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Performance and Experimental Studies on Vortex-Circulating Bed Solar Dryer

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Abstract - Numerous types of solar dryers have been designed and developed in various part of the world. Various topics in sun and solar drying are discussed in many scientific reports, research manuscripts and books. This research paper focused on fabricating and testing for drying chillies by using flat plate collector and vortex- circulating bed solar dryer. The advantage of the vortex circulating bed is to provide constant movement of the chillies over the bed in order to enhance the resident time with hot air. Vortex circular motion technique provides efficient agitation. The model can predict the change in the temperature of air, relative humidity, the moisture content and the dryer thermal efficiency. In this project the experiment is performed on 6m/s. 5m/s and 4m/s of velocity of air. On that particular velocity of air the moisture removal from chillies of solar dryer is observed that 42.85%, 39.35% and 38.15% respectively. As compared to open sun drying it is much higher. The average efficiencies are obtained for mentioned air velocities are 18.92%, 17.42% and 18.60% respectively. The quality of the product obtained after solar drying is much better than open sun drying. The dryer exhibited sufficient ability to dry food items reasonably rapidly to a safe moisture level and simultaneously it ensures a superior quality of the dried product.
Keywords–solar flat plate collector, relative humidity, vortex- circulating bed, moisture content, dryer thermal efficiency.

I. INTRODUCTION

Drying particularly of crops is an important human activity and globally the use of dried products is widespread. For preservation, quality improvement and processing purposes, moisture must often be removed from both organic and inorganic materials. Sun drying and mechanical dehydration using fossil fuels are the most common technologies used, Sun drying is a low-cost drying method but the final quality is variable, while mechanical dehydration is an energy intensive process and contributes substantially to energy use and greenhouse gas emissions. The shortage of energy is an issue in many countries, particularly those in the developing world. Even where conventional energy is plentiful, there is pressure to reduce the amount of fossil fuels used. Concern over global warming is universal and this has focused our attention on energy intensive processes like drying where fossil fuels can often be replaced by renewable and non-polluting sources of energy. The solar dryer consists of flat plate collector, a blower with pipe connections, and vortex circulating bed. The blower is used to circulate the hot air from the collector to the bed and Vortex-Circulating bed of the solar dryer is circulating while drying chillies that are present in it, this model can predict the change in the relative humidity of air across the bed with digital hygrometer, change in the air temperature, change in the moisture content and the efficiency of the dryer.

II. EXPERIMENTAL SETUP

The solar dryer system consists of a flat plate collector, blower with flexible pipe connections, and vortex circulating-bed. The flat plate collector is used to heat the ambient air into hot air. The flat plate collector consists of collector plate, absorber plate with baffles. The material use for absorber plate is pure aluminium having thermal conductivity of 204.2 W/mk with black colour. For measuring temperatures at various points J-type thermocouples are provide having rating of 0 to 600°C. Temperature meter shows the reading of temperatures at various points. A regulator is providing to the blower for regulating the flow rate of air. The flow rate of air is measured with the help of anemometer and regulator is adjusted on that particular marking of flow rate of air. Collector plate is made up of glass which can be use for trapping the solar radiations. The blower is used to suck air from atmosphere and circulate hot air from the collector to the bed.

The flat-plate solar collector is always oriented in such a way that it receives maximum solar radiation during the desired season of used. The best stationary orientation is due south in the northern hemisphere and due north in southern hemisphere. Therefore, solar collector in this work is oriented facing north-south direction.The drying cabinet of this project is vortex-circulating bed. As the name suggests, the bed is move in both vortex and circular motion while drying chillies. . The advantage of the vortex circulating bed is to provide constant movement of the chillies over the bed in order to enhance the resident time with hot air.

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III. EXPERIMENTAL PROCEDURE

Experiment was performed in Nagpur on 29 May 2016, 30 May 2016 and 31May 2016. The experiment was performed on various mass flow rate of air. On 29 May 2016 the velocity of air should be taken as 6m/s whereas on 30 May 2016 and 31 May 2016 the velocity of air should be taken as 5m/s and 4m/s respectively. In this experiment 2000gm of chillies are fed into the solar dryer and same amount of chillies are dry in open sun drying. After feeding chillies the project was run. As the project run the hourly basis readings are taken. After every hour collector inlet temperature (T_{ci}), absorber plate temperature ($T_{absorber\ plate}$),collector outlet temperature (T_{co}), solar bed inlet temperature(T_{bi}), solar bed outlet temperature(T_{bo}) these temperatures at various points are recorded with the help of J-type thermocouple on temperature meter. After measuring temperatures, initial mass of chillies (M_i) and final mass of chillies (M_f) are measured with the help of electronic weighing machine of both solar dryer and open sun drying. At the same time relative humidity of ambient air and solar dryer bed are recorded with the help of digital hygrometer. These all values are tabulated in observation table for particular day and calculations are done.

The dryer is active system in the sense that it has moving parts. It is energized by the electrical energy. The trapping of the rays is enhanced by the inside surfaces of the collector that were painted black and the trapped energy heats the air inside the collector. The centrifugal blower drives the air current from collector to the drying chamber. The chillies are fed in the bed and are spread over the bed as a thin layer due to bed circulation. The advantage of the vortex circulating bed is to provide constant movement of the chillies over the bed in order to enhance the resident time with hot air.

IV. CALCULATIONS

A. Determination of moisture loss

Moisture loss of chillies is calculated every hour using the formula,

$M_L=(m_i-m_f)$where,

m_i= initial mass of chillies

m_f= final mass of chillies

B. Determination of Moisture Content

The % of moisture content on wet basis (M_{wb}) is calculated by using formula

$$\%\ Mwb = \frac{(mi-mf)}{mi}\times 100$$

where,

m_i= initial mass of chillies

m_f= final mass of chillies

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C. Determinationof dryer thermal efficiency

The thermal efficiency of solar dryer is calculated by using the formula,

$$\eta th = \frac{mw \times hfg}{ma \times Cpa \times (Tco - Tci) + Pb + Pm + ma \times Cpa \times (Tbi - Tbo)}$$

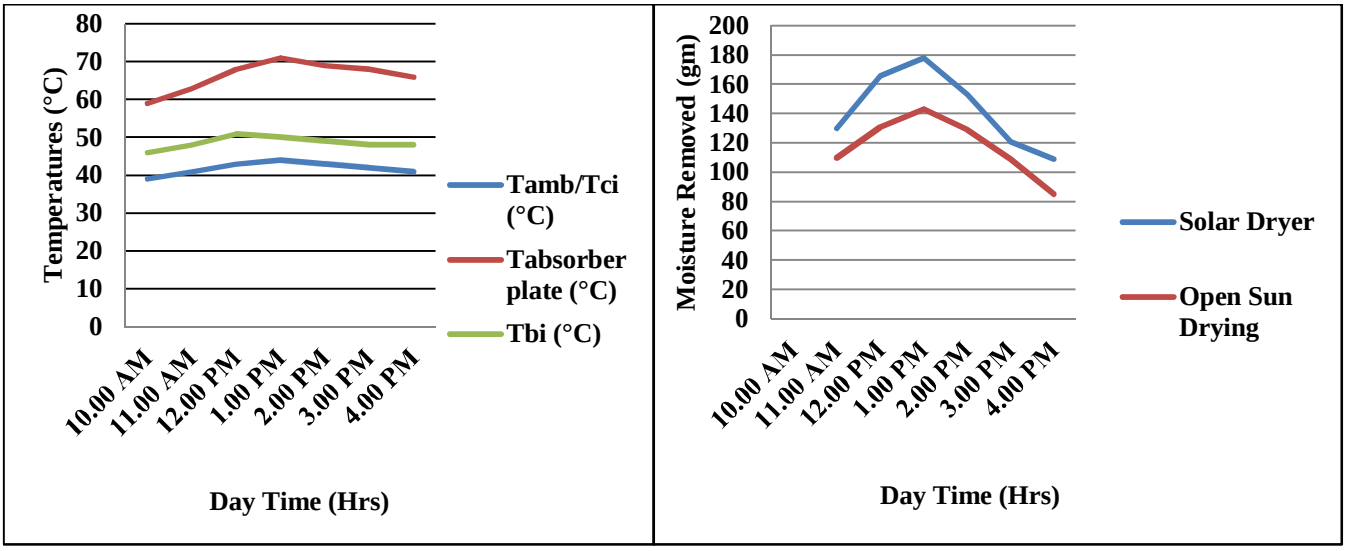
Where,
$m_{w=}$ moisture evaporated in time t, kg/s
h_{fg}= latent heat of vaporization of water, kj/kg
m_a= mass flow rate of air, kg/s
Cp_a= specific heat of air, kj/kgk
P_b= power used by blower, kwhr
P_m= power used by moter, kwhr
T_{co}= collector outlet temperature, °C
T_{ci}= collector inlet temperature,°C

V.RESULTS AND DISCUSSION

This project presents the fabrication and performance on vortex-circulating bed solar dryer for food preservation. In this dryer, the experiment is performed on different mass flow rate of air. After performing on different mass flow rate of air it is observed that as the mass flow rate of air is increasing the moisture removal from the chillies also increases as per the meteorological conditions of atmosphere. In this project the experiment is performed on 6m/s. 5m/s and 4m/s of velocity of air. On that particular velocity of air the moisture removal from chillies of solar dryer is observed that 42.85%, 39.35% and 38.15% respectively. As compared to open sun drying it is much higher. The average efficiencies are obtained for mentioned air velocities are 18.92%, 17.42% and 18.60% respectively. The quality of the product obtained after solar drying is much better than open sun drying. The dryer exhibited sufficient ability to dry food items reasonably rapidly to a safe moisture level and simultaneously it ensures a superior quality of the dried product

A. Graphs for the calculations on 29 May 2016,

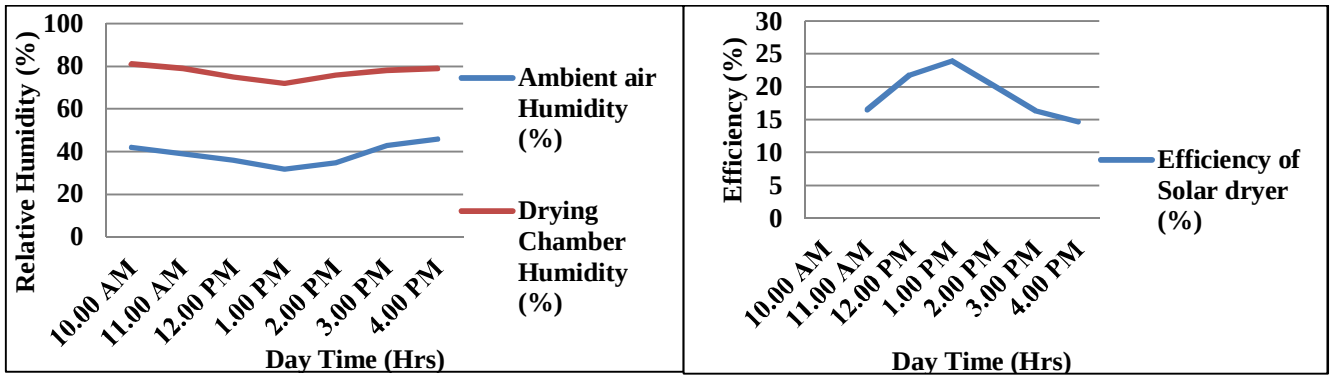
1) Variation of the temperatures in the solar collector and2. Variation of moisture removal with respect to time inand the drying cabinet compared to the ambient temperature solar dryer and open sun drying



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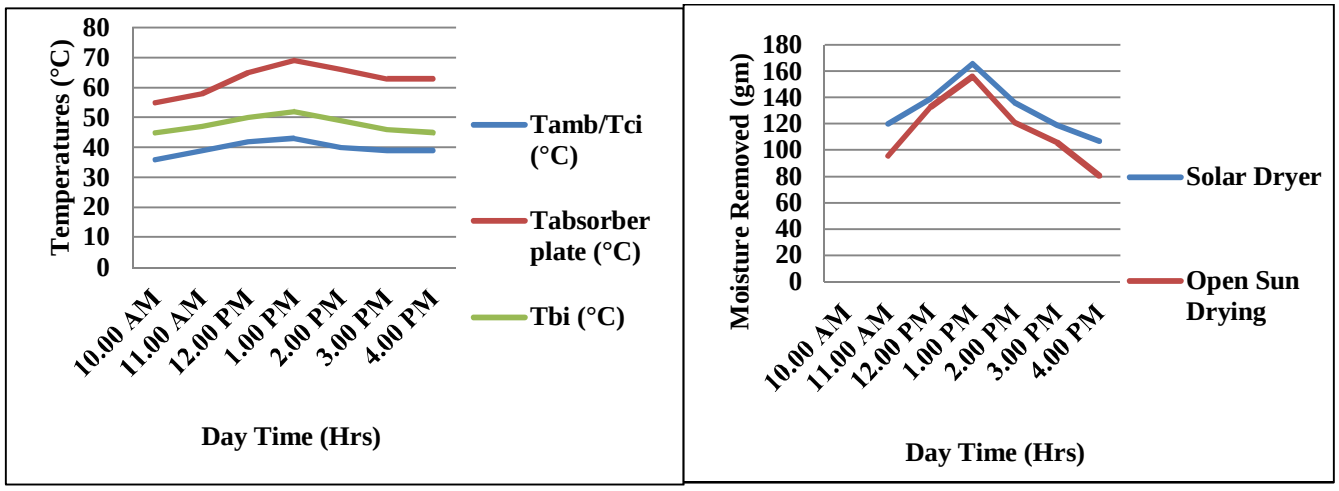
Volume 4 Issue VIII, August 2016
ISSN: 2321-9653
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2) Variation of the relative humidity of the ambient air 4) Variation of thermal efficiency with respect to time and drying chamber

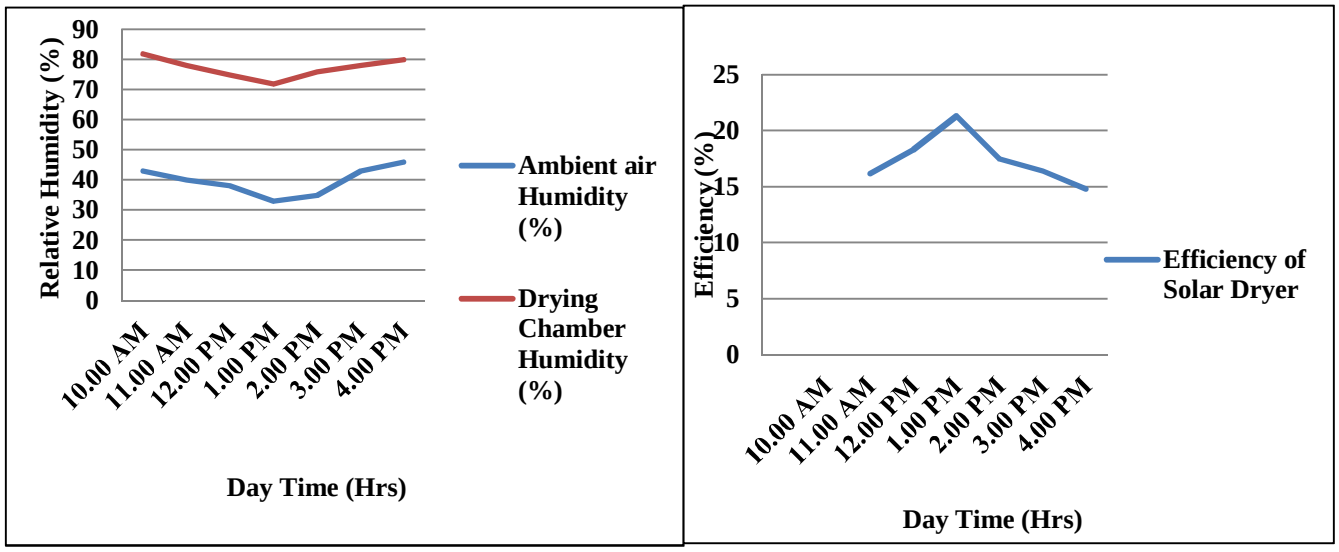


B. Graphs for the calculations on 30 May 2016,

1) Variation of the temperatures in the solar collector 2. Variation of moisture removal with respect to time and the drying cabinet compared to the ambienttemperatureinsolar dryer and open sun drying



2) Variation of the relative humidity of the ambient air 4) Variation of thermal efficiency with respect to timeand drying chamber

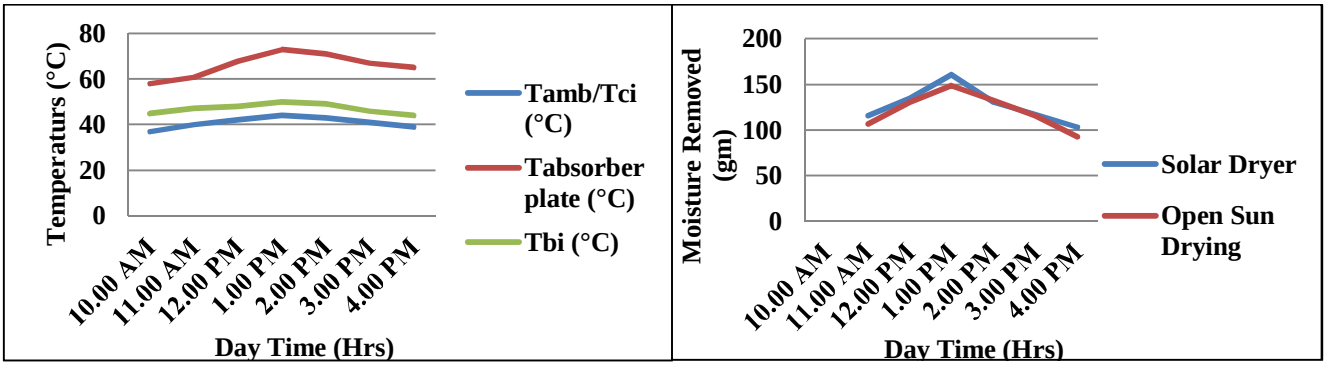


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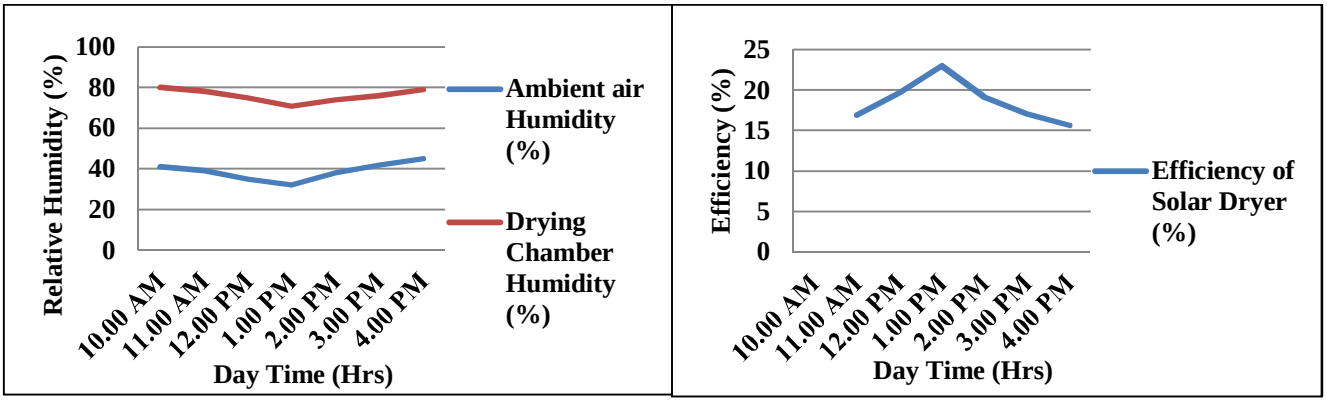
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D. Graphs for the calculations on 31 May 2016,

1) Variation of the temperatures in the solar collector2. Variation of moisture removal with respect to time in and the drying cabinet compared to the ambient temperature solar dryer and open sun drying



2) Variation of the relative humidity of the ambient air and4) Variation of thermal efficiency with respect to time drying chamber



VI. CONCLUSION

From the performance carried out, the following conclusions were made. The solar dryer can raise the ambient air temperature to a considerable high value for increasing the drying rate of agricultural crops. The product inside the dryer requires less attentions, like attack of the product by rain or pest (both human and animals), compared with those in the open sun drying. Although the dryer was used to dry chillies, it can be used to dry other crops like yams, cassava, maize, potato and plantain etc. There is ease in monitoring when compared to the natural sun drying technique. The capital cost involved in the construction of a solar dryer is much lower to that of a mechanical dryer. Also from the performance carried out, the simple and inexpensive vortex-circulating bed solar dryer was constructed using locally sourced materials. The hourly variation of the temperatures inside the cabinet and air-heater are much higher than the ambient temperature during the most hours of the day-light.

In this dryer, the experiment is performed on different mass flow rate of air. After performing on different mass flow rate of air it is observed that as the mass flow rate of air is increasing the moisture removal from the chillies also increases as per the meteorological conditions of atmosphere. In this project the experiment is performed on 6m/s. 5m/s and 4m/s of velocity of air. On that particular velocity of air the moisture removal from chillies of solar dryer is observed that 42.85%, 39.35% and 38.15% respectively. As compared to open sun drying it is much higher. The average efficiencies are obtained for mentioned air velocities are 18.92%, 17.42% and 18.60% respectively. The quality of the product obtained after solar drying is much better than open sun drying. The dryer exhibited sufficient ability to dry food items reasonably rapidly to a safe moisture level and simultaneously it ensures a superior quality of the dried product.

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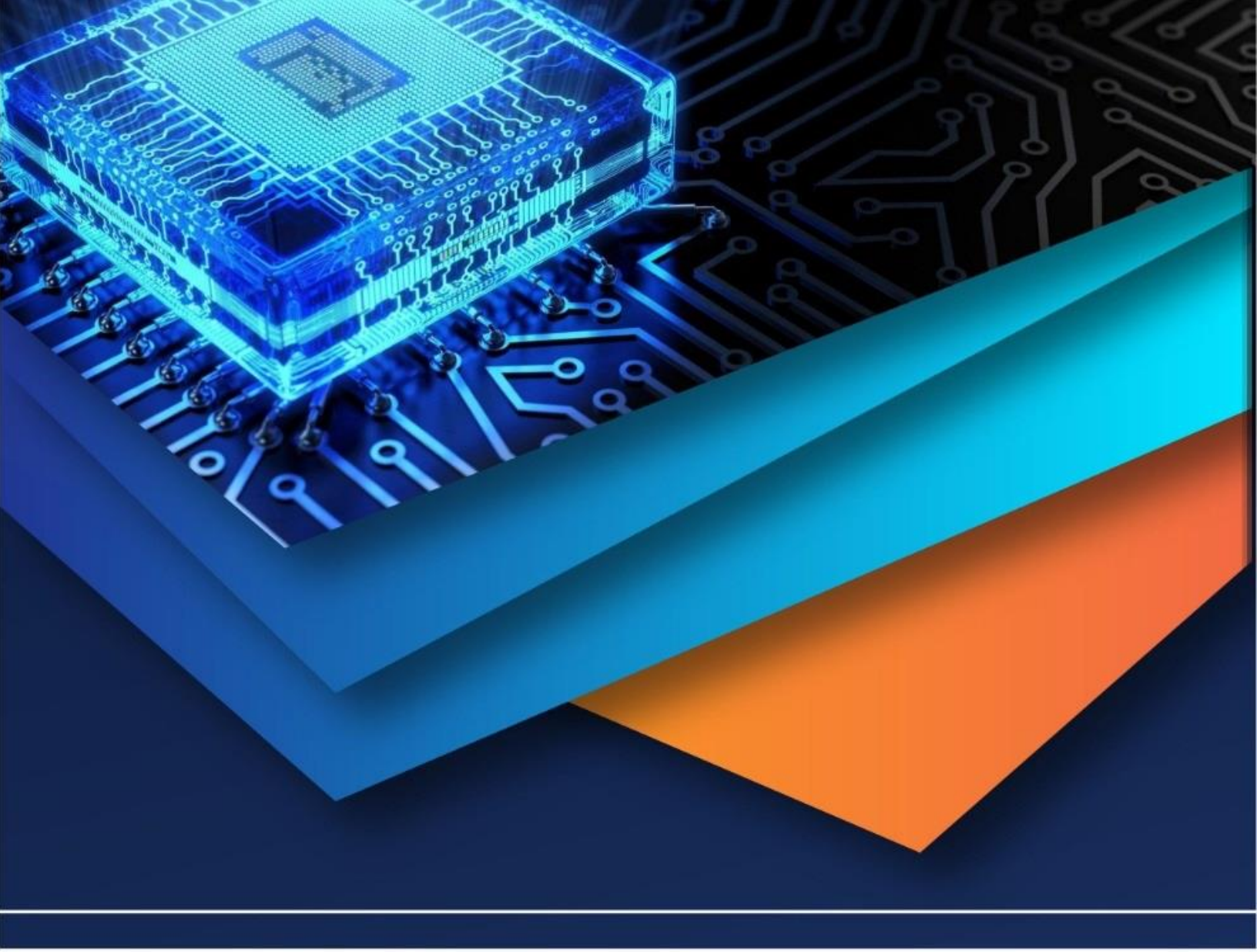
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