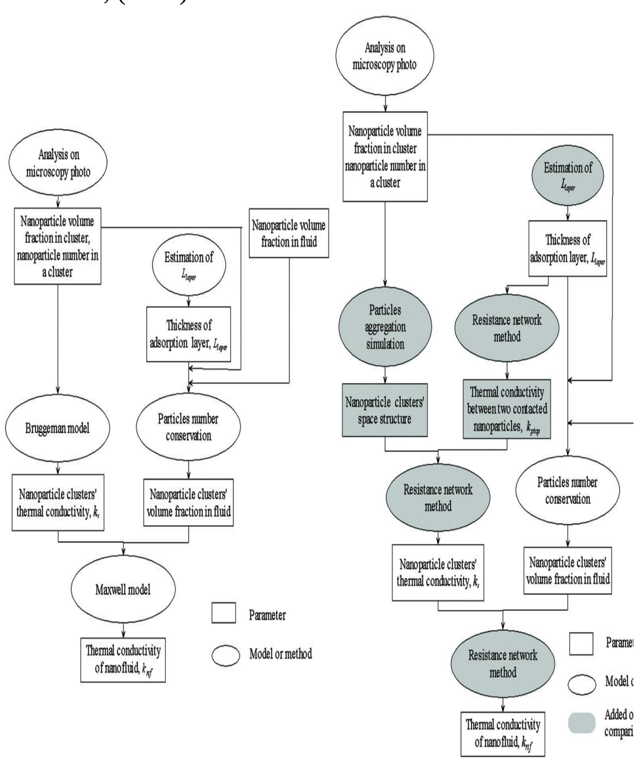

Fig. 1 Flow charts of (a) the Wang model (2003) and (b) the Peng model (2009).

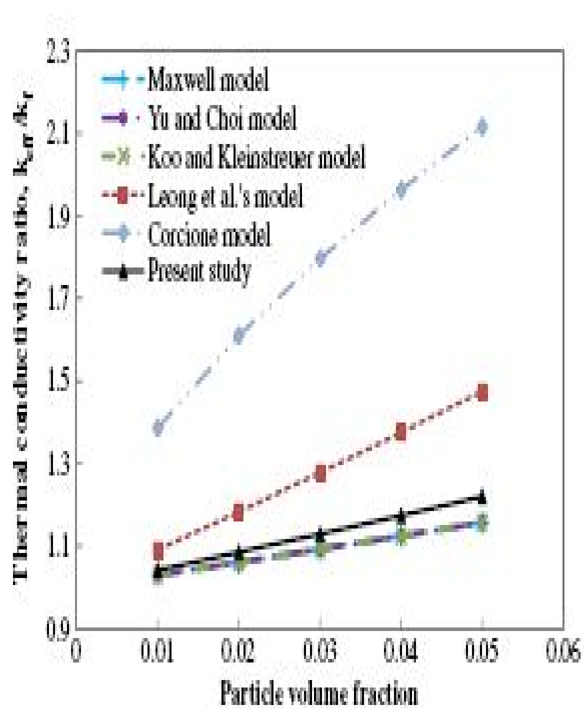

Fig. 2 Variation of thermal conductivity as a function of particle volume fraction (Mahbubul et al., 2013)

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B. Viscosity

The viscosity of nanorefrigerant is another important property like thermal conductivity. With the addition of nanoparticles to the refrigerant, the viscosity of the resultant nanorefrigerant increases as a result of which the pressure drop also increases during the flow. Recently, Alawi et al., (2015) observed viscosity variations in a SWCNT-R134a nanorefrigerant at different particle concentrations and fluid temperatures. They conducted their study by comparing viscosity values obtained from various viscosity models and concluded that the effective viscosity of a nanorefrigerant increases with an increase in particle volume fraction but decreases with an increase in temperature.

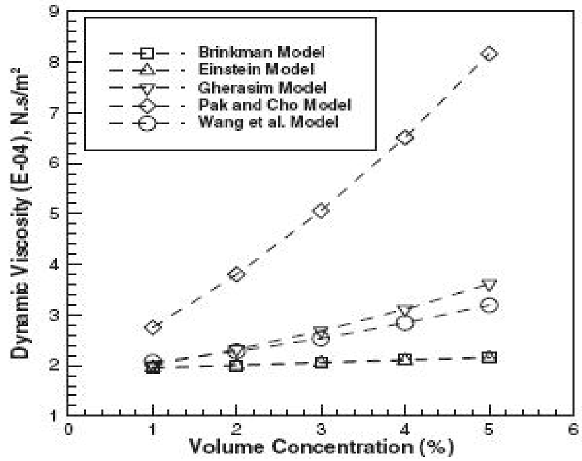

Fig. 3 Viscosity of SWCNT/R134a increases with the increase in particle volume fractions (at 300 K) (*Alawi et al., 2015*)

C. Density

For proper lubrication performance of a compressor, the viscosity and density of the nanolubricant are important. Kedzierski (2012) experimentally observed the variation of viscosity and density of CuO nanolubricant with different nanoparticle volume fractions (2%, 4%, and 40%) for a temperature range of 288 to 318 K with spherical nanoparticles of a diameter of 30 nm. The author found that the density of the CuO nanolubricant decreases with increases in temperature. The author also concluded that density increases with an increase in the CuO volume fraction at atmospheric pressure.

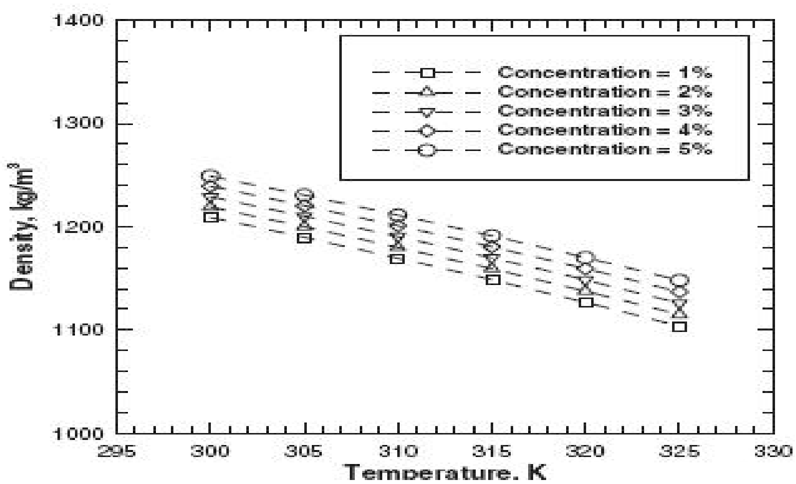

Fig. 4 Density of CuO/R134a decreases with increase in temperature (*Alawi et al., 2015*)

D. Specific Heat

The specific heat capacity of nanorefrigerant is one of the important thermophysical property because of its utilization in energy performance analysis of the system. Shahrul et al. (2014) presented an extensive and comparative review of the specific heat capacity behavior of nanofluids. It is observed that the specific heat of nanofluids mainly depends on the type of nanoparticles, the volume concentration of nanoparticles, temperature and the type of base fluid. Therefore, the specific heat of nanofluids can either increase or decrease by the addition of nanoparticles. Alawi et al., (2015) investigated that specific heat increases by increasing nanorefrigerant temperature from 300 K to 325 K and decreases by increasing volume concentration ranges from 1 to 5% of CuO/R134a.

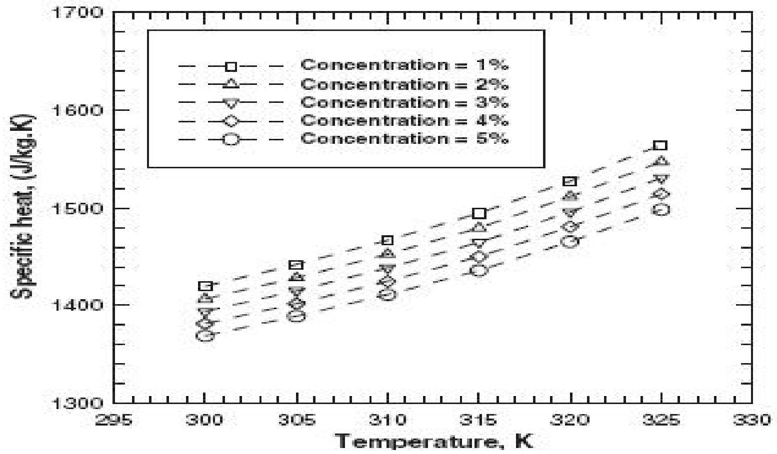

Fig. 5 Specific heat of CuO/R134a enhances accordingly with increase in temperature (*Alawi et al., 2015*)

E. Latent Heat

Latent heat (hfg) is also an important thermophysical property. Ameen et al., (2010) proposed that an enhancement of latent heat (hfg) in platinum and aluminum oxide nanofluids as a function of volume fraction and size of nanoparticles. It is observed that hfg increases with increase in the volume fraction and with a decrease in the size of nanoparticles. The authors presented the methodology in their work is found to be effective in evaluating the modification in the latent heat of nanofluids, with a change in volume fraction and size of nanoparticles.

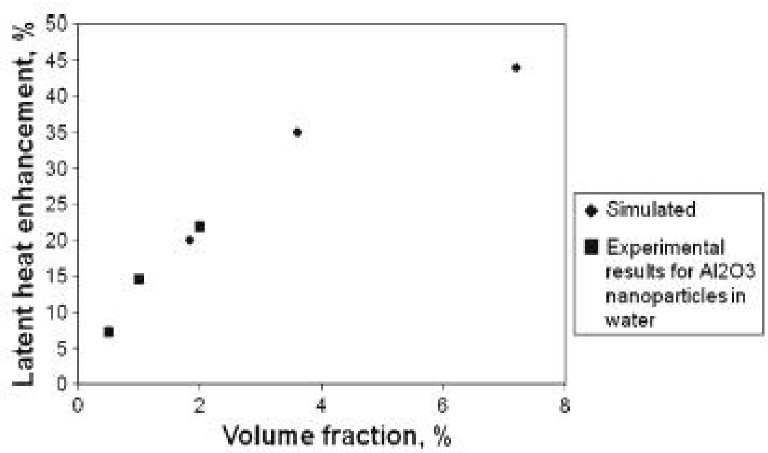

Fig. 6 Latent heat enhancement as a function of the volume fraction of nanoparticles, for a simulation of the Pt nanofluids with a particle size of 0.5 nm, compared with experimental data for Al2O3 nanofluids with 20nm sized particles (*Ameen et al., 2010*)

V. PERFORMANCE CHARACTERISTICS OF REFRIGERATION SYSTEM

Nanorefrigerants are considered as very effective to improve the performance of various thermal systems like refrigerators and air conditioners because it will improve the heat transfer capacity of refrigeration systems. Previously researchers suggested that the use of nanorefrigerants instead of pure refrigerants in refrigeration systems can provide several benefits.

A. Coefficient of performance(COP)

Mahbubul et al. (2015) analyzed the effect of temperature on thermal conductivity, viscosity, density, and specific heat of Al_2O_3/R134a nanorefrigerant. Additionally, it is observed the effects of modified thermo-physical properties on the COP of the nanorefrigerant and compared them with the effects of a base fluid. The author observed that the COP increases with the increase in the temperature. The highest rise of 15% in the COP was found at higher temperatures because of higher thermal conductivity.For investigating the effect of viscosity on the COP, the authors considered the R134a refrigerant and Al_2O_3/R134a nanorefrigerant with 5 vol% concentrations.

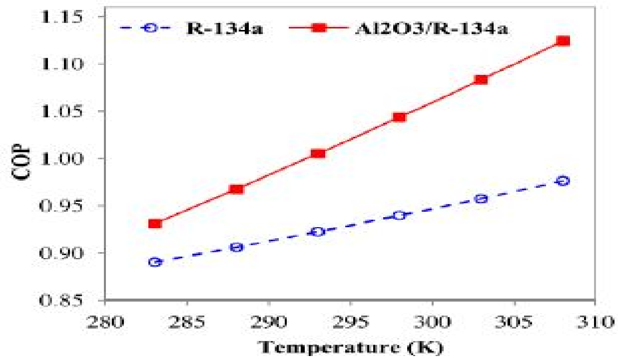

Fig. 7 Effect of thermal conductivity of Al_2O_3/R134a nanorefrigerant on COP at different temperatures (*Mahbubul et al., 2015*)

B. Energy Consumption

Bi et al., (2011) experimentally performed an energy consumption test and freezing capacity test on a domestic refrigerator in which TiO_2/R600a nanorefrigerant was used. The authors observed that the refrigerator with nanorefrigerant consumed 9.6% less energy with 0.5 g/L TiO_2/R600a nanorefrigerant as compared with pure refrigerant. Subramani et al. (2011) conducted an experimental test on an R134a refrigeration system by introducing a mixture of mineral oil and alumina nanoparticles instead of POE (polyester) oil. It is found that the freezing capacity was higher and power consumption reduced by 25%.

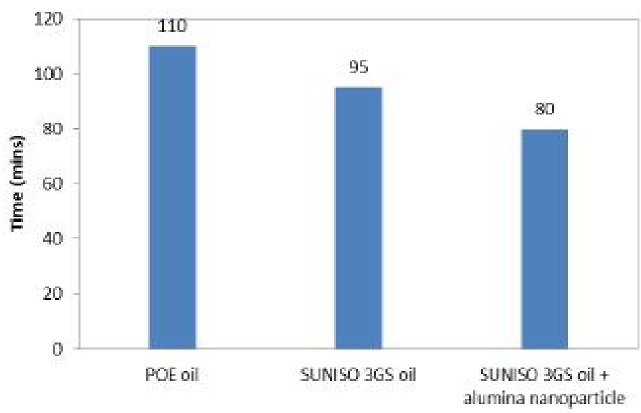

Fig. 8 Effect of nanoparticle on freezing capacity (Subramani N., Prakash M.J., 2011)

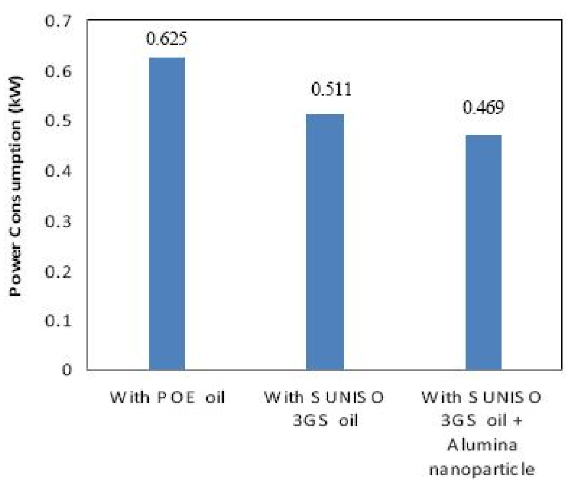

Fig. 9 Comparison of power consumption (Subramani N., Prakash M.J., 2011)

VI. CONCLUSION

Based on the literature review it is studied that nanofluids are to be a very efficient alternative to traditional fluids. Nanorefrigerants are superior fluids containing nano-sized particles. Nanorefrigerants are used to enhance the performance of a refrigeration system. This paper presents a review of the thermophysical properties and performance of the nanorefrigerants based refrigeration system. From the above literature, taking review into consideration I am going to study the performance of refrigeration system i.e., cooling capacity and power consumption by using nanofluids into various refrigerants and its blends.

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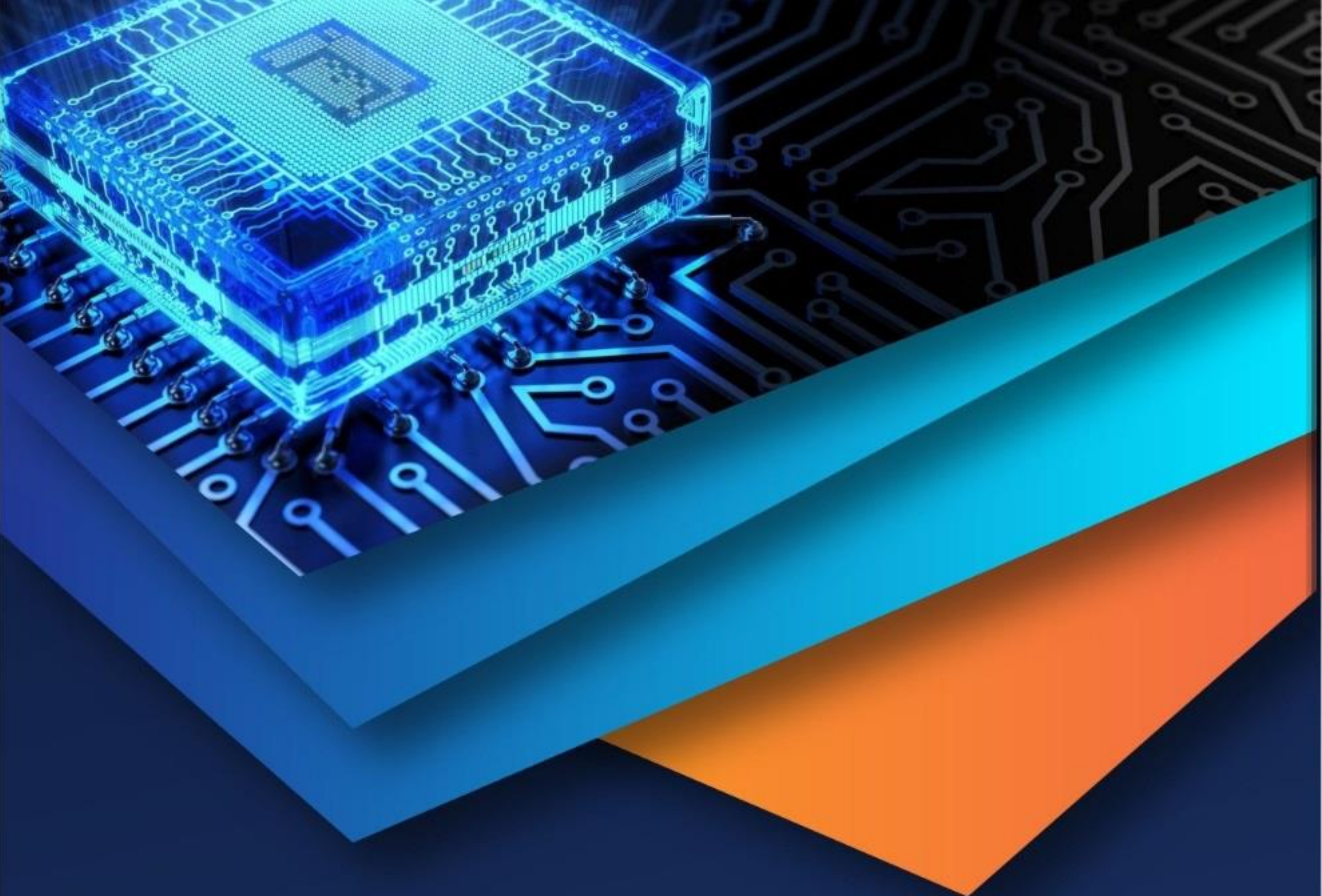

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