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Performance Evaluation of Domestic Refrigerator Using Eco-Friendly Refrigerant

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Abstract: Refrigerator is an important device in our day to day life. At present 80% of domestic refrigerators are working on R-134a which is having zero ODP(ozone depleting potential) value but higher GWP (global worming potential) value so there is need to find the eco-friendly refrigerant. In the present work eco-friendly refrigerant was used in the domestic refrigerator. The performance of the refrigerator was studied using R-134a refrigerant and mixture of propane R290 and iso-butane R600a (50/50) by mass. Then this enhanced performance due to mixture of propane R290 and iso-butane R600a (50/50) was compared with performance of refrigerator working with R134a and percentage of enhancement will be calculated on the basis of COP of the refrigerator. The refrigerator is also incorporated with the condenser fan and acrylic door. The performance of refrigerator using R-134a incorporated with condenser fan and acrylic door is compared with refrigerator using hydrocarbon incorporated with condenser fan and acrylic door. The comparison made between the COP of both refrigerant incorporated with and without acrylic door and condenser fan. Hence, the average coefficient of performance of refrigerant mixture of propane R290 and iso-butane R600a (50/50) by mass with Acrylic door and fan is enhanced up to 21.29 % than R-134a without acrylic door and fan.
Keywords: Refrigerator, Propane R-290 and Iso-butane R-600a, Condenser Fan, Acrylic Door, COP.

I. INTRODUCTION

The refrigerating machine is a device which will either cool or maintain a body temperature below that of the surrounding. Hence, heat must be made to flow from a body at low temperature to the surrounding at high temperature. Refrigerator is very important part in our day to day life. The refrigerator consists of thermally insulated compartment which when work, transfer heat from inside of compartment to the external environment so that the inside of the thermally insulated compartment is cooled to the temperature below the ambient temperature. Heat rejection may occur directly to the atmosphere in case of air cooled condenser and to water in case of water cooled condenser. The thermally insulated compartment mainly consists of condenser, compressor, evaporator and expansion device. The following processes take place in the refrigeration cycle. Heat is absorbed in the evaporator by the evaporation of the liquid refrigerant at a low pressure and corresponding low saturation temperature. The evaporated refrigerant vapour is compressed to a high pressure in the compressor consuming work. The pressure after compression is such that the corresponding saturation temperature is higher that the temperature of the surrounding. Heat Q is then rejected in the condenser to the surrounding at high temperature.

In the late 1800s and in the early 1900s, ammonia, carbon dioxide, sulphur dioxide and methyl chloride were used as refrigerant. But all these refrigerant were found to be toxic and hazardous. After 1900s chlorofluorocarbons and hydro chlorofluorocarbons were used as refrigerant because they possess many suitable properties like stability, nontoxicity, non-flammable, good material compatibility etc. The main problem with CFC and HCFC is they contain chlorine which goes to the stratosphere where they react with ozone. As we know ozone layers protect the UV rays to fall on the earth surface. So it is not good to continue the use of halogenated fluids. The CFCs have been banned in developed countries since 1996, and in 2030, producing and using CFCs will be prohibited completely in the whole world. HCFCs will be prohibited in the future. at present the household refrigerators work on refrigerant R-134a which is having low ODP(ozone depleting potential) but large value of GWP (global worming potential) .Many researchers are finding out the alternative refrigerant to use in refrigerators which are ecofriendly i.e refrigerant does not harm the environment and also the UV protective ozone layer.

A. Refrigeration system: working principle and construction

Refrigeration system is based upon the Clausius statement of second law of thermodynamics. This statement shows, “It is impossible to construct a device which, operating in a cycle, will produce no affect other than the transfer of heat from a cooler to a hotter body. The construction of vapour compression refrigeration system is illustrated in figure 1. This system consists of four basic components, i.e. a compressor, an evaporator, a condenser and capillary tubes.

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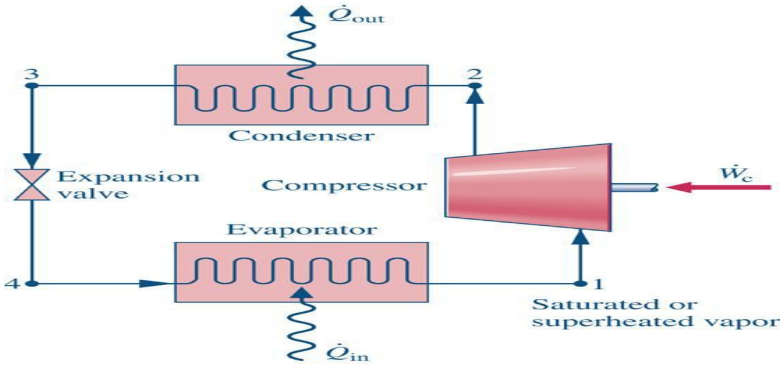


Fig 1: Vapour Compression Refrigeration Cycle

Here the compressor delivery head, discharge line, condenser and liquid line form the high pressure side of the system. The expansion line, evaporator, suction line and compressor suction head form the low pressure side of the system.

II. EXPERIMENTAL SET-UP

The aim of the present work is to evaluate experimentally, the effect of hydrocarbon (mixture of R290 and R600a) as refrigerant in the 165liters Allwyn refrigerator which is design to work on refrigerant R134a. The refrigerator is also incorporated with condenser fan and acrylic door.


Fig.2: Photographic View of Experimental set-up

Table 1: Details of Experimental Set-up

Sr. No.	Description	Dimension/range
1	Refrigerator Capacity	Allwyns,165 litres
2	Compressor	Hermetically Sealed 360 btu/hours 92 watts
3	Evaporator	Roll Bond Evaporator
4	Capillary tube	Diameter:- 0.31 inch Length:- 11 feet
5	Condenser	Air cooled Diameter:-1’4 inch

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6	Pressure Gauges	Suction gauge:0-250 psi Pressure gauge:0-500psi
7	Thermocouples	Temperature range: -50^{0}C to 99^{0}C
8	Digital temperature Controller	Temperature range:-50^{0}C to 99^{0}C
9	Condenser fan	4 square inch 12 watts Speed:-1300 rpm
10	Energy meter	5-30A,240V,50Hz

A. The component of experimental set-up

1) *Refrigerant:* The refrigerant flows through all the internal parts of the refrigerator. It is the refrigerant that carries out the cooling effect in the evaporator. It absorbs the heat from the substance to be cooled in the evaporator (chiller or freezer) and throws it to the atmosphere via condenser. The refrigerant keeps on re-circulating through all the internal parts of the refrigerator in cycle.
2) *Compressor*: The compressor is located at the back of the refrigerator and in the bottom area. The compressor sucks the refrigerant from the evaporator and discharges it at high pressure and temperature. The compressor is driven by the electric motor and it is the major power consuming devise of the refrigerator. the compressor used is hermetically sealed compressor.
3) *Condenser:* The condenser is the thin coil of copper tubing located at the back of the refrigerator. The refrigerant from the compressor enters the condenser where it is cooled by the atmospheric air thus losing heat absorbed by it in the evaporator and the compressor. To increase the heat transfer rate of the condenser, it is finned externally. the condenser used is air cooled condenser.
4) *Expansive valve or the capillary:* The refrigerant leaving the condenser enters the expansion devise, which is the capillary tube in case of the domestic refrigerators. The capillary is the thin copper tubing made up of number of turns of the copper coil. When the refrigerant is passed through the capillary its pressure and temperature drops down suddenly
5) Evaporator or chillers or freezer: The refrigerant at very low pressure and temperature enters the evaporator or the freezer. The evaporator is the heat exchanger made up of several turns of copper or aluminium tubing. In domestic refrigerators the plate types of evaporator is used as shown in the figure above. The refrigerant absorbs the heat from the substance to be cooled in the evaporator, gets evaporated and it then sucked by the compressor. This cycle keeps on repeating
6) *Freezer compartment:* The food items that are to be kept at the freezing temperature are stored in the freezer compartment. The temperature here is below zero degrees Celsius so the water and many other fluids freeze in this compartment. If you want to make ice cream, ice, freeze the food etc. they have to be kept in the freezer compartment.
7) *Acrylic gate:* Being made from high grade impact resistant materials, they will not shatter in the event of accidental damage. Tested to withstand 100kg trolley impacts without catastrophic failure. Even after major impacts and breakage, they may still remain serviceable until a replacement can be fitted. Various handle options available. A choice of face mounted, or 'full length' for added protection. Far greater clarity and thermal insulation when compared to the equivalent thickness 'glass' door. Soft-close dampers to reduce noise and fatigue. Also available with a scratch resistant coating.
8) *Refrigerator compartment:* The refrigerator compartment is the biggest part of the refrigerator. Here all the food items that are to be maintained at temperature above zero degrees Celsius but in cooled condition are kept. The refrigerator compartment can be divided into number of smaller shelves like meat keeper, and others as per the requirement.
9) *Refrigerator door compartment:* There are number of smaller subsections in the refrigerator main door compartment. Some of these are egg compartment, butter, dairy, etc.

B. Experimental Procedure

1) The refrigerator compressor is charged with R-134a refrigerant. The evaporator temperature is set on -15^{0}C. The readings were taken without the acrylic door and fan at an interval of 5 minutes till the temperature of evaporator reached the set value.
2) The refrigerator is attached with the acrylic door inside the main door and condenser fan was started. Again same readings were calculated
3) Now the refrigerator is charged with hydrocarbon mixture (R290/R600a) (50/50) by mass and the above procedure is repeated with acrylic door and fan and readings were taken.

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4) Now the readings were taken without door and fan.

III.RESULTS AND DISCUSSIONS

Here performance of Refrigeration system is discussed. It also discusses graphical relationship between average coefficient of performance with respect to time and freezer temperature. Experiments have been performed for achieving the freezer temperature -15^{0}C for both Refrigerant R134a and Hydrocarbon with and without acrylic door and fan.

A. Variation of Coefficient of performance by comparison between Refrigerant R-134a with and without Acrylic door and Fan:

1) Variation of COP vs. Time for R-134a with and without Acrylic door and Fan:

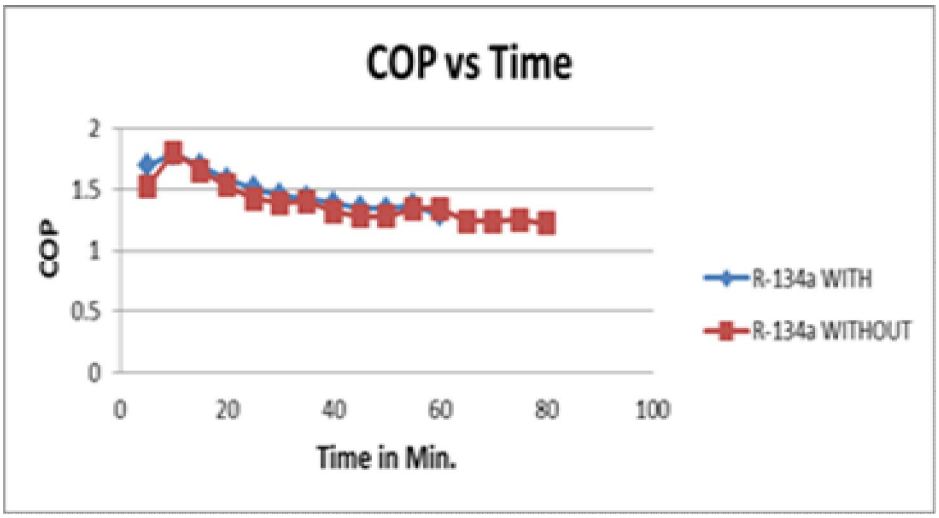


Fig.3: Variation of COP vs. Time for R-134a with and without Acrylic door and Fan

B. Variation of Coefficient of performance by comparison between Refrigerant Hydrocarbon with and without Acrylic door and Fan:

1) Variation of COP vs. Time for HC with and without Acrylic door and Fan

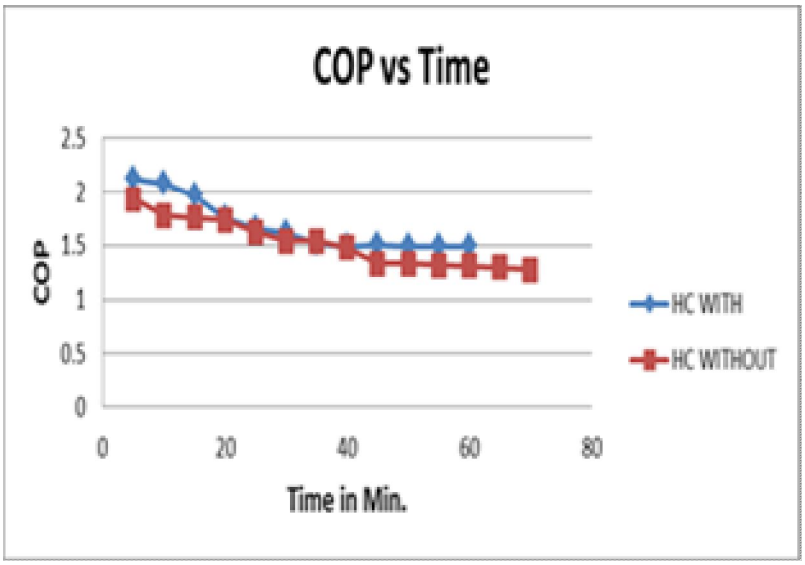


Fig. 4: Variation of COP vs. Time for HC with and without Acrylic door and Fan

C. Variation of Coefficient of performance by comparison between Refrigerant R-134a with and Hydrocarbon without Acrylic door and Fan

1) Variation of COP vs. Time for R-134a with and HC without Acrylic door and Fan:

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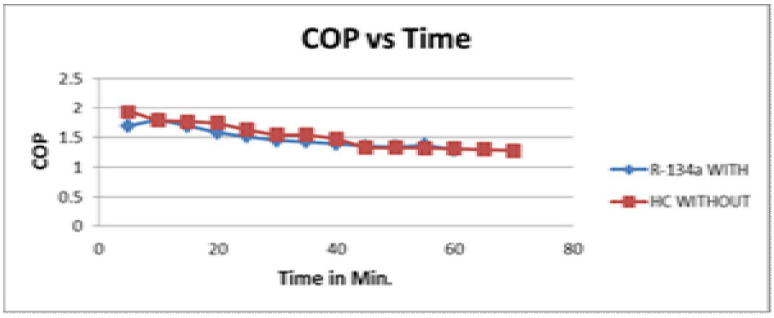


Fig. 5: Variation of COP vs. Time for R-134a with and HC without Acrylic door and Fan

D. Variation of Coefficient of performance by comparison between Refrigerant Hydrocarbon with R-134a without Acrylic door and Fan

1) Variation of COP vs. Time for HC with and R-134a without Acrylic door and Fan:

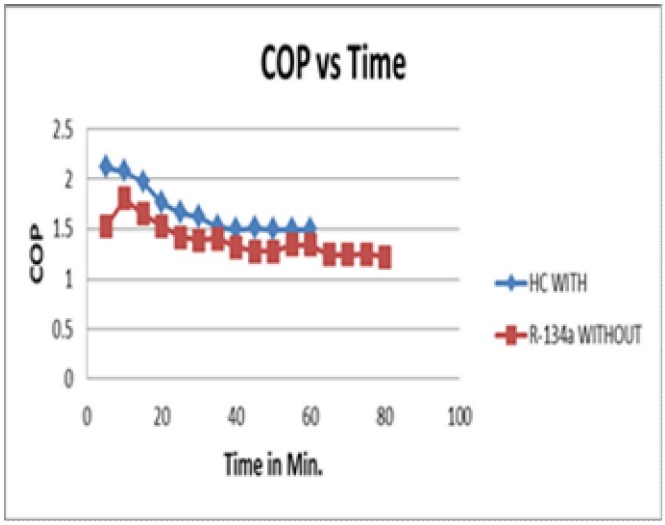


Fig. 6: Variation of COP vs. Time for HC with and R-134a without Acrylic door and Fan

E. Variation of Coefficient of performance by comparison between Refrigerant R-134a and Hydrocarbon without Acrylic door and Fan:

1) Reaction of COP vs. Time for R-134a and HC without Acrylic door and Fan:

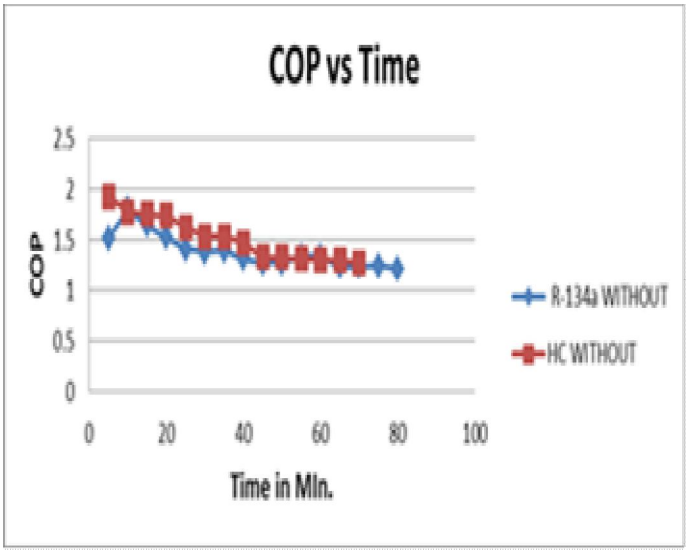


Fig. 7: Variation of COP vs. Time for R-134a and HC without Acrylic door and Fan

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F. Variation of Coefficient of performance by comparison between Refrigerant R-134a and Hydrocarbon with Acrylic door and Fan

1) Variation of COP vs. Time for R-134a and HC with Acrylic door and Fan:

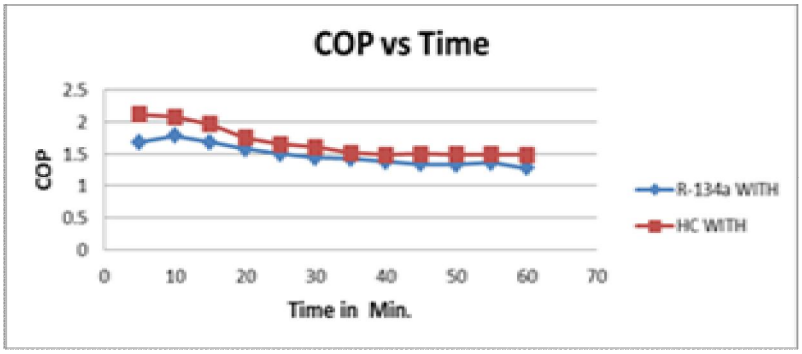


Fig. 8: Variation of COP vs. Time for R-134a and HC with Acrylic door and Fan

From above graphs are plotted between the coefficient of performance and time taken for achieving freezer temperature. -15^0C It has been observed that by comparing average coefficient of performance between Refrigerant R-134a and HC at with and without acrylic door and fan. Hence, the average coefficient of performance of HC with Acrylic door and fan is enhanced up to 21.29 % than R-134a without acrylic door and fan.

IV. CONCLUSIONS

The purpose of this work is to study Performance Evaluation of Domestic Refrigerator using Eco-Friendly Refrigerant. The experimental study was conducted for R-134a refrigerant and mixture of propane R290 and iso-butane R600a (50/50) by mass with and without acrylic door and condenser fan. During the experimentation, the time is varied for achieving freezer temperature -15^0C. The experimental results are obtained can be summarized as below;

It has been observed that the experimental results show enhancement of average coefficient of performance depends on the time taken for achieving the freezer temperature.

The average coefficient of performance is enhanced by 21.29 % at mixture of propane R290 and iso-butane R600a (50/50) by mass with Acrylic door and Condenser fan and R-134a without Acrylic door and Condenser fan.

The performance of domestic refrigerator is improved by using mixture of propane R290 and iso-butane R600a (50/50) by mass with acrylic door and condenser fan.

It also observed that with acrylic gate the desired temperature is achieved early in the evaporator.

As the freezer temperature decreases it decreases the coefficient of performance of the refrigerator.

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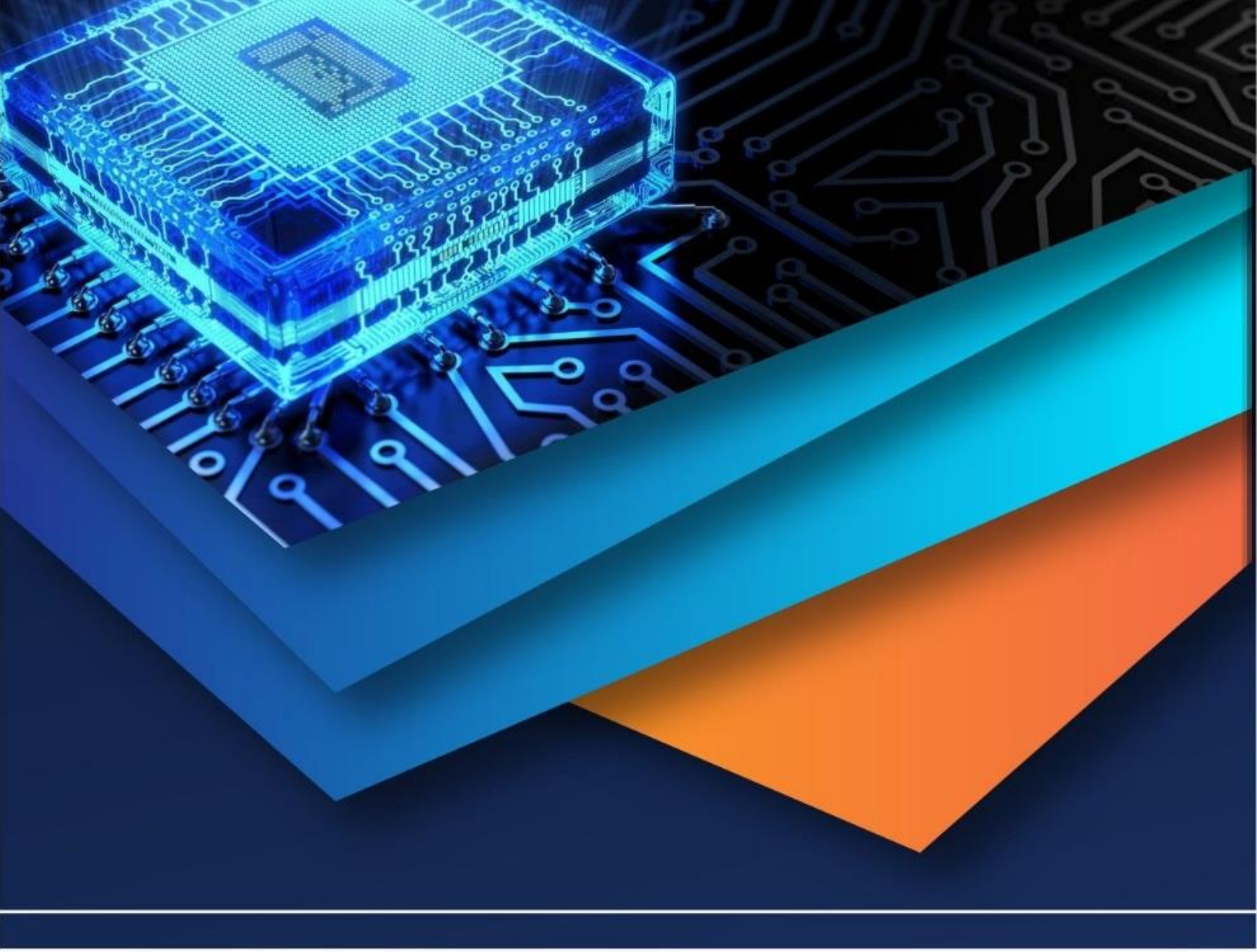
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