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Solar Drying Of Ginger Using Cabinet Dryer & Periodic Tabulation of Data

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Abstract— Solar Energy is going to be one of the world's latest energy trends. Now there are many advancements in solar energy techniques but still yet to be developed for better utilization of it. Actually due to variations in the intensity of solar radiation it is not the trusted form of energy, but yet it can be stored and then it will be used during the times of low radiation or during hazy sunny days. Objective of the present experimentation is to present the various parameters of the solar cabinet dryer in tabulated as well as in graphical form and then to analyse whether the dryer needs any modification for latter experimentation. In the same dryer we had dried chilli for the analysis of the dryer, Mukundjee and Ipsita[23] had dried the chilli in the same cabinet dryer for the evaluation of the various parameters. After the experimentation on this drier we will going to modify it and what will be the result after that will see and discuss in our other paper. Let's move on to the topic, here the dryer we are using is in both natural and forced mode solar cabinet dryer, the capacity of the dryer is for 2 Kg of raw product and the various desired parameters are measured with the help of digitally calibrated instruments. Various tabulations related to temperature, solar intensity, wind speed and relative humidity is presented in the tabulated form for the periodic evaluation of the various parameters. With many series of experiments it is one of those which is presented here for the clear cut observation techniques to the readers.

Keywords— Solar Drier, Solar Collector, Pyrometer, Anemometer, Thermocouples and Hygrometer

I. INTRODUCTION

We live in an environment where the solar energy have the most influential impact on our life but we never ever think how to extract more of it; so that when all the resources may go on extinct we will have the option to fully rely upon it. When we will see on the other side of the coin we will gona see that solar energy is among one of the most reliable sources of energy from other renewable sources of energy. Solar energy is one of the most pay-back sources of energy. Yet the initial cost of solar equipments and machines are higher as compared to other forms of energy but on latter on the pay- back period is very good and will lead to a profit of 10 times as compared to other sources of energy. But for more energy utilization and good pay-back periods we have to think beyond our imagination for the modification and reconstruction of its subsystems. India is among one of the countries to get the desired and quality radiation from the sun, but here still there are not any advancements in solar energy capturing techniques, while other countries have good impact on the solar market, like Japan and China are in the top zone of solar equipment producing countries. Solar dryer is among one of the equipments or we can say a machine which is used for drying purpose, it can be either in natural mode or in forced mode. People are actually not very confident in using solar dryer because of its initial cost, but they are not thinking about its pay back periods and its effectiveness as compared to open drying. Actually we have to do a lot of research work related to solar energy, inspite of its abundantly availability and one of the oldest sources of energy to mankind it had not been given enough attention for its development. Almost all the old civilizations from Egypt to Inca have built solar temples and solar operated monuments to trace the position of stars and to set the flow of wind in their desired directions. If you have noticed then you could have seen that there is a network of energy points of pyramids of all civilizations over the globe, perhaps it may be used in for communication. Hossain and Bala[1] had dried chili using solar tunnel drier and showed the effectiveness of dryer than open drying, also they showed that there was a considerable reduction in drying time. Ceylan and Ergun[2] had studied the relation between the psychrometry working upon the thermo-dynamic analysis of humid air and drying at a timber dryer. The thin layer silk cocoon drying was studied by Singh[3] in a forced convection[21-22] type of solar dryer, the drying air temperature varied from 50 to 75 C and the cotton was dried from the initial moisture content[17-18-19] of about 60-12(wb). Akintunde[4] studied the four layer drying models. The page model was found to best describe the drying behavior of chili pepper for sun and solar drying. The kinetics of heat pump drying of cocoa beans was investigated by C.L Hii et al.[5]. Chowdhury et al. studied the exergy and energy analysis of jackfruit leather in solar tunnel dryer. The various drying curve characteristics of tomato were studied by Manna et al.[6]. Saxena et al.[24] tried to show how to enhance the performance of the dryer using the heat storage medium. Crisosmoto et al.[25] had showed their interest on the hybrid PV/T collector and tried to show its performance evaluation. Latter on we will be discussing on how we

have modified and redesigned the dryer based on its performance on our next paper. You will be amazed to see how we have utilized limited resources in its modification and reconstruction also the design calculations will make you more confident in attempting the same in your project. So wait for our latest paper which we will going to submit in the month of april. Saxena et al. [26] studied about the performance of solar air heater. Kim et al. [27] had studied and showed how a lattent heat storage medium is used for the concentrated solar power plant. For any query please contact in our e-mail.

II. EXPERIMENTATION AND TABULATION

A. *Experimental setup and approach*

The solar dryer we had used in our experiment is of cabinet type solar dryer. The design of the solar dryer is based on the climatic conditions of the place, nature of the product and the quantity of the product to be dried. The indirect type of the solar dryer was designed and constructed and then it was coupled with already available solar collector. The dimension of the solar collector is 1.55 by 1.09 m. The dryer is of 0.6m height from the ground, the inlet ambient air enters through the inlet of the collector of square cross-section having dimension of 12cm by 12cm. After that the inlet air is heated up with the help of solar air collector and the outlet is connected to the solar dryer inlet, where the hot heated-up air carries out the moisture content of the product to be dried and the extra moisture carried by the air is then thrown by the outlet of the drier. The electric blower used here have a capacity of 379W, as already mentioned the capacity of the drier is of 2kg of raw product. Matt black paint is used on the absorber plate to increase the absorptivity to solar radiation. The collectors were oriented due south at an angle of 45 Degree. More details on the solar air collector can be found out from Wankhade et al.[6] where they had discussed the drying characteristics of Okra slices. A 1000W auxiliary heater was constructed from a galvanized steel sheet with a square cross-section area that had a slide length of 0.27m; heating filament was wrapped on ceramic isolators. A constant variable resistance is provided to control the output power required to provide the selected air inlet temperature to the drying chamber. The power is calculated from the reading of the voltage provided by the variac and the amperage read by a digital multimeter (type ID-1000, range: 0-30 A and accuracy 0.75).An aluminum drying chamber, which had the dimension of 1.05 0.5 0.9m (length $\times width \times heig$) was insulated from the outside by a 30-mm aluminum coated rock wool sheet. 8 numbers of trays are inserted in the dryer. The drying of the materials involve the migration of water from the inner of the material to its surface, and then removal of the water from the surface; which in turns requires an equivalent of latent heat of evaporation of water.

The efficiency of the drying system is calculated by multiplying the efficiencies of the individual components of the system. Several tests were carried on using the flow rates 0.0378, 0.05619, 0.0689, and 0.0793m^3/sec. Calibrated thermocouples are used to measure the temperatures at the desired points for each interval of time. The temperature measurements were taken at the inlet to the collector, outlet to the collector, inlet to the dryer, outlet to the dryer, dryer inlet temperature, absorber plate temperature. Equal quantities of product were taken both for natural and forced convection, and for drying the product was uniformly spread over the 8 shelves of the dryer. The sample of dried product were taken and weighted with the help of weight balance, then the sample was dried with the help of oven and again its weight was measured with the help of the same weight balance after the sample was completely dried off. The weight balance used here is of type PE-3600, range0-500g and accuracy $\pm$1.5% [8-9-10-11]:

B. *Design approach*

We had tried to represent the design and drying analysis of the solar dryer.[12-13-14-15-16]

1) Drying analysis: Percentage of moisture removed from the product, M%

$$\frac{m_w - m_d}{m_w} \times 100\% \ on\ wet\ basis$$

Where $m_w$and $m_d$are the masses of wet and dried products respectively.

Average Dry Rate, m_{avg}

$$m_{avg} = \frac{m}{t}$$

Where t is the daily sunshine hours.

Drying Time, T

$$\frac{mh_{fg}}{3600IA_T t\eta_c\eta_s}$$

Based on the above formulae and the given below the various graphs are plotted in the results and discussion section of this paper and then only the conclusion is drawn from that.

Here the emphasis has been laid downed on the observation techniques for the solar dryer and how to represent it in the tabular

form.

2) Tabulation and data: The various experimental data that are taken during each day of reading are presented below.

1st Observation table

2 Kg of sample were taken with initial moisture content of 88.5 and is reduced to the moisture content of 72.2 % and to the sample weight of 0.883 Kg in 10 hours.

Serial number	Time	Absorber plate temp.	Collector outlet	Dryer inlet	Lower shelf	Upper shelf	Dryer outlet	Ambient temp	Drying chamber	Relative humidity (inside)	Relative humidity (outlet)	Average solar isolation	Moisture content	Wind speed	Sample weight
1	8	22.3	10	10	-	-	-	-	-	-	83.29	320.39	88.5	0.4	2
2	9	25.9	20	15	-	-	-	-	-	-	78.42	417.43	86.8	0.4	1.752
3	10	37.8	30	28	26	25	23	15.7	35	65.9	75.39	523.82	85.2	0.5	1.559
4	11	51.5	39	37	36	34	32	17.8	46	59.3	69.37	635.01	83.6	0.6	1.406
5	12	60.7	50	48	49	45	43	19.2	48	42.1	54.28	691.13	82.07	0.7	1.282
6	13	70	55	52	52	51	50	20.9	55	36.9	46.53	804.11	80.3	0.4	1.117
7	14	84.3	52	50	48	48	47	21.7	58	32.6	42.78	759.92	78.6	0.4	1.079
8	15	66.3	45	45	44	44	42	22.1	54	44.6	54.17	754.85	77.1	0.7	1.004
9	16	55.7	40	40	39	39	37	19.7	48	44.9	54.99	588.78	75.5	0.5	0.940
10	17	39.77	33	31	29	27	26	16.2	43	40.1	56.3	450.48	73.9	0.6	0.937
11	18	24.3	19	17	15	13	12	13.1	30	50.3	60.12	343.07	72.2	0.4	0.883

2nd Observation

In 2nd spell the moisture content was reduced from 82.49 to 60.83% and for the sample weight it was from 0.88 to 0.55 Kg.

Serial number	Time	Absorber plate temp.	Collector outlet	Dryer inlet	Lower shelf	Upper shelf	Dryer outlet	Ambient temp	Drying chamber	Relative humidity (inside)	Relative humidity (outlet)	Average solar isolation	Moisture content	Wind speed	Sample weight
1	8	23.9	12	11	-	-	-	-	-	-	82.49	325.89	72.3	0.4	0.88
2	9	24.9	22	17	-	-	-	-	-	-	79.82	427.32	70.6	0.4	0.83
3	10	38.7	29	27	25	24	22	16.6	34	66.5	74.89	533.73	68.9	0.5	0.78
4	11	50.2	40	38	37	35	33	18.9	47	58.7	68.76	625.71	67.3	0.6	0.74
5	12	61.8	49	47	48	44	42	20.3	48.9	43.6	55.86	681.93	65.6	0.7	0.71
6	13	70.9	54	51	51	50	49	21.7	56	37.5	45.35	812.61	63.9	0.4	0.67
7	14	83.2	53	51	49	49	48	22.4	59	33.9	43.89	749.72	62.1	0.4	0.64
8	15	65.4	44	44	43	43	41	23.6	53	45.8	55.57	764.78	60.6	0.7	0.62
9	16	54.9	39	39	38	38	36	20.1	47	43.7	53.49	578.98	59.1	0.5	0.59
10	17	35.44	34	32	30	28	27	17.5	42	39.1	57.37	440.98	57.5	0.6	0.57
11	18	23.32	20	18	16	14	13	14.9	29	51.5	60.83	393.97	55.7	0.4	0.55

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3rd Observation

In 3rd spell moisture content was reduced from 55.7 to 39.3 %and the weight was reduced from 0.55 to 0.40 Kg, this was thenthird day of 10 hours.

Serial number	Time	Absorber plate temp.	Collector outlet	Dryer inlet	Lower shelf	Upper shelf	Dryer outlet	Ambient temp	Drying chamber	Relative humidity (inside)	Relative humidity (outlet)	Average solar isolation	Moisture content	Wind speed	Sample weight
1	8	22.8	11	10	-	-	-	-	-	-	83.42	345.56	55.7	0.4	0.55
2	9	26.7	21	16	-	-	-	-	-	-	78.76	430.57	54.1	0.4	0.53
3	10	38.4	29.9	28	26	23.3	22	15.6	35	66.4	76.79	518.53	52.5	0.5	0.51
4	11	52.6	41	37	37.5	34.7	33	17.9	46	59.5	69.36	630.11	50.9	0.6	0.49
5	12	62.7	50.1	48	47.8	44.6	42	18.3	48.9	42.7	54.75	670.23	49.2	0.7	0.48
6	13	70.6	55.7	52	51	50	49	22.7	56	36.4	46.33	832.11	47.6	0.4	0.46
7	14	84.7	53	50.4	48	49	48	23.4	58	34.1	42.73	733.21	45.9	0.4	0.45
8	15	67.7	45.8	45	43	42	41	25.6	55	45.7	53.63	750.81	44.4	0.7	0.43
9	16	55.19	40	40.6	39	37	36	19.1	48	45.3	55.42	565.78	42.7	0.5	0.42
10	17	38.48	33.7	33.7	31	28.8	27	18.5	44	39.2	56.45	446.83	41.0	0.6	0.41
11	18	25.27	19.78	18	16	15	13	12.9	30	50.5	59.56	398.73	39.3	0.4	0.40

4th Observation

In this day of spell the moisture content was reduced from 39.3 to 22.8 %and the weight was reduced from 0.40 to 0.31Kg.

Serial number	Time	Absorber plate temp.	Collector outlet	Dryer inlet	Lower shelf	Upper shelf	Dryer outlet	Ambient temp	Drying chamber	Relative humidity (inside)	Relative humidity (outlet)	Average solar isolation	Moisture content	Wind speed	Sample weight
1	8	22.3	10	10	-	-	-	-	-	-	83.29	320.39	39.3	0.4	0.40
2	9	25.9	20	15	-	-	-	-	-	-	78.42	417.43	37.7	0.4	0.39
3	10	37.8	30	28	26	25	23	15.7	35	65.9	75.39	523.82	36.1	0.5	0.38
4	11	51.5	39	37	36	34	32	17.8	46	59.3	69.37	635.01	34.4	0.6	0.37
5	12	60.7	50	48	49	45	43	19.2	48	42.1	54.28	691.13	32.7	0.7	0.37
6	13	70	55	52	52	51	50	20.9	55	36.9	46.53	804.11	31.1	0.4	0.36
7	14	84.3	52	50	48	48	47	21.7	58	32.6	42.78	759.92	29.4	0.4	0.35
8	15	66.3	45	45	44	44	42	22.1	54	44.6	54.17	754.85	27.7	0.7	0.34
9	16	55.7	40	40	39	39	37	19.7	48	44.9	54.99	588.78	26.0	0.5	0.33
10	17	39.77	33	31	29	27	26	16.2	43	40.1	56.3	450.48	24.4	0.6	0.32
11	18	24.3	19	17	15	13	12	13.1	30	50.3	60.12	343.07	22.8	0.4	0.31

5th Observation In this day, it was the day to relax after a lot of work as it's final. The moisture content was reduced from moisture content of 22.8 to 7.3 % and weight was reduced from 0.316 to 0.263 Kg.

Serial number	Time	Absorber plate temp.	Collector outlet	Dryer inlet	Lower shelf	Upper shelf	Dryer outlet	Ambient temp	Drying chamber	Relative humidity (inside)	Relative humidity (outlet)	Average solar isolation	Moisture content	Wind speed	Sample weight
1	8	22.8	11	10	-	-	-	-	-	-	83.42	345.56	22.8	0.4	0.316
2	9	26.7	21	16	-	-	-	-	-	-	78.76	430.57	21.2	0.4	0.310
3	10	38.4	29.9	28	26	23.3	22	15.6	35	66.4	76.79	518.53	19.6	0.5	0.304
4	11	52.6	41	37	37.5	34.7	33	17.9	46	59.5	69.36	630.11	17.9	0.6	0.298
5	12	62.7	50.1	48	47.8	44.6	42	18.3	48.9	42.7	54.75	670.23	16.2	0.7	0.292
6	13	70.6	55.7	52	51	50	49	22.7	56	36.4	46.33	832.11	14.6	0.4	0.286
7	14	84.7	53	50.4	48	49	48	23.4	58	34.1	42.73	733.21	13.0	0.4	0.281
8	15	67.7	45.8	45	43	42	41	25.6	55	45.7	53.63	750.81	11.3	0.7	0.275
9	16	55.19	40	40.6	39	37	36	19.1	48	45.3	55.42	565.78	9.6	0.5	0.270
10	17	38.48	33.7	33.7	31	28.8	27	18.5	44	39.2	56.45	446.83	8.0	0.6	0.266
11	18	25.27	19.78	18	16	15	13	12.9	30	50.5	59.56	398.73	7.3	0.4	0.263

III. RESULTS AND DISCUSSION

A. *Moisture content*

Fig. 1 and 2 shows the time variation of moisture content for different airflow rates for solar(using blower) and mixed drying(using blower and heater) of Ginger respectively in comparison to natural drying. The benefit over natural drying of solar and mixed drying is obvious from the graph. It is seen that faster drying rates are observed for mixed drying as compared to solar drying. It should be noted that the effect of changing the air flow rate on the drying time is more noticeable in solar drying than in mixed drying.

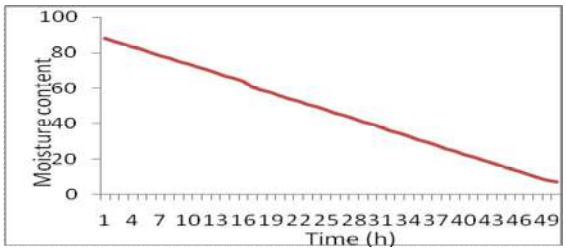

Figure1 (a). Shows the graph between moisture and time (hrs) for natural mode drying.

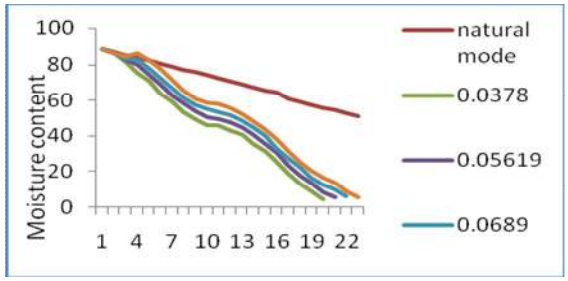

Figure1 (b). The graph between moisture and time (hrs) for natural and forced mode for different flow rates

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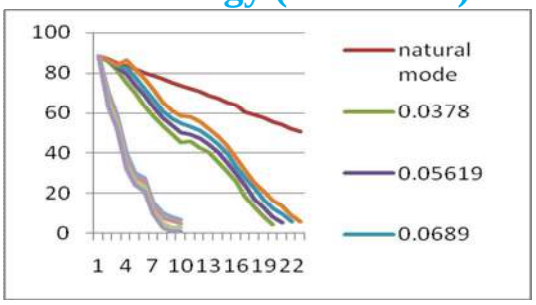

Figure2. The variation of moisture content with different flow rate and is compared with using heater with forced convection mode.

B. Collector efficiency

The collector efficiency is given by the graph; this graph shows the relation between the collector efficiency and drying time. The collector efficiency was seen to be first increasing and then decreasing. As the solar intensity of the radiation first increases and then decreases and this is due to this reason that the collector efficiency was seen to be monotonically increasing and then decreasing.

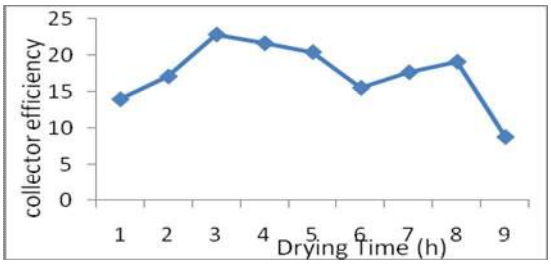

Figure 3. The variation of collector efficiency with time

C. Drying rate

The drying rate was seen to be decreasing with the time and is shown by the given graph in fig4.

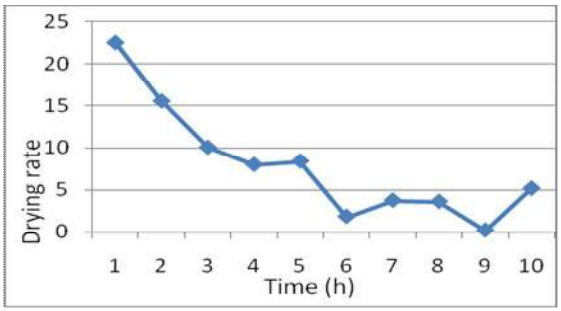

Figure4. The variation of drying rate with time.

D. Drying efficiency

The drying efficiency was seen to be decreasing with time and is shown in the fig5. There are some peaks and falls in the curve and the curve is not monotonically decreasing.

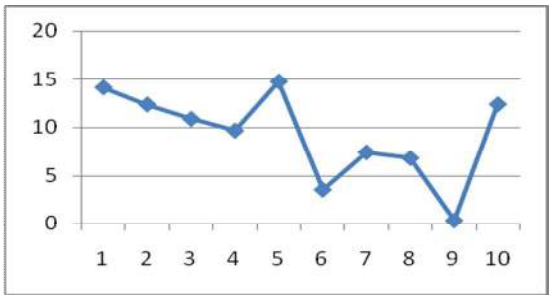

Figure5. The graph between drying efficiency with time.

E. Relative humidity

The relative humidity at the desired points is shown in the fig6, and it was found to be first decreasing and then increasing. The relative humidity inside was found to be higher than relative humidity at outside.

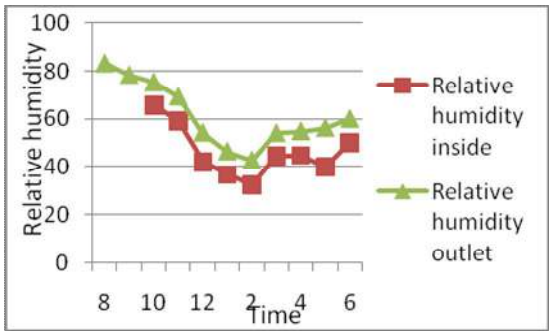

Figure6. The variation of relative humidity with time.

F. Temperature

The temperature variations in the system are shown in the fig7, and it was found to be first increasing and then decreasing. The reason for this monotonically increasing and then decreasing is due to available solar intensity which was seen to be increasing first and then decreasing.

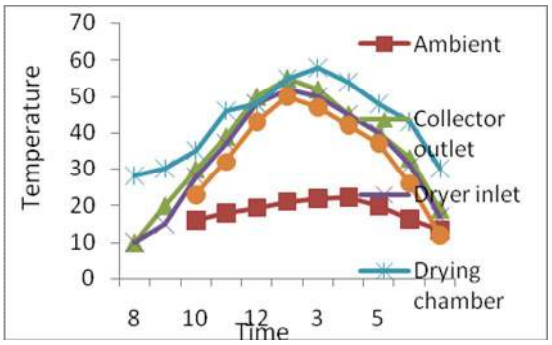

Figure7. Shows the variation of temperature vs. time

G. Solar intensity

The variation of solar intensity with time is shown in the fig8, and it was first seen to be increasing and then decreasing.

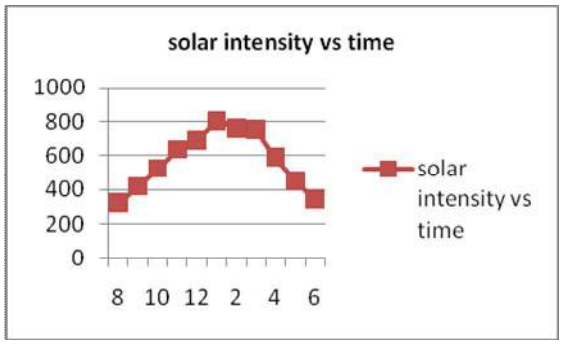

Figure8. Shows the variation of solar intensity vs. time

IV. CONCLUSION

How to represent the various parameters in the Tabular Form is presented here, tabular form of data taken is very important to calculate for the various parameters. As it was seen that with the increase in flow rate there will be a considerable increase in the drying rate and moisture removal rate would be faster. Also it was seen that when heater was used there were almost negligible effect of flow variation in the moisture removal rate. Thus it was seen that it will be beneficial to use blower with different flow

rates instead of using a completely natural solar dryer. It should be noted that using a blower may consume more energy but it adds to less time in drying the product and may lead to more net profit.

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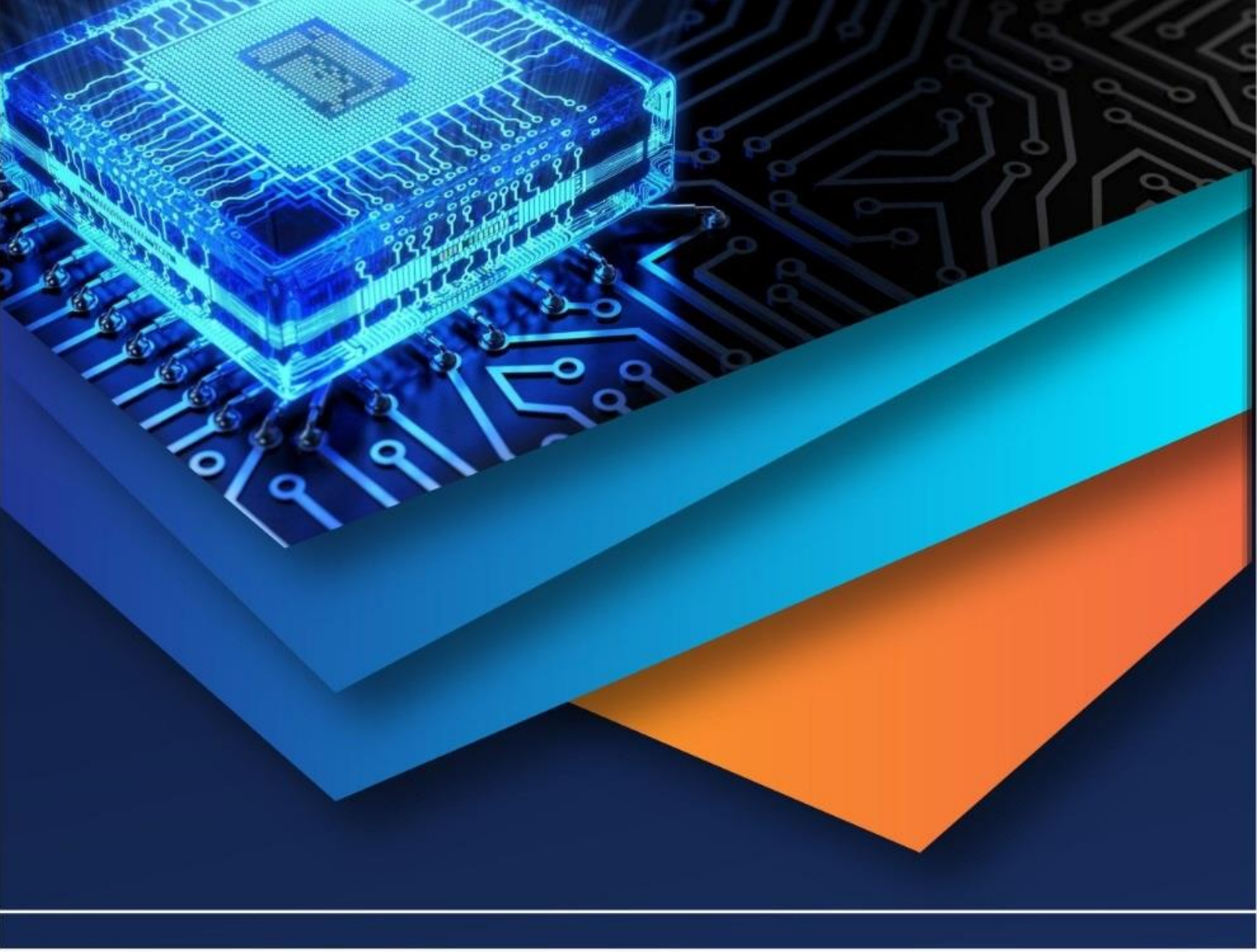

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