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# Design & Optimization of Pot-In-Pot Refrigerator

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***Abstract:* Pot-in-pot refrigerator is a refrigeration device which uses evaporative cooling and works without consuming electricity. Evaporation takes place through porous pot material in which vegetables & fruits can be preserved for longer time. The design and optimization of conventional pot-in-pot refrigeration has been cited in this report. It gives a brief introduction on evaporative cooling and factor affecting it. Pot-in-pot is also designed in Solid Works with an addition of 'fins' in order to increase surface area to volume ratio, which in-turn increases the pot cooling efficiency. The design is further simulated in Solid Works to determine safe design parameters. After getting the safe dimensions, pots are manufactured with the help of a local potter. Experiments are done on finned and non-finned pot and results are compared. Various filler mediums like sand, charcoal, gunny-cloth are used between the outer and inner pot during experimentation on PIP and cooling efficiency result graphs are plotted.***

***Keywords: Pot-in-pot refrigerator, evaporative cooling, porous pot, fins, Filler medium, Solid Works.***

## I. INTRODUCTION

Fruits and vegetables have very short life and are liable to spoil due to their high moisture content if not kept in cool environment. More than half the population of India is low income group who cannot afford electronic refrigerators. Moreover, the rural regions of India faces problem of shortage of electricity.

In order to overcome and solve this problem we have opted this project which was initially taken up by a Nigerian resident, named, Mohammad Bah Abba, and we are trying to optimize the "Pot-in-Pot Refrigerator" by increasing its cooling efficiency.

The project aims to help optimize the performance of existing model even in humid regions with alteration in design. And provide the experimental comparison of same with existing model of Pot-in-pot refrigerator available. And thus provide people with efficient cooling refrigerator at low cost, low energy consumption.

## II. POT-IN-POT REFRIGERATOR

### *A. Operating Principle*

When evaporation occurs from a surface, there is an energy associated with the phase change known as the latent heat of vaporization. In a given system, as air flows over the wet surface, water on the surface of pot evaporates also by absorbing heat from inside of pot. This cooing effect is known as evaporative cooling and is most effective in dry climates due to the lack of moisture content (relative humidity) in the air. In the case of the pot-in-pot refrigerator, water evaporates out of the sand through the surface of outer clay pot.

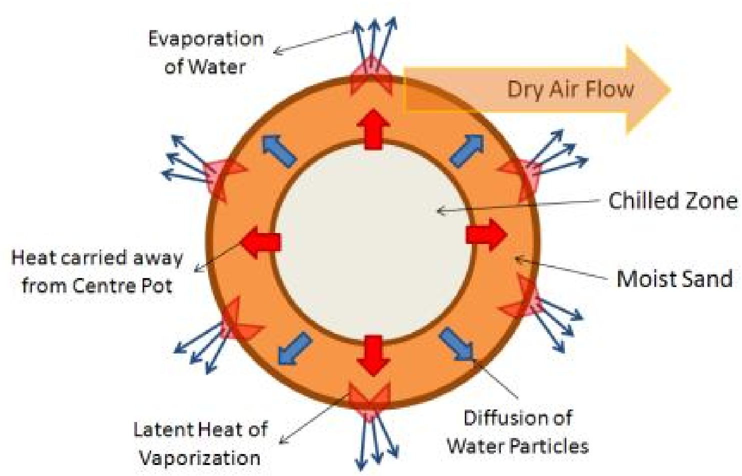


Fig.1 : Conceptual Flow of Energy and Water in PIP Refrigerator[1]

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*B. Affecting Parameters:*[12]

1) *Relative Humidity*: When the relative humidity is low, amount of water vapor in air is very less. Under this condition air is capable to take additional amount of moisture, hence the rate of evaporation and cooling rate are more. Atmospheric temperature measured is called as 'Dry Bulb Temperature'(Tdbt). The temperature at 100% relative humidity is called as 'Wet Bulb Temperature'(Twbt). In evaporative cooling we can cool upto the Twbt only.[9]*Air Movement:* The movement
2) down. On other hand if humid air is removed away and replaced with fresh air, the evaporation rate will increase
3) *Air Temperature:* Areas with high temperatures will have higher rate of evaporation and more cooling will occur. With lower air temperature less evaporation and lesser cooling will take place
4) *Surface Area:* The greater the surface area to volume ratio available for evaporation the more amount of water can evaporate, the greater the rate of evaporation.

## III. DESIGN OF FINNED POT

In order to increase the cooling rate so as to achieve the optimum lowest temperature for the pot, we searched for various methods. One such simple technique is constructions of fins on the outer surface of the pot. Fins are extended surfaces developed on the existing surface to increase the surface area of given model. Let us see various models with fins, possible for pot using SOLIDWORKS as a CAD Software.

Fig.2: Vertical fins

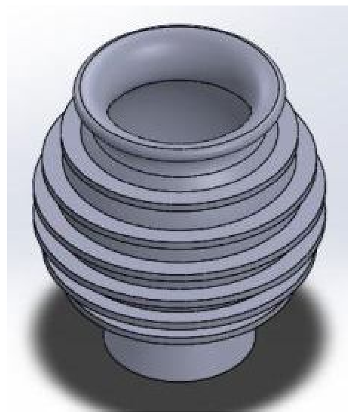

Fig.3: Annular fins

The annular fins are easy to produce on the outer surface of pot while working on rotating wheel, as compared to the vertical fins. While actual manufacturing, pot shown in fig.3 had failed due to crack formation, as in this design addition of fins increases stress on bottom portion of pot.

Fig.4: Spherical cracked pot

Hence, we designed cylindrical pot with slight bulge in middle as shown in fig.5. It sustained all the stresses while manufacturing. The manufactured pot is shown in fig.6

Fig.5: Annular fins2

Fig.6: Annular fins2 manf.

## IV. EXPERIMENTATION

*A.* We took finned pot as shown in fig.6 and a simple(non-finned) pot of similar shape
*B.* equal quantities of water in both.
*C.* of water was measured at equal intervals of 30min of both the pots.
*D.* Similar steps are followed in forced convection also, where a fan is used to create air movement(~5m/s)
*E.* Respective readings are plotted.

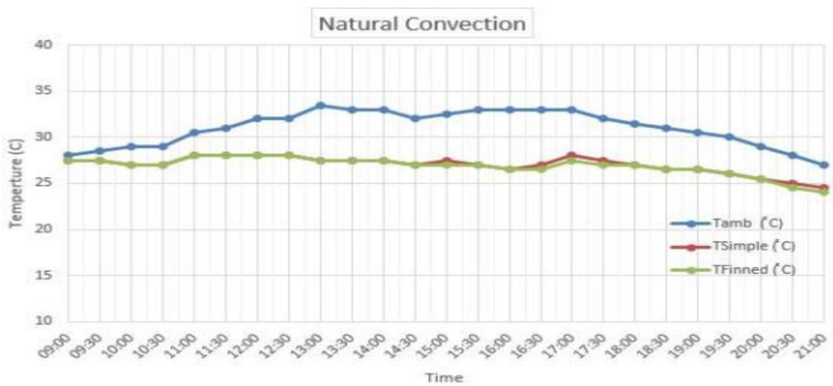


Fig.7: Natural convection

From fig.7, we can see that in natural convection, both the temperature curves of simple & finned pot are nearly similar. Hence, advantage of fins on pot is less in free convection.

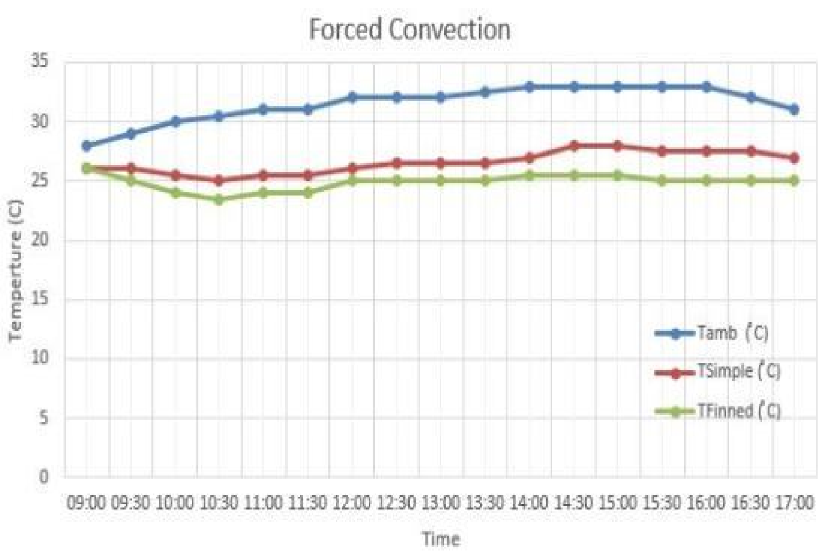


Fig.8: Forced convection

But in forced convection it can be clearly seen that the finned pot provides higher temperature drop than the simple pot. At any time finned pot provides 2~3°C more cooling than simple pot. Hence we decided to use this finned pot in pot-in-pot refrigerator.

## V. POT-IN-POT MODEL

### *A. Simulation*

Load acting on both the pots in pot-in-pot refrigerator is calculated and simulation is done on SolidWorks.

*1) Inner pot:* Here max. 5kg load (fruits, vegetables) is considered to act, which is equivalent to nearly 50N. The load acts on bottom surface, whereas the same bottom surface also seats in the outer pot hence considered as fixed support.

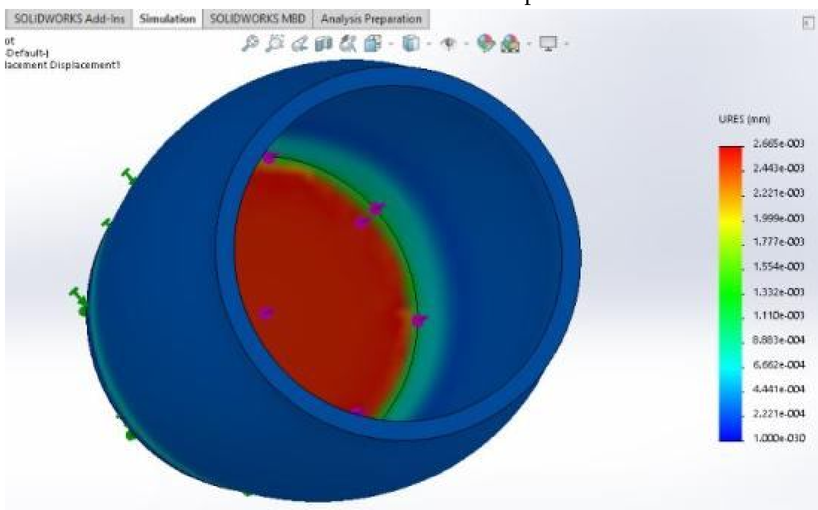


Fig.9 : Static analysis of inner pot

After the simulation the max deformation is found to be 2.66 microns, which is negligible. Hence the thickness of 8 mm is considered, as it is also feasible to manufacture by the potter.

*2) Outer pot:* Here along with load due to inner pot, the load of sand plus water is also acting.

Total load = food wt. + inner pot wt. + sand-water wt.

= (5 + 1.6 + 2) Kg = 8.6 Kg

To be on safer side the load is considered to be 100N. This load acts on the bottom surface of the outer pot, whereas the bottom surface which rests on the stand is considered as fixed.

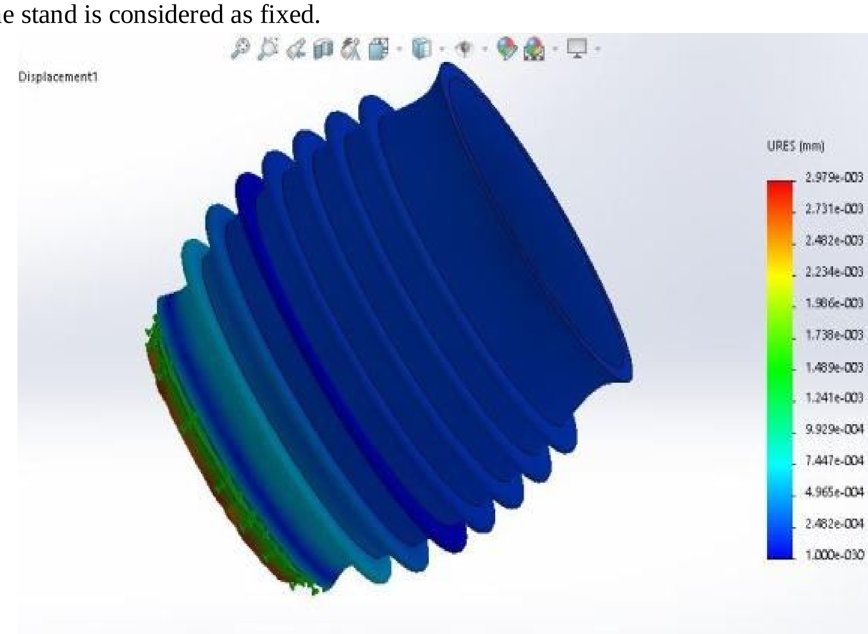


Fig.10 : Static analysis of outer pot

After simulation, max deformation comes to be 2.97 microns, which is negligible. Hence thickness of 10mm is considered, as it is also feasible to manufacture by the potter.

### *B. Assembly*

Grooves are made on the inner surface of outer pot, to increase the contact surface area, so as to increase the water sip rate. Fins are only on the outer pot. Inner pot is then assembled in outer pot. The gap between inner and outer pot is filled with different filler materials during experimentation.

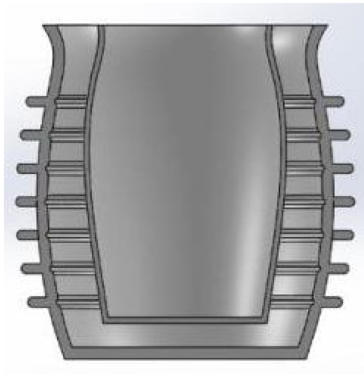

Fig.11 : Sectional figure

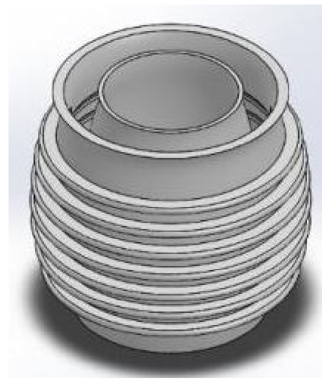

Fig.12 Isometric View

## VI. EXPERIMENT ON FINNED POT-IN-POT

Firstly sand is taken as filler material and following procedure is followed.

Fig.13: Assembly procedure (sand as filler)

Ambient temperature, ambient humidity and inner cold space temperature readings are noted at every 30min interval, using 'Digital Hygrometer' and 'Analog Thermometer'.

Similar procedure is followed using charcoal and gunny cloth as filler medium between the two pots.


Fig.14: Charcoal as filler


Fig.15: Gunny cloth as filler[2]

After getting these results, we might think that minimum temperature achieved in free convection is better than forced, but here we should also note that atmospheric conditions are different, as readings are taken at different times of different days.
Hence, to be able to compare the observations, we used another parameter 'cooling efficiency $\eta$', which takes care of every affecting parameter. In formula it is given as,

$$\eta = \frac{T_{amb} - T_{cold}}{T_{amb} - T_{wbt}} [4]$$

As explained earlier, in evaporative cooling we can cool upto the Twbt only. So, if the temperature achieved is Twbt, then cooling efficiency is 100%. For various readings throughout the day for both free and forced convection, cooling efficiency is calculated and the resultant graph is plotted.(Twbt values are calculated from Tdbt and Humidity from internet)

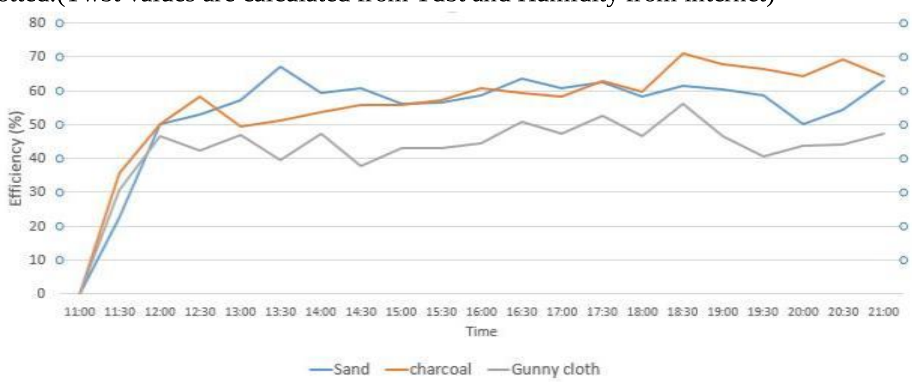


Fig.16: PIP free convection

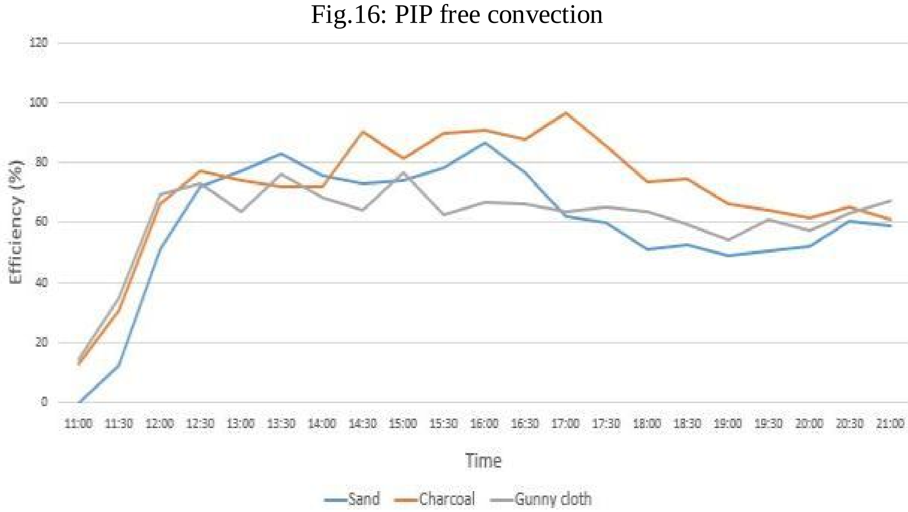


Fig.17: PIP forced convection

From graph shown in fig.16, it can be inferred that cooling efficiency in free convection rarely goes above 70%, and coal performs well as a filler as compared to sand and gunny cloth.

But from graph shown in fig.17, it can be seen that in forced convection the cooling efficiency is mostly greater than 80%, and sometimes it also achieves 96%(charcoal), and here also charcoal performs very well in cooling, as compared to sand and gunny cloth.

## VII. CONCLUSION

Increasing the surface area by means of addition of fins is observed to be successful technique to enhance the cooling. It is also an inexpensive and easiest method for optimization.

Different materials are used as filler mediums, out of which charcoal is found to be the best for cooling, then sand and followed by gunny cloth.

Forced convection is better than free convection in order to increase the cooling effect, and it is most suitable for finned pot as compared to simple pot.

