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PLC Operated Cutting Machine

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Abstract: Currently, every industry is approaching lean manufacturing with enormous automation to increase productivity, reduce lead time, save labor cost and what not. Programmable Logic Controllers (PLC) is fast and very flexible automation technology that is used in almost every system whether it is as small as residential lift or as big as washing machines, control panels etc. Electro-pneumatic system is combined system consisting of electronic circuits designed to control pneumatic system. To provide raw material in required size for machining, operations, etc we first need to bring it in size so that it can be operated. For this purpose cutting machines are used with varying features and specifications. Material handling equipments like conveyor is used to give feed of materials to be cut to reduce human efforts and feed material to length required after cutting. Rate of materials to be cut can also be varied as per requirement by designing conveyor for such and then adjusting vice through electro-pneumatic system. Combining the advantages of PLC and electro-pneumatic system, conventional cutting machines can be upgraded to overcome the shortcoming in them and simultaneously development on same can be carried out to use it on desired level in industries.

Keywords: Automation, PLC, Electro-pneumatic, Material handling.

I. INTRODUCTION

Today engineers are finding many ways to reduce human efforts which ultimately save labor cost and valuable time. Raw materials to be used, it is necessary to cut them and then take for further operations. This cutting machine is therefore designed and developed for raw materials like solid or hollow metallic or non-metallic cylinders, bars of square or rectangular cross section, etc. This electro-pneumatic cutting machine encompasses with PLC and conveyor which plays major role of producing number of materials to be cut, to hacksaw blade at one time. PLC continues the cutting cycle as by following ladder logic that is built by user. Conveyor is there to give feed of materials for cutting thereby reducing human efforts.

Many researchers and scholars have done number of findings, analysis and various applications using PLC. Students of ITM university have a reviewed PLC for bottle filling application. They have presented data that is; what is PLC, how it works, how PLC is used for different applications.

Researchers from Bapurao Deshmukh College of Engineering, Wardha have published research paper on conveyor system; how to design conveyor, mechanical analysis of conveyor, manufacturing of conveyor, etc.

In present time, there is immense development in ideas suggested by students, professionals, intellectuals. Similar type of cutting machine idea is researched by Rushikesh Gadale, Mahendra Pisal, Sanchit Tayade and S.V. Kulkarni. Their valuable research has helped us in great way.

In our research, a simple cutting machine is developed by designing system of PLC, conveyor and hacksaw arrangement for cutting purpose. For demonstration purpose, 1 inch PVC pipes are tested. Mitsubishi Electric make PLC; Graphic Operation Controller (GOC) is used. A small conveyor for transporting PVC pipes is designed and developed for automatic feed of cutting material. Capacitive proximity sensor is used for detecting material to length required to be cut. Electro-pneumatic system comprises of double acting cylinder, 5/2 direction control valve with solenoid. To support these system various other components like DC motors, relay, DC to DC converter, etc are used.

II. OBJECTIVE

The main objective of this project is to reduce the efforts of feeding workpiece by using conveyor, to cut more than one workpieces at a time, to make arrangement of variable cutting speed as per requirement and to automate the system by using PLC.

III. METHODOLOGY

The main parts of this machine are cutting machine, PLC, conveyor and electro-pneumatic system.

A. Cutting Machine

It is a simple cutting machine arrangement which comprises of hacksaw blade which is 0.3m long. To get the cutting action from blade, slider crank arrangement is used. Length of connecting rod is 0.22m and diameter of crank is 0.11m. DC geared motor is used for setting cutting action. DC geared motor have respective specifications: Operating voltage – 0 to 12V, Speed – 300 rpm .

To balance the jerk that is produced by motor's during operation, speed of motor is reduced by using DC to DC converter. At 12V speed of motor is 300rpm. After, setting voltage to 6-7V speed is reduced to 150 to 160rpm. This reduces vibrations of motor. Capacitive proximitive sensor is also used to detect the cutting material which is going to be cut. Sliding arrangement is employed to set position of sensor to required length to which cutting material is needed to be cut.

Fig 1. Cutting machine

B. PLC

Graphic Operation Controