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Optimal Availability Analysis of Drill Bit Manufacturing System by using Markov Approach

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Abstract: Reliability analysis plays crucial role in the design process. In order to increase reliability of a system, analysis of failure data is essential. The conventional techniques such as reliability block diagram, fault tree analysis & reliability graphs are not applicable when repairs and other dependencies are incorporated in the model. In this paper, a layout of drill bit manufacturing system is considered in which four subcomponents are present i.e., Lathe, heat treatment, grinding and surface finishing machines. This is a hybrid type of system whose reliability block diagram is a combination of series and parallel network. The Markov approach is selected for modelling since it can incorporate repair and other dependency features in the model. Keeping in mind that the failure and repair rates are constant in Markov's model, all the feasible states and, failure and repair transitions are identified to develop the system model. The set of ordinary differential equations are obtained for the change of probability of being in respective system states with respect to time in each model. This system of equations is solved using Runge- Kutta method in MATLAB. The system availability assessment is based on the sum of probabilities of all working states. These results are helpful to identify the critical design parameters. It also includes how reliability analysis is fruitful for Life cycle cost management.

Keywords: Corrective maintenance, Preventive maintenance, Mean time to failure, Mean time to repair

I. INTRODUCTION

Reliability of a system can be defined as the ability of the system to perform its required function under stated conditions for a specified period of time. This technology is used to increase the efficiency of the system. A minor failure in any industry can lead to a disaster. That's why maintenance is needed. Maintenance is generally of two types- Preventive maintenance (PM) and corrective maintenance (CM) [4],[8]. PM control the operational behaviour of the system while CM restores the defective machine or component in the operating condition. Barlow and Hunter [8] studied the preventive maintenance model with minimal repairs. CM is necessary to bring the system to its original conditions and make the system/component "as good as new"[5].

Availability is a measure that allows for a system to be repaired when failures occur. Parvinder Singh & Atul Goyal [2] proposed Behaviour Analysis of a Biscuit Making Plant using Markov Regenerative Modelling" in which methodology to study the transient behaviour of repairable mechanical biscuit shaping System pertaining to a biscuit manufacturing plant is present. AtulGoyal, S.K. Sharma, Pardeep Gupta [3] evaluated availability of a part of rubber tube production system under preemptive resume priority repair under preemptive resume priority repair discipline is based on markov modelling.

This paper deals with the availability analysis of a complex hybrid system of a Drill Bit manufacturing system which combines the machines in series and parallel structure. Its availability depends upon its failure and repair rate. In this model availability is calculated by making the state space diagram and then generating the linear differential equations and solving them by Runge-Kutta method with the help of MATLAB.

II. WORKING PRINCIPLE

The process flow diagram presenting the process of the Drill Bit preparation multiple component system is shown in Fig.-1. A heat treatment machine is connected in series with the lathe machine. Two parallel grinding machines are connected in series with the heat treatment machine. Further, two parallel surface finishing machines are connected in series.

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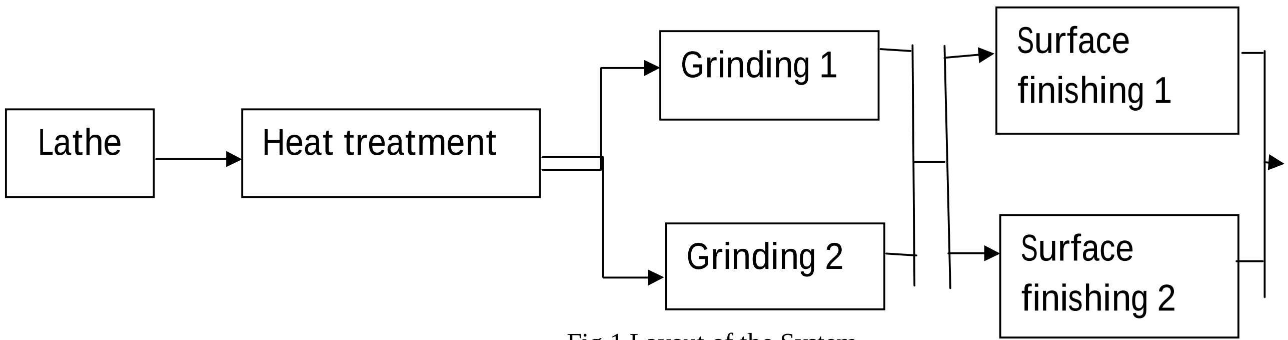


Fig.1 Layout of the System

A. Assumptions

There are the following assumptions

1) The states of all sub-systems are mutually independent and the failure and repairrates are constant over time and follows exponential distribution.
2) There are sufficient repair or replacement facilities available.
3) There is only one failure at a time.
4) When one subsystem fails, it is instantaneously replaced by one of the standby Subsystems and the switchover devices are perfect and the repaired sub-system behave as new sub-system.
5) Failure and repair rates are statistically independent.
6) Repair is carried on the basis of importance of the sub-system.