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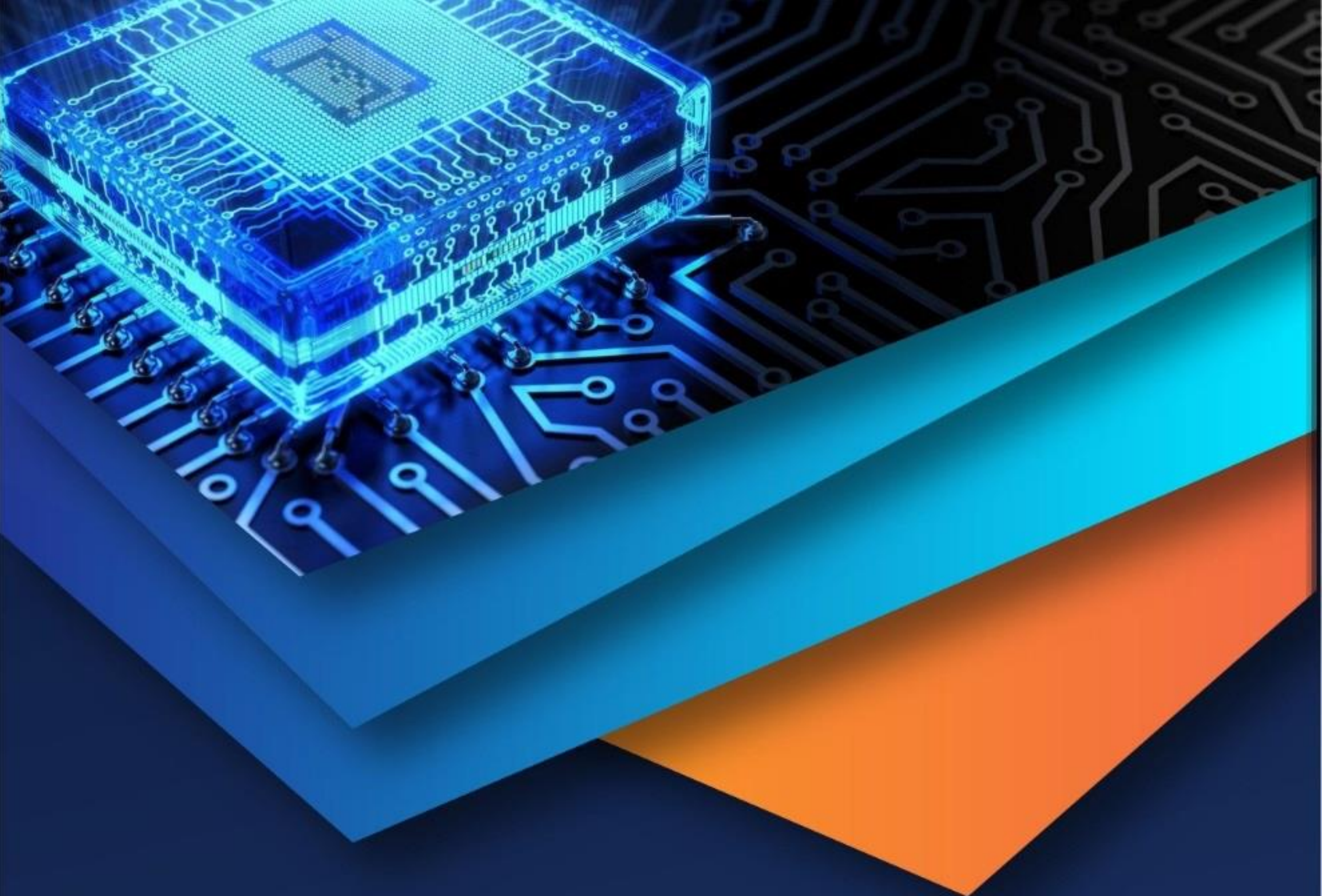


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