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Non contact Active Vibration control of Cantilever Beam Using Neural Networking

Ms Srishti Srivastava[1], Dr. Sankha Bhaduri[2]
[1-2]*Department of Mechanical Engineering, Birla Institute of Technology Mesra, Jharkhand, India*

Abstract—The aim of this study is to propose an active non-contact vibration damper to minimize the amplitude vibration of structure. The damper is made of an electromagnet. A neural network control system is proposed in this study to control the current flow through the coil of the electromagnet. The vibration of a cantilever beam type structure is controlled in this study using the proposed electromagnetic actuator. The electromagnet is placed just below the free end of the cantilever beam. The direct current is passed through the coil of the electromagnet during the upward motion of the beam. During the downward motion of the beam the current through the coil of the electromagnet is switch off. Therefore during the upward motion of the beam an attractive force will be applied on the beam which will try to minimize the amplitude of vibration of the structure. In this study it is shown that the non contact damper.
Keywords—Electromagnetic actuator, Neural network controller, Active vibration control, cantilever beam,

I. INTRODUCTION

Vibration has an adverse effect on machines so, it is necessary to control the vibration. We can control the vibration using two different methods one is active and the other one is passive. Passive vibration control is less effective and has some limits to their effectiveness. Nowadays the active vibration control is more familiar and there are many methods that are available for active vibration control and one of them is soft computing. The neural network control system has been applied by different authors to control the vibration of smart structures.

In 1997 Yang and Lee [1] implemented the neural network technique to smart structure for system identification & vibration suppression. Smart structure with build in PZT actuator and sensor was used for vibration control. In 1999 the neural network for non linear active control of vibration was studied by Bouchard et al. [2].They developed a new algorithm which has faster convergence speed and lower computational load. In this paper author used multi layer perceptron neural network based control system and the result led to the improvement in learning rate of neural network control system.Again the same study was done by Martin bouchard [3] on non linear active vibration control using advanced techniques. Here they used two multi layer neural networks in which one is for non linear controller and other is for non linear plant model. Using this new algorithm a better performance was achieved as compared to previous one.

In year 2009 Xia and Ghasempoor [4] had published a paper in which neural network and digital signal processing techniques were used which automatically detects the sinusoidal waves of vibrations of the cantilever beam and generates a control signal to an actuator which could reduce the vibrations.

In 2013 Amit Kumar and Deepak Chhabra [5] worked on neural network technique to control the vibration of cantilever plate. Finite element model along with piezoelectric patch sensor and actuator was used in order to obtain the better results. In 2014 Wang Hongbo[6] uses the feedback and the feed forward control method for reducing the vibration of load disturbance.

In 2015 Lin and Chang [7] improved the performance and practicability of neural network controller by introducing a hybrid controller where repetitive controller was added with NN controller for active vibration control of smart structure. Back propagation algorithm was used in neural network controller for performance evaluation. In this study an active vibration control system is proposed using neural networking to minimize the amplitude of vibration of a cantilever beam. The magnetic force is applied on the beam using an electromagnetic actuator. The current flow through the coil of the magnet is controlled through the neural networking system

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II. LAYOUT

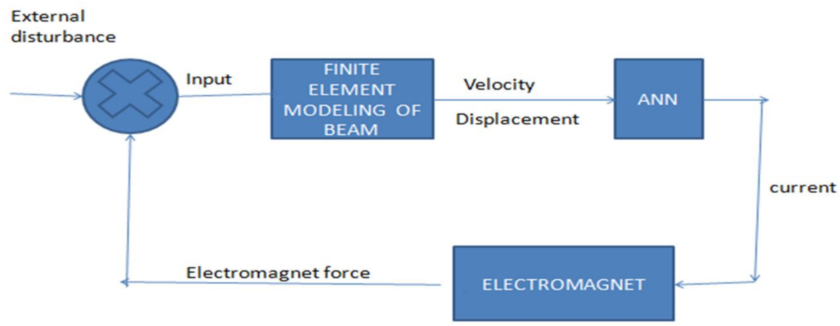

Fig.1 represents the block diagram of layout

The fig.1 is representing the layout of the proposed active vibration system. The external disturbance in the form of vibration is applied on the beam. The displacement and the velocity at the free end of the beam is sent as the input the neural network controller. From neural network controller current is obtained which is passed through the coils of electromagnet actuator. The direct current is passed through the coil of the electromagnet during the upward motion of the beam. During the downward motion of the beam the current through the coil of the electromagnet is switch off. Therefore during the upward motion of the beam an attractive force will be applied on the beam which will try to minimize the amplitude of vibration of the structure

III. ELECTROMAGNETIC ACTUATOR

Electromagnetic actuator is also known as solenoid. Electromagnetic actuator consists of two main parts the first is the coil and the other one is movable iron core which is also known as armature. Both parts are composed of insulated ferromagnetic sheets. Here the force exerted by structure due to actuator is directly proportional to square of current in electromagnet and inversely proportional to square of gap between the actuator and the structure.

The external applied force on the desired structure is given by F where,

$$F = k' \frac{i^2}{(x_0 - x)^2} \quad \text{.......(1)}$$

Then "i" denotes the current flowing in the coil of electromagnets, the gap between the actuator and the free end of the beam is denoted by x_0 and displacement is shown by x. Hence the constant

$$k' = \frac{\mu_0 n^2 A_m}{4} \quad \text{..........(2)}$$

where, μ_0 is permeability of free space = $4\pi * 10^{-7}$N/A^2, n denotes the number of turns in the coil of electromagnet, A_m is the cross sectional area of magnet.

IV. MDOF MODEL

Let the displacement of the beam contains n x1vector{X}.At the jth degree of freedom the actuator force is applied. Let the [M] be the mass, [K] be the stiffness and [C] be the damping matrices of size nxn. So the governing equation can be represented as:-

$$[M]\{\ddot{X}\} + [C]\{\dot{X}\} + [K]\{X\} = \{T_E\}f + \{T_C\}(-F) \text{........ (3)}$$

where, $\{T_C\}$ is t he nx1 vector which has zero entities except for jth row. The row has unity entry. Where $\{T_E\}$ has its unity entry when the external excitation is applied.

The space state notation of MDOF Model can be given as:-

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$$\begin{Bmatrix}\{\ddot{X}\}\\ \{\dot{X}\}\end{Bmatrix} = \begin{bmatrix}[M]^{-1}[C] & [M]^{-1}[K]\\ [-1] & [0]\end{bmatrix}\begin{Bmatrix}\{\dot{X}\}\\ \{X\}\end{Bmatrix} + \begin{bmatrix}[M]^{-1}[T_E] & [M]^{-1}[T_C]\\ [0] & [0]\end{bmatrix}\begin{Bmatrix} f\\ -F\end{Bmatrix} \ldots\ldots. (4.1)$$

or,

$$\{\dot{Z}\} = [A]\{Z\} + [B]\begin{Bmatrix} f\\ (-F)\end{Bmatrix} \ldots\ldots..(4.2)$$

So the displacement of the beam at the location of actuator can be given as:

$x\ = [C_1]\{Z\}$.......... (5)

V. NEURAL NETWORK CONTROLLER

A neural network is an artificial representation of human brain that tries to simulate its learning process. As human brain consist of neural cell for processing the information, similarly in neural network there are nodes which are interlinked to each other for processing the information.

A. Basics of neural network

Basically neural networks are typically organized in layers, and the formation of these layers depends on nodes along with the activation function.

Training and generating simulation diagram using neural networking

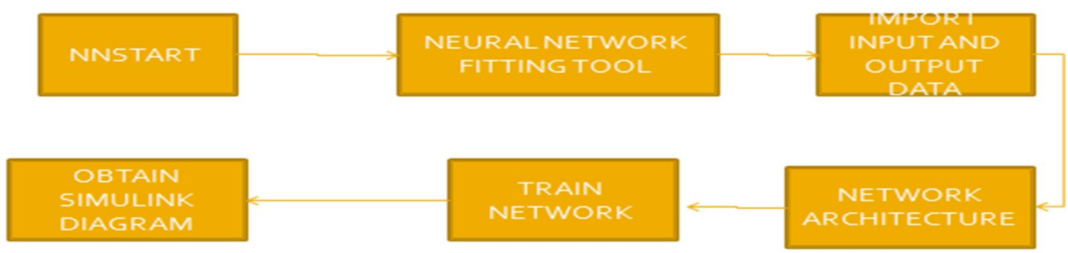

Fig.2 representing the block diagram for training and generating simulation diagram.

There are certain steps which are used to obtain the simulation diagram as shown in above fig.2

Step1. nnstart
Step2. neural network fitting tool
Step3. Import input and output data...here the input data are velocity and displacement and the output data is current.
Step4. Network architecture..from this step it is clearly seen the number of input layer, hidden layer and the output layer.
Step5.train network..
step6. Obtaining simulink diagram.... after training the network the simulink diagram is obtained

B. Simulink Model For Training Of Neural Network

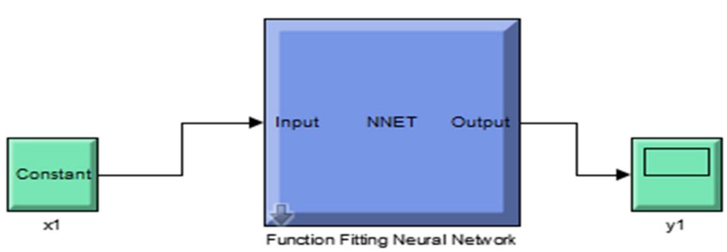

Fig.3. simulink model for neural network training.

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Here this simulink model comprises of an input layer, hidden layer and an output layer. The input layer has an input values of displacement and velocity and the output layer has an output value of current. In this way we obtain the values of velocity, displacement and current and according to which we are going to train our neural network model. We can retrain our neural network model until we obtain the desired output and during training process backpropogaion theory was used.

Basically backpropogation is multilayered feedforward neural network. It is the simplest approach for the supervised training of multilayered neural network .It works by approximating the non linear relationship between the input and the output by adjusting the weight values internally.

C. Matlab Simulink Model

This simulink model represents the working performance of single electromagnetic actuator.

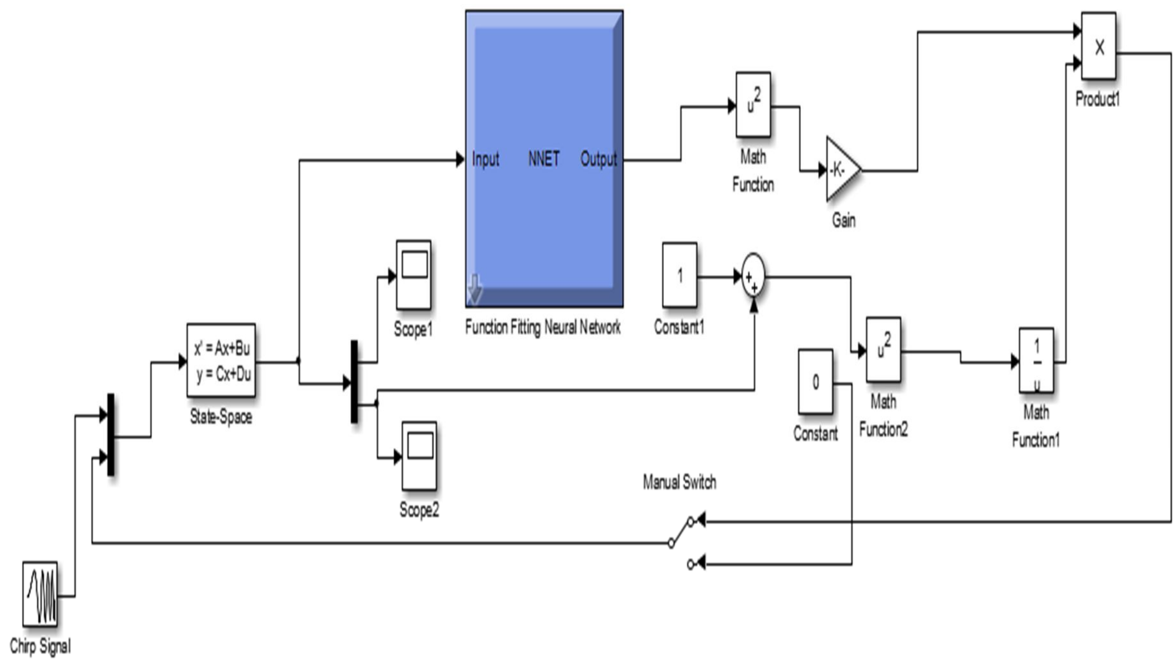

Fig.4 Block diagram of simulink model with single electromagnetic actuator.

VI. NUMERICAL STUDY

In this study a multi degrees of freedom model of cantilever beam is analyzed. Ten element discretization of the cantilever beam is considered in this study. A small damping force is considered using Rayleigh damping. State space block is used for defining the beam model in state space form in the above simulink model block diagram. The dimension of the beam is given by its cross sectional area of 18mm x 10mm and length is of 200 mm. the single electromagnetic actuator is placed at the free end of cantilever beam. There are some specifications for electromagnetic actuator i.e.., number of turns in the coil of electromagnet n=100, cross sectional area of core A_m= 200mm^2 and the permeability of air is given by $4\pi * 10^{-7}$N/A^2.

In this paper two types of analysis are done using single electromagnetic actuator. First is for step excitation and the second is for chirp signal.

In step excitation the beam is subjected to the step excitation at time t=1. Depending upon the displacement and velocity at the free end of cantilever beam, the current through the coil of electromagnetic actuator is controlled by using the neural network controller and the actuating force is produced for bringing back the beam to a stable position. Because of the presence of small damping force the amplitude of uncontrolled vibration is slowly reducing with time. From fig.5 it is clearly visible that by using electromagnetic

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actuator the vibration of the beam is controlled rapidly.

In the case of chirp signal the amplitude of signal is kept at a constant value of 2N. The frequency of the chirp signal is varied keeping the natural frequency of the beam within the lower and upper values of the chirp signal frequencies. It is observed that in case of the uncontrolled vibration of the beam there is a distinct resonance which is controlled using this active vibration control system. It has been observed in fig.6 that the actuator can easily reduce the vibration using neural network controller.

VII. RESULT

The response of the cantilever beam under step excitation and chirp excitation is shown in the fig. 5 and fig. 6 respectively. The uncontrolled and controlled response clearly suggest that the non contact active vibration control method is very effective and it successfully controls the amplitude of structural vibration.

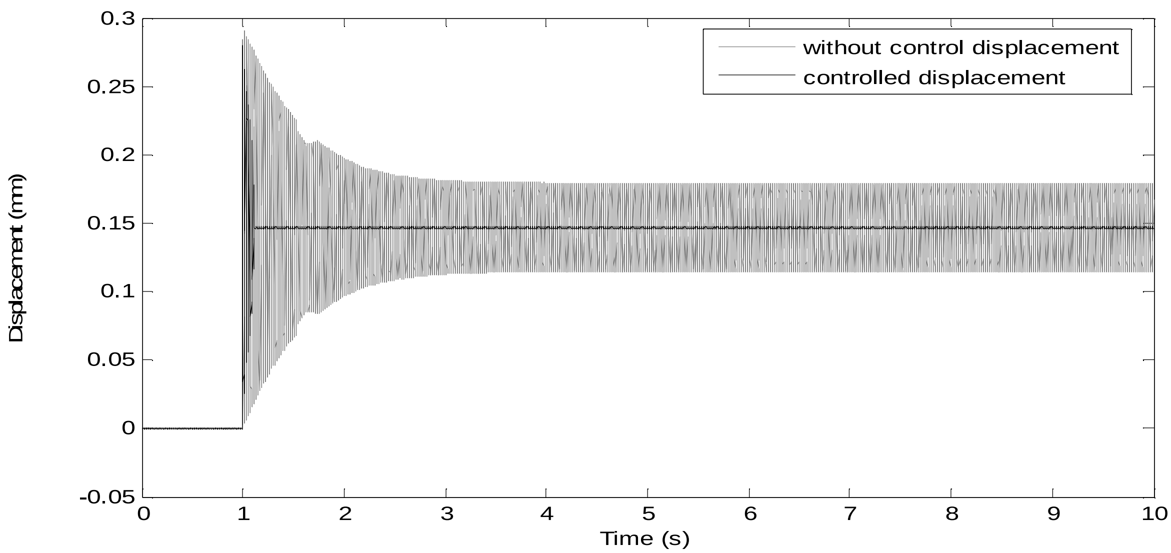

Fig.5 shows the controlled and without controlled response of beam at free end using step excitation.

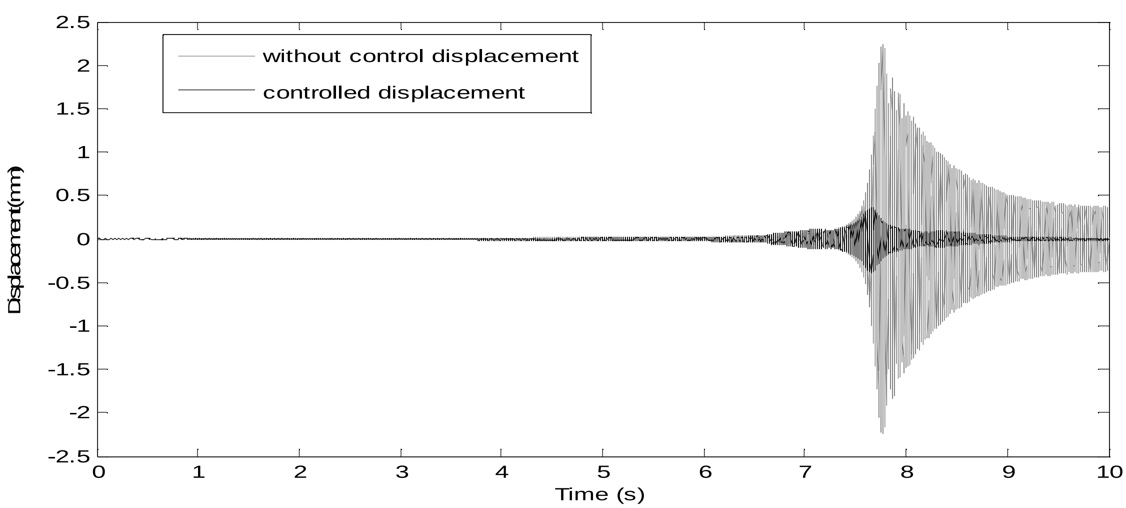

Fig.6 shows the controlled and without controlled response of beam at free end using chirp signal.

VIII. CONCLUSION

In this study the active vibration control technique is proposed to control the vibration of the cantilever beam. An electromagnet is

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considered to apply the magnetic force on the beam. The neural network control technique is adopted here to control the current through the coil of the electromagnet. It is observed in this study that the proposed actuator successfully controls the amplitude of the vibration of the beam. The proposed actuator is very simple in construction therefore it is very easy to apply.

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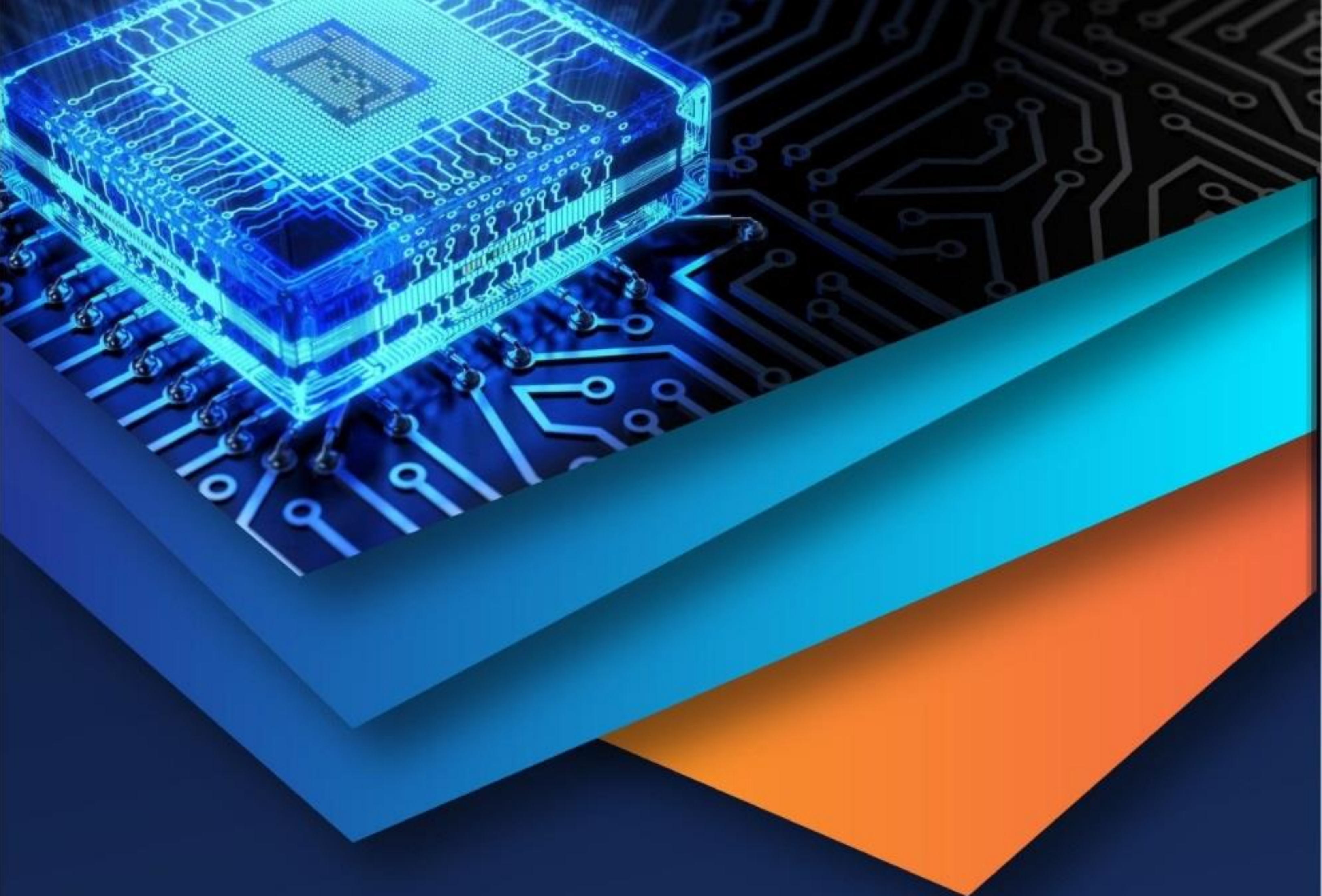

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