iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 11 **Issue:** V **Month of publication:** May 2023

DOI: https://doi.org/10.22214/ijraset.2023.53368

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Development of Solar still using Thermosyphon Effect

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Abstract: Thermal energy is a crucial important part of the economic growth of a country. The source of energy is constant, but consumption is growing exponentially over the last few years. In the traditional way of living, thermal energy is vitally used for air heating, water heating, cooking, etc. All these daily chores contribute to the huge amount of thermal energy consumption. A Solar still is designed to improve the performance and efficiency with the help of thermosyphon effect for fulfilling these daily needs. Brief experimentation was carried out to enhance the performance of Solar still compared to conventional solar still. Where conventional solar still have efficiency of mere 20% or less, the new proposed design provides higher efficiency and better utility .The purpose of this project is to design a water distillation system that can purify water from nearly any source, a system that is relatively cheap, portable, and depends only on renewable solar energy.
Keywords: Solar still, Thermosyphon effect, Thermal energy

I. INTRODUCTION

Biomass has been a vital ingredient for satisfying the needs of basic thermal energy used for cooking, heating water, etc. Application of conventional solar still is usually made to complete this need of thermal energy. As the efficiency of a conventional solar still is less than 15%, it is necessary to work on increasing the efficiency of solar still. In India were the major population lives in a rural area, makes use of conventional solar still on a huge scale for production of drinkable water. Hence, there lies a tremendous scope of improvement for the solar still, in terms of efficiency, its output, its capability to obtain fresh drinkable water. A brief study of various types of solar still was covered during the development of a proposed new design. This paper shall cover the development, and experimentation of the new proposed design of the solar still.

II. TO IMPLEMENT THE CONCEPT IN THIS RESEARCH STUDY NUMBER OF LITERATURE SURVEY HAS BEEN CARRIED OUT AS FOLLOWING

Anwarul Islam Sifat et.al [2015] (1) has explained the Water Distillation Method Using Solar Power. This paper investigates the optimization of different parameters of the distillation process like the Basin type water distillation system was discussed in this paper. An experimental prototype is presented to evaluate individual factors that affect the performance of water distillation. To begin with, an elementary principle of water distillation is labeled. Some patent models of distillation are presented by focusing the cost and effectiveness towards water purification. After that, a theoretical analysis of an asymmetrical solar distiller is presented. The theoretical analysis is divided into two different categories. At first, the thermal circuit was illustrated to demonstrate the mathematical equation of conduction, convection and radiation process. Also, the basin size is calculated through this. Next, by calculating the slope of the collector the optimal direction was predicted. Finally, the proposed prototyped design of water distillation system is presented. A schematic structure diagram is depicted with different components that are further discussed in detail. Finally, predicted output from the prototype device is presented in a table. According to this maximum output is possible in the months of March and April.

Bhupendra Gupta et.al [2017] (2) has explained the Experimental Investigation on Modified Solar Still Using Nanoparticles and Water Sprinkler Attachment. The experimental investigation was done in the month of April 2015 for the climate condition of Jabalpur, Madhya Pradesh, India) during a full day. The performance of the solar still with modification of water flow over the glass cover (sprinkler attachment) and nanoparticles (cuprous oxide) in basin water has been observed, recorded, and compared with conventional still. It has been found that the collection of pure water in modified solar sill was 4,000 ml/(m2-day) as compared to 2,900 ml/(m2-day) in conventional solar still. The efficiency of 34 and 22% has been obtained for modified solar still and conventional still, respectively. With design amendments, an increase in overall effectiveness was found to be 54.54%. The computed cost of pure water produced in modified still is expected to be (INR) Rs. 0.98/l, in view of 12-year life of the solar still.

Sartori et.al [1996] (3) had explained solar still versus solar evaporator: A comparative study between their thermal behaviors. This paper presents a theoretical comparison between the thermal behaviour of a basin type solar still and that from a solar evaporator. The analyses are twofold: (a) comparing the system temperatures and the heat and mass transfer rates in the transient mode; (b) obtaining parametric representations from both systems using their heat and mass transfer equations. Such comparisons had never been done before. It is shown, among other things that the evaporation in solar stills is much less than that in open evaporation despite the higher water temperatures in the former system. This is also true even when the water temperature of both systems is the same. It is also observed that the distillation and evaporation rates increase with the increasing water temperature and temperature difference. For relatively high water temperatures of each system the evaporative fraction is equivalent to more than 50% of the corresponding total heat transfer rate.

Aseem Dubey et.al [2018] (4) has described the Performance of Various Designs of Active Solar Stills. In this paper a review on the comparative performance of various designs of active solar stills has been carried out in terms of their design, efficiency and output per m2 of Solar still. Numerical computation is performed on the basis of experimental performance of the solar stills reported by various researchers. Average annual productivity estimated from various types of solar stills for 300 clear sunshine days in a year. Energy efficiency and production cost on the basis of life cycle cost analysis has also been estimated.

Mohamed M. Khairat Dawood et.al [2022] (5) has explained the 3E enhancement of freshwater productivity of solar still with heater, vibration, and cover cooling. This study focused on experimentally increasing the productivity of freshwater from solar stills. The performance of a single solar still system could be augmented with the combination of an electric heater, vibration motion, and thermoelectric cooling. The study investigated the effects of combining two of these components and finally combining all of them on freshwater productivity. The electric heater and vibration motion are used to enrich the evaporation rate, while thermoelectric coolers are used to enhance the condensation rate, leading to high freshwater productivity. The proposal, construction, and testing of two identical solar stills were performed under the local climate conditions of the city of Alexandria in north-western Egypt during the summer and winter times. The two solar stills had a 1-m2 base area. An electric heater of 450 W was placed inside the modified solar still. The modified solar still was fixed on four coiled springs. A 1-hp power DC motor, an inverter, a control unit, and two 330-W photovoltaic solar panels were attached to the modified solar still. Eccentric masses were mounted on the rotating disk attached to the DC motor to generate the vibration. Under the same climate conditions, the daily output of freshwater was measured experimentally for the modified case and the conventional solar. The daily rates of freshwater productivity in summer were investigated for four cases and the conventional one. Results showed that the peak daily freshwater productivity achieved with the solar heater, thermoelectric coolers, and vibration motion was 12.82 kg/day, with a maximum estimated cost of 0.01786 $/L/m2.The exergo economic of the modified solar still with heater, vibration, and thermoelectric cooler was greater than that of conventional ones. The highest CO2 mitigation of the case (5) and that of the conventional solar desalination were about 160 tons and 28 tons, respectively.

Dsilva Winfred Rufus et.al [2018] (5) has described the “A comprehensive review of designs, performance and material advances”. This paper aims to give a detailed review about the various types of solar stills, covering passive and active designs, single- and multi-effect types, and the various modifications for improved greenhouse type solar stills are also covered. Material advances in the area of phase change materials and nanocomposites are very promising to enhance further performance; future research should be carried out in these and other areas for the greater uptake of solar still technology.

Husham M. Ahmed et.al [2016] (7) has explained the “Performance Evaluation of a Conventional Solar Still with Different Types and layouts of Wick Materials”. In this research, three identical conventional basin type solar stills were designed and constructed in order to experimentally investigate the affect of using different wick materials in two different layout arrangements. The first solar still was used as a reference still for comparison. The second solar still was used for uniformly spreading the wick material sheets in the saline water. In this case, the wick materials sheets were completely immersed in the saline water covering the total still basin area. The third solar still had a specially designed set up of steel mesh wires. In this case, the wick materials were partially immersed in the saline. The five wick materials were light black cotton fabric, light jute fabric, black velvet fabric, black sheer mesh fabric, and a 4 mm thick sponge sheet. Therefore three identical single slope basin Type solar stills were designed and constructed.

Husham M. Ahmed et.al [2015] (8) has described the “An Experimental Investigation into the Performance of Hemispherical Basin Type Solar Still”. In this article a single basin hemispherical solar still was designed and constructed. Its performance was experimentally evaluated, with and without external reflectors, under the climate of the Kingdom of Bahrain during the autumn season. The hemispherical cover has a base diameter of 1m and a depth of 0.4 m, die cast from a 6 mm thick Lexan plastic sheet. The net effective area was 0.785 m2. It has been found that the average daily production rate obtained from the hemispherical solar still is 3.610 liter/day.

This yield is 11.1% higher than the yield of a conventional simple type single slope solar still having 20 slope glass cover and a larger effective area of 1 m2 obtained in^{O} previous research under similar climatic conditions. It has also been found that adding 1.2 m long by 0.15 m curved reflectors increased the yield of the hemispherical solar still by 5.5 %, while the 1.2 long by 0.3m curved reflector increased the yield by about 8%.

Bhardwaj et al. [2015] had explained "The effect of the water depth on the productivity for single and double basin double slope glass solar stills", This paper presents a new approach to enhance the productivity of the solar still by introducing glass as the basin material. Single and double basin double slope solar stills of same basin area were fabricated using glass. The experiments were carried out by varying the water depths from 1 to 5 cm under both insulated and un-insulated conditions. The production of single basin is more than the double basin during the heating period and double basin is more during the cooling period. The performance of the double basin Double slope solar still was higher than the single basin double slope solar still under insulated and un-insulated conditions. The productivity of the stills was more at the lowest water depth of 1 cm. Of the two sets of experiments which were conducted under insulated and un-insulated conditions, insulated stills gave more production. At 1 cm water

Dsilva Winfred Rufus et.al [2018] (9) has described the "A comprehensive review of designs, performance and material advances". This paper aims to give a detailed review about the various types of solar stills, covering passive and active designs, single- and multi-effect types, and the various modifications for improved 7 depth, double basin insulated and un-insulated stills gave 17.38% and 8.12% higher production than the single basin still.

Ahmed Rahmani et al [2015] (10) has described the "An experimental approach to improve the basin type solar still using an integrated natural circulation loop", in this paper, a new experimental approach is proposed to enhance the performances of the conventional solar still using the natural circulation effect inside the still. The idea consists in generating air flow by a rectangular natural circulation loop appended to the rear side of the still. The proposed still was tested during summer period and the experimental data presented in this paper concerns four typical days. The convective heat transfer coefficient is evaluated and compared with Dunkle's model. The comparison shows that convective heat transfer is considerably improved by the air convection created inside the still. The natural circulation phenomenon in the still is studied and a good agreement between the experimental data and Vijajan's laminar correlation is found. Therefore, natural circulation phenomenon is found to have a good effect on the still performances where the still daily productivity is of 3.72 kg/m2 and the maximum efficiency is of 45.15%.

El-Agouz S.A et.al [2015] (11) has explained the "Performance evaluation of a continuous flow inclined solar still desalination system" In the present work, theoretical study of the performance evaluation of a continuous water flow inclined solar still desalination system is performed. Three models are studied for inclined solar still desalination system with and without water close loop. The effects of the water mass, water film thickness; water film velocity and air wind velocity on the performance of the three models are studied. The results show that the inclined solar still with a makeup water is superior in productivity (57.2% improvement) compared with a conventional basin-type solar still. Also, the application of inclined solar still with open water loop is recommended when combined with other still desalination system due to high water temperature output. The inclined solar still with a makeup (Model 3) gives the highest performance while Model 1 gives the lowest performance. Finally, the water film thickness, and velocity as well as wind velocity plays important roles in improving the still productivity and efficiency.

Sakthivel M et.al [2010] (12) has described the "An experimental study on a regenerative solar still with energy storage medium — Jute cloth", this paper deals with the Experiments conducted on a conventional single slope solar still and on a regenerative solar still with jute cloth. The conventional still has been modified with the energy storage medium viz., jute cloth which is kept vertically in the middle of basin saline water and also attached with the rear wall of the still. To show the effectiveness of the modification, theoretical still hourly yield from the basin water and from the jute cloth is calculated using Dunkle's model. Its performance is compared with the Dsilva Winfred Rufus et.al [2018] has described the "A comprehensive review of designs, performance and material advances". This paper aims to give a detailed review about the various types of solar stills, covering passive and active designs, single- and multi-effect types, and the various modifications for improved 8conventional still under the same climatic condition. It is also found that there is 9% deviation from the experimental result. It is found that cumulative still yield in the regenerative still with jute cloth increases approximately by 20% and efficiency increases by 8% with low cost for this modification as the jute cloth is very cheap and easily available.

G. N. TIWARI et.al [2007] (13) has explained "Characterization of Solar Stills". This paper presents the transient analysis of a conventional solar still and the derivation of suitable parameters to assist in the characterization of various designs of solar stills. The methodology to test and compare the various designs of solar stills is presented. Further an attempt is made to incorporate the effect of glass cover inclination and the resulting triangular cavity volume on the performance of solar still.

The expressions given by various authors are considered to take into account the glass cover inclination. Based on experimental and theoretical computations it is inferred that there is good agreement between experimental and theoretical results.

H. Tanaka, et.al [2004] (14) had described “Parametric investigation of a basin-type-multiple-effect coupled solar still” Parametric analysis was performed for the basin-type multiple-effect coupled solar still with a triangle cross-section consisting of a horizontal basin liner and a number of vertical parallel partitions in contact with saline-soaked wicks with narrow gaps between the partitions, under dry weather conditions at 26.1 °N latitude. The productivity of the still increased in winter with an increase in the angle between the glass cover and the basin and decreased in summer. In the spring and autumn seasons productivity had a gentle peak between a 40° and 45° angle. Increasing supply rates of saline water to the wicks and increasing initial mass of the basin water decreased productivity. With a decrease in diffusion gaps between partitions, productivity exponentially increased, and it also showed exponential increases with an increase in the number of distillation cells between the partitions. The productivity of the still of 13 partitions with 5-mm gaps and a 40° angle of the glass cover was four times more than the basin-type stills, and the still was more productive than the conventional multiple-effect stills by about 40% or more.

Mehdi Bahiraei, at.el [2000] (15) has described “Modeling of energy efficiency for a solar still fitted with thermoelectric modules by ANFIS and PSO-enhanced neural network: A nanofluid application”. An accurate model is developed for predicting the energy efficiency of a single-slope solar still equipped with thermoelectric modules. Adaptive Neuro-Fuzzy Inference System (ANFIS) and Artificial Neural Network (ANN) enhanced by Particle Swarm Optimization (PSO) are employed. Cu2O nanoparticles are utilized in the solar still basin, and the energy efficiency is modeled as a function of the time, glass temperature, fan power, solar radiation, ambient temperature, water temperature, basin temperature as well as the nanoparticle volume fraction. The experimental data are utilized for training the artificial intelligence methods. The ANN with three hidden neurons and the ANFIS with nine clusters present the best predictions. Applying the PSO profoundly enhances the prediction performance. The comparison between the performances of PSO-based ensemble models reveals superiority of the PSO-ANFIS compared with the PSO-ANN. The R2 values for the PSO-ANFIS model are 0.9884 and 0.9906 for the training and test sets, respectively.

V. Velmurugan at.el [2007] (16) had explained “Desalination of effluent using fin type solar still”. In this work, an attempt is made to produce potable water from industrial effluents. An ordinary basin type solar still integrated with fins at the basin plate is used for experimentation. Since industrial effluent is used as feed, before this still, an effluent settling tank is provided to get clarified effluent. This effluent settling tank is fabricated with three chambers, consists of pebble, coal and sand for settling the impurities and removing the bacteria in the effluents. Sponges, pebbles, black rubber and sand are used in the fin type single basin solar still for enhancing the yield. Results show that the productivity increases considerably due to this modification. A theoretical analysis is also carried out which, closely converges with experimental results. The economic analysis proved that the approximate payback period of such kinds of still is 1 year.

J.C. Torchia-Núñez et.al [2007] (17) has explained “Exergy analysis of a passive solar still”. This paper presents a steady-state and transient theoretical exergy analysis of a solar still, focused on the exergy destruction in the components of the still: collector plate, brine and glass cover. The analytical approach states an energy balance for each component resulting in three coupled equations where three parameters—solar irradiance, ambient temperature and insulation thickness—are studied. The energy balances are solved to find temperatures of each component; these temperatures are used to compute energy and exergy flows. Results in the steady-state regime show that the irreversibility’s produced in the collector account for the largest exergy destruction, up to 615 W/m2 for a 935 W/m^2 solar exergy input, whereas irreversibility rates in the brine and in the glass cover can be neglected. For the same exergy input a collector, brine and solar still exergy efficiency of 12.9%, 6% and 5% are obtained, respectively. The most influential parameter is solar irradiance. During the transient regime, irreversibility rates and still temperatures find a maximum 6 h after dawn when solar irradiance has a maximum value. However, maximum exergy brine efficiency, close to 93%, is found once $T_{col} < T_w$ (dusk) and the heat capacity of the brine plays an important role in the modelling of collector–brine interaction. Nocturnal distillation is characterized by very low irreversibility rates due to reduced temperature difference between collector and an increase in exergy efficiency towards dawn due to ambient temperature decrease.

Anil Kr. Tiwariet.al [2005] (18) has described “Effect of water depths on heat and mass transfer in a passive solar still: in summer climatic condition”. In this communication, an attempt has been made to find out the effect of water depth on evaporative mass transfer coefficient for a passive single-slope distillation system in summer climatic condition. The experiments have been conducted on a south facing, single slope, solar still of 30° inclination of condensing cover, in summer climatic condition for 24 h on different five days for different five water depths from 0.04 m to 0.18 m. The objective of the present paper is to study the behavioral variation in internal heat transfer coefficients with respect to the water depth in the still. It is understood that the heat transfer coefficients depends significantly on water depths.

It is also observed that the nocturnal distillation is significant in the case of higher water depths because of reduced ambient and stored energy within it.

T. Kiatsiriroat et.al [1986] (19) has explained “Prediction of mass transfer rates in solar stills”. This paper presents a modification of a mass transfer theory developed by Spalding to predict mass transfer rates in solar stills of different inclinations. In previous applications to solar stills, the authors considered the mass fractions at the evaporating surface and the bulk state to evaluate the driving force for mass transfer. In this study, the mass fraction at the condensing surface on the cover is employed instead of the bulk mass fraction on the moist air in the still, since the former can be more accurately determined. Predicted results from the modified theory and results from relation of Dunkle1 are compared with experimental values. The results of the modified theory agree very well with the experimental results, whereas Dunkle's relation is accurate only in horizontal stills and stills with small inclinations.

Vimal Dimri et.al [2007] (20) had explained “Effect of condensing cover material on yield of an active solar still: an experimental validation”. An attempt has been made to evaluate inner and outer glass temperature and its effects on yield. Numerical computations have been performed for a typical day in the month of December, 2005, for the climatic condition of New Delhi (latitude: 28°35´ N; longitude: 77°12´ E and an altitude of 216 m above mean sea level). Higher yield was observed for an active solar distillation system as compared to the passive mode due to higher operating temperature differences between water and inner glass cover. The parametric study has also been performed to find out the effects of various parameters, namely thickness of condensing cover, collector absorbing surface, wind velocity and water depth of the still. It is observed that there is significant effect on daily yield due to change in the values of collector absorbing surface, wind velocity and water depth. For all the cases, the correlation of coefficients (r) between predicted and experimental values have been verified and they showed fair agreement with $0.90 < r < 0.99$ and root mean square percent deviation $3.22\% < e < 22.64\%$. Effect of condensing cover materials, namely copper and polyvinyl chloride (PVC), on daily yield have also been investigated and compared.

III. EXPERIMENTAL SET UP

Choose a suitable location: Find a sunny spot with ample sunlight exposure throughout the day. Ideally, the location should be flat and free from shading objects.

Construct the base: Build a base or platform using mild still to elevate the solar still off the ground. This will facilitate easy access to the water collection container. Create the condensation surface: Cut the transparent polycarbonate sheet to the desired size for the condensation surface. Apply a thin, even layer of black paint or cover it with a black plastic sheet. The black color enhances heat absorption and promotes condensation. Seal the condensation surface: Fix the condensation surface at an angle facing the sun on the base using waterproof sealant or adhesive. Ensure it is secure and doesn't allow any water leakage.

Construct the thermosyphon loop: Using the copper tubing, create a loop. The size and length of the tubing will depend on the scale of solar still. The coil should have an inlet and an outlet. Attach the thermosyphon loop: Place the thermosyphon loop below the condensation surface, preferably in contact with it. Use heat-resistant adhesive tape to secure the tubing in place.

Install the water containers: Position a water container or basin above the condensation surface. This will serve as the water source for the solar still. Ensure it is elevated higher than the condensation surface to allow gravity-driven flow. Connect the thermosyphon loop: Attach one end of the thermosyphon loop to the water container or basin's outlet. Connect the other end to the water collection container. The thermosyphon effect will facilitate the natural circulation of water through the loop. Insulate the system: Surround the condensation surface, thermosyphon loop, and water container with insulation material. This helps retain heat and prevent heat loss, enhancing the efficiency of the solar still. Test the setup: Fill the water container or basin with water. Ensure the tubing is properly connected, and there are no leaks. Place the system in direct sunlight and monitor the condensation and water flow.

Figure 2: Solar still model

Figure 2: Condensation Occure

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 11 Issue V May 2023- Available at www.ijraset.com

IV. CONCLUSION

From experimental results, it is concluded that the efficiency of a modified solar still with thermosyphon effect is greater than a traditional solar still. Brief experimentation is carried out. Solar still is the simplest device to distillate the water using solar energy as fuel. The productivity of the solar still can be increased by increasing the evaporation rate and by minimizing the losses in still. The evaporation rate can be increased effectively by using different absorbing materials. Researchers have modified the conventional solar still system to get a better performance hence solar stills look like the best option to obtain fresh drinkable water in remote areas usage.

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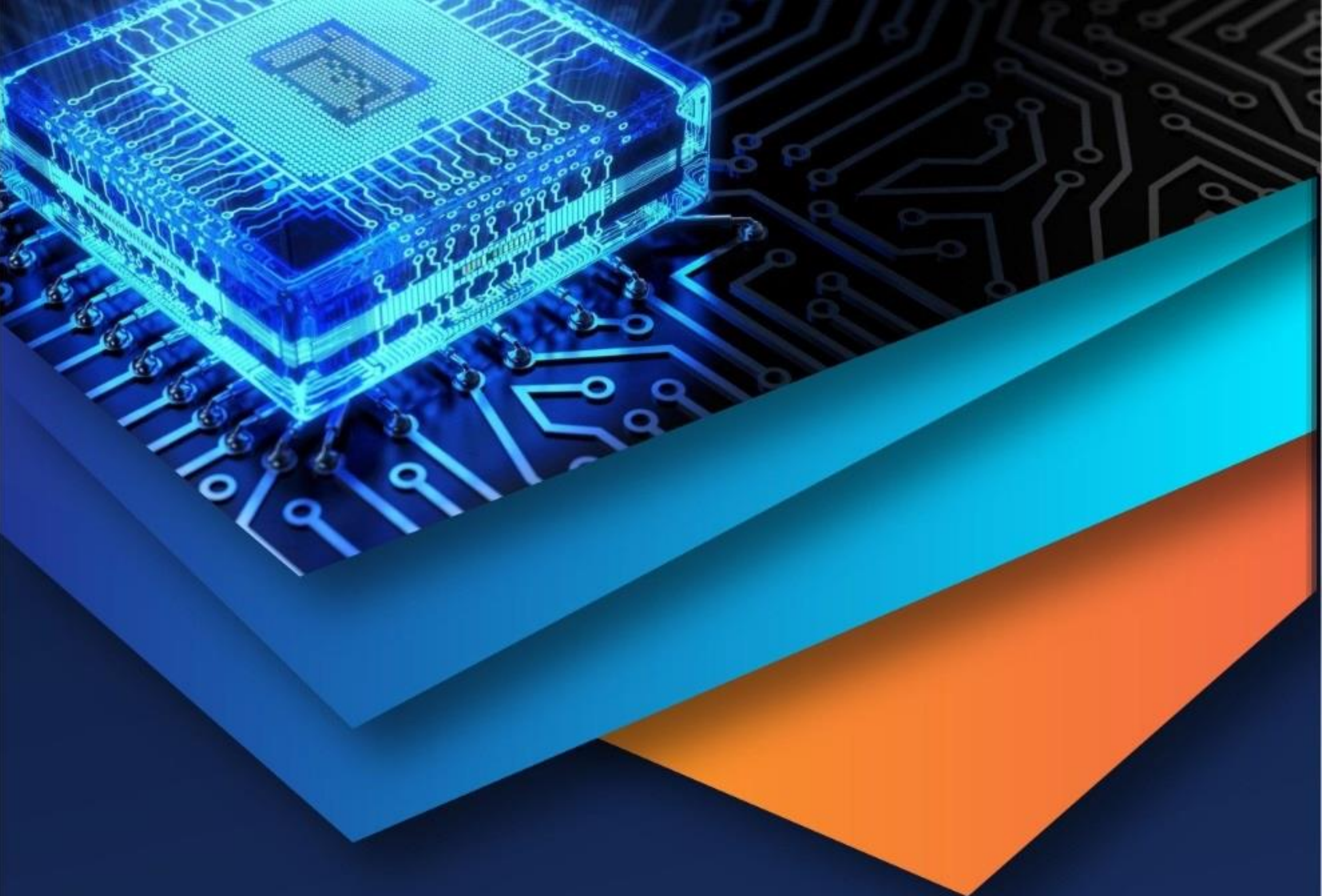

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