III. RELIABILITY ANALYSIS

After analysis,it had been seen that in Lathe machine, failure occur after 192.3 hours, in heat treatment, failure occur after 500 hours. In Grinding machine 1, failure occur after 50 hours,similar with the Grinding machine 2, it occur after 50 hours. In surface finishing machine 1, failure occur after 80 hours and similarly in surface finishing machine 2, failure occur after 80 hours.

λ (MTTF) = 1/ failure time (hrs)

Taking $\lambda1$= .0052, $\lambda2$ = .002, $\lambda3$= .02, $\lambda4$= .02, $\lambda5$= .0125, $\lambda6$= .0125

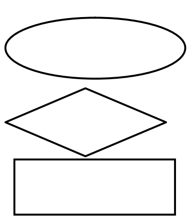
It has been seen that Lathe machine is repaired in 47.62 hours, heat treatment machine is repaired in 25 hours. Grinding machines are repaired after every 12.5 hours and surface finishing machines are repaired in 20 hours.

μ (MTTR) = 1/ repair time (hrs)

Taking$\mu1$= .021, $\mu2$= .04, $\mu3$= .08, $\mu4$= .08, $\mu5$= .05, $\mu6$= .05

Time taken:500 hours

B. Notation



= System in full working state

= operating state

= Failed State

A= lathe in working State

B= Heat treatment machine in working state

C= Grinding machine 1 in working state

C1= Grinding machine 2 in working state

D= Surface finishing machine 1 in working state

D1= Surface finishing machine 2 in working state

a,b,c,d = lathe, heat treatment, grinding and surface finishing machine in failure staterespectively

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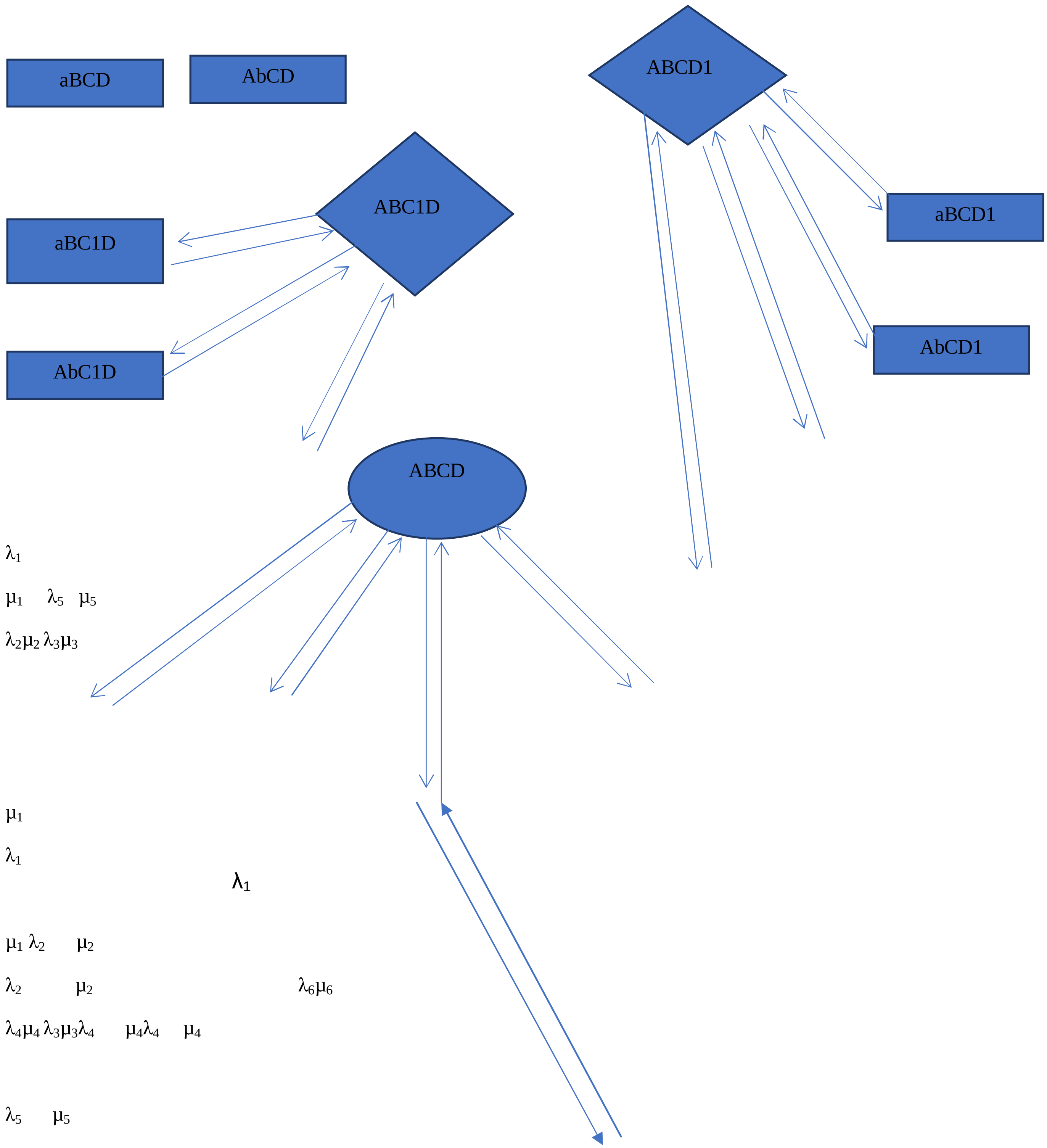

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$\lambda_1\mu_1\lambda_6\mu_6$

$\lambda_2\mu_2\lambda_4\mu_4$

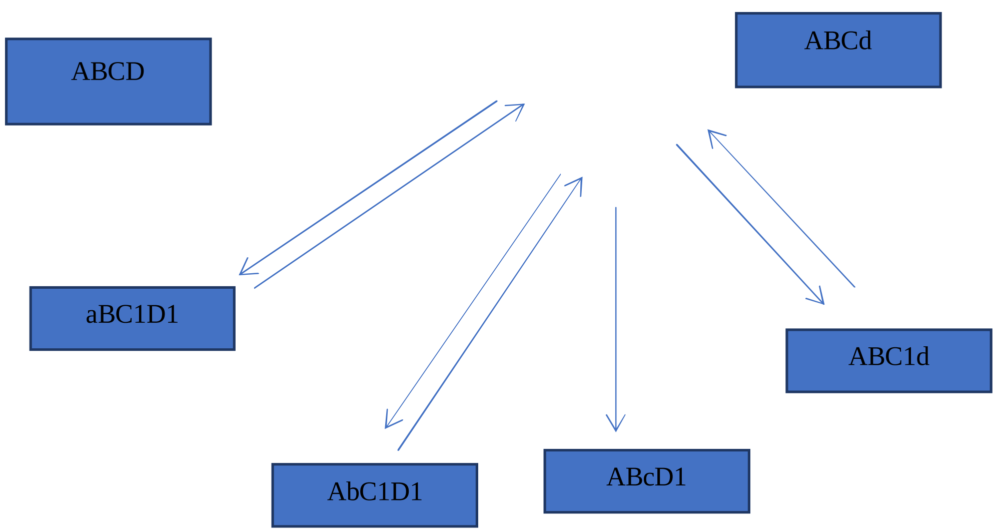
Fig.2 System Transition Diagram

IV. MATHEMATICAL FORMULATION OF THE MODEL

Model can be formulised in the form of differential equation as under

$$\frac{dP_1}{dt} = -(\lambda_1 + \lambda_2 + \lambda_3 + \lambda_5)P_1(t) + \mu_1 P_2(t) + \mu_2 P_3(t) + \mu_3 P_4(t) + \mu_5 P_5(t)$$

$$\frac{dP2}{dt} = -\mu_1 P_2(t) + \lambda_1 P_1(t)$$



$$\frac{dP3}{dt} = -\mu_2 P_3(t) + d_2 P_1(t)$$

$$\frac{dP_4}{dt} = -(\mu_3 + \lambda_4 + \lambda_1 + \lambda_2 + \lambda_5)P_4(t) + \lambda_3 P_1(t) + \mu_4 P_8(t) + \mu_1 P_6(t) + \mu_2 P_7(t) + \mu_5 P_9(t)$$

$$\frac{dP_5}{dt} = -(\lambda_1 + \lambda_2 + \lambda_3 + \lambda_6 + \mu_5)P_5(t) + \mu_1 P_{12}(t) + \mu_2 P_{11}(t) + \mu_6 P_{10}(t) + \mu_3 P_9(t) + \lambda_5 P_1(t)$$

$$\frac{dP_6}{dt} = -\mu_1 P_6(t) + \lambda P_4(t)$$

$$\frac{dP_7}{dt} = -\mu_2 P_7(t) + \lambda_2 P_4(t)$$

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$$\frac{dP_8}{dt} = -\mu_4 P_8(t) + \lambda_4 P_4(t)$$

$$\frac{dP_9}{dt} = -(\lambda_1 + \lambda_2 + \lambda_4 + \lambda_6 + \mu_3 + \mu_5)P_9(t) + \mu_1 P_{13}(t) + \mu_2 P_{14}(t) + \mu_4 P_{15}(t) + \mu_6 P_{16}(t) + \lambda_3 P_5(t) + \mu_5 P_4(t)$$

$$\frac{dP_{10}}{dt} = -\mu_6 P_{10}(t) + \lambda_6 P_5(t)$$

$$\frac{dP_{11}}{dt} = -\mu_2 P_{11}(t) + \lambda_2 P_5(t)$$

$$\frac{dP_{12}}{dt} = -\mu_1 P_{12}(t) + \lambda_1 P_5(t)$$

$$\frac{dP_{13}}{dt} = -\mu_1 P_{13}(t) + \lambda_1 P_9(t)$$

$$\frac{dP_{14}}{dt} = -\mu_2 P_{14}(t) + \lambda_2 P_9(t)$$

$$\frac{dP_{15}}{dt} = -\mu_4 P_{15}(t) + \lambda_4 P_9(t)$$

$$\frac{dP_{16}}{dt} = -\mu_6 P_{16}(t) + \lambda_6 P_9(t)$$

These equations are solved by Runge- Kutta method in MATLAB

V. RESULT

Availability can be evaluated with the help of all available state. Failed state does not give any contribution in system availability.

Av = $P1 + P4 + P5 + P9$

Av =71.55 %

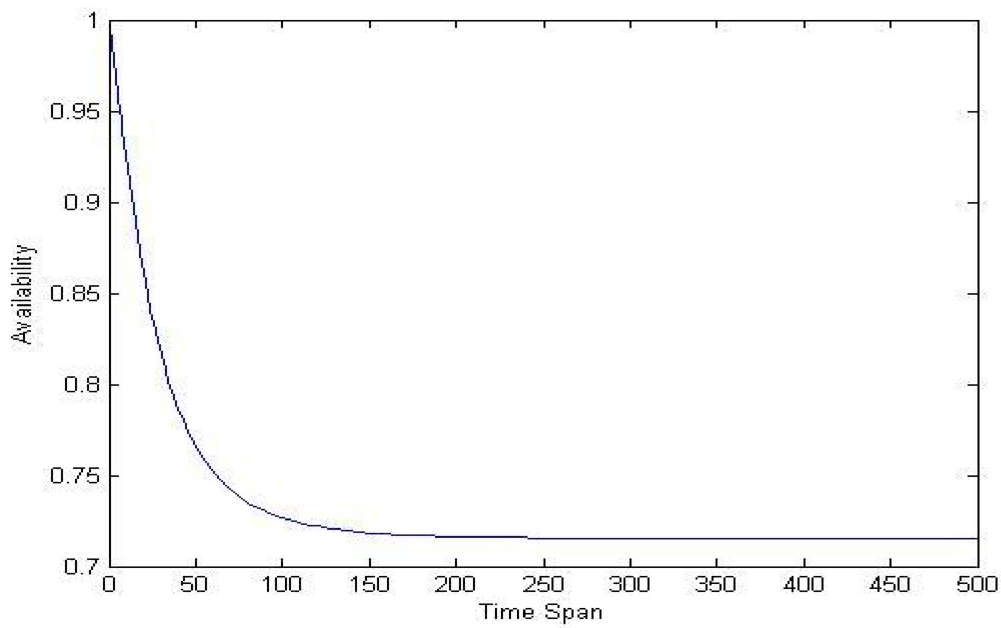

Fig.3 Curve between Availability of the system and time taken

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VI. CONCLUSION

A. Conclusions of this project study are

1) The approach is useful for design and development of reliable, maintainable and highly available systems.
2) The model is responsive to change of system parameters, thereby enabling us to design systems of required availability.
3) Transition probability is not dependent on the past (history) of the system.
4)

VII. LIMITATIONS

The major drawback of Markov methods is the explosion of the number of states as the size of the system increases. The resulting diagrams for large systems are generally extremely large and complicated, difficult to construct and computationally extensive.

VIII. FUTURE SCOPE

A. Optimization of mechanical system can be done on availability basis.

1) The approach can be applied to a real life industrial system which will help for performance monitoring of the system.
2) The approach can be extended for quantifying the actual gains in terms of revenues by increasing the availability by investing on maintenance resources.
3) The extension of this approach to design, operation, maintenance and other production aspects specifically.

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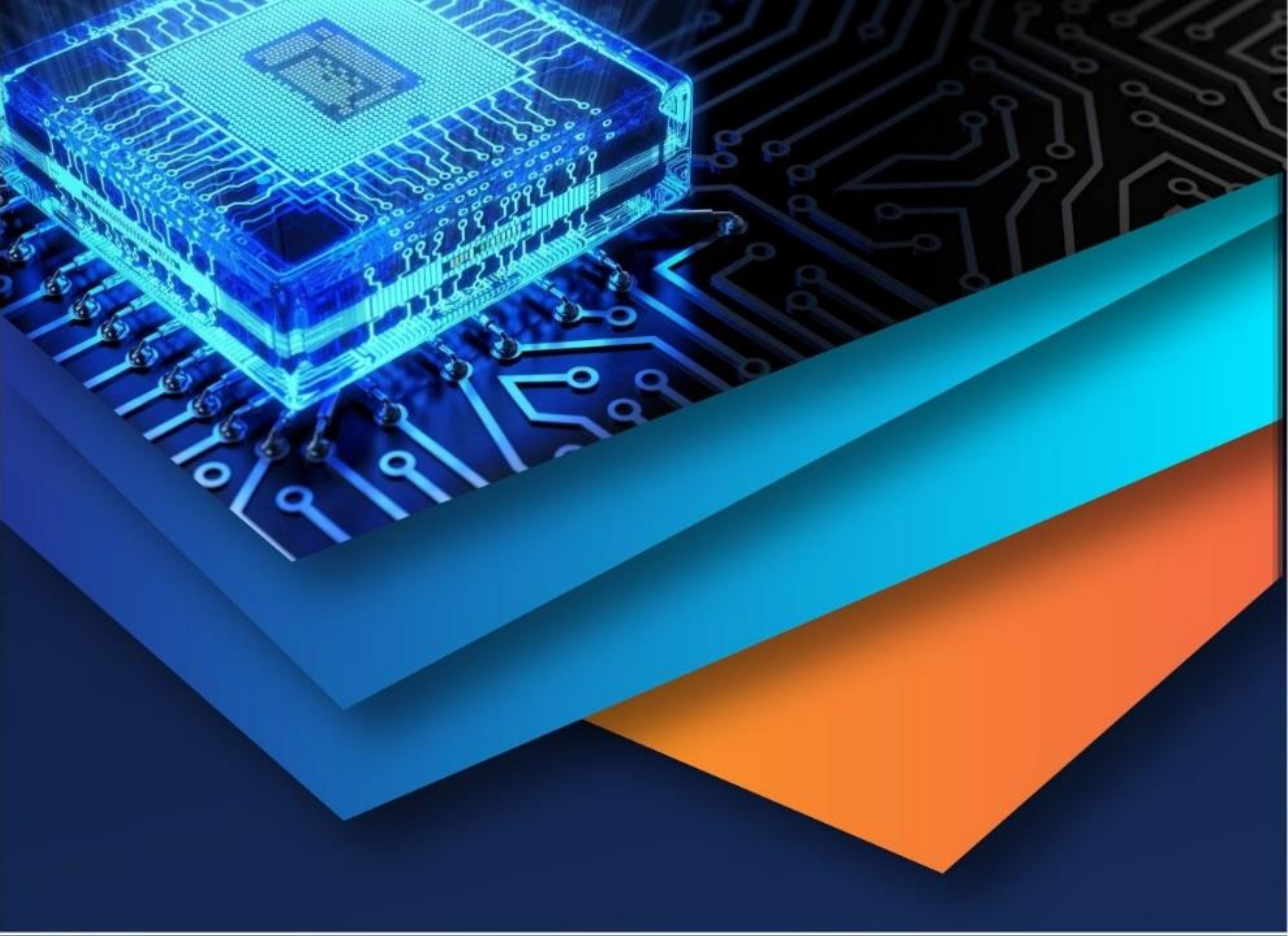

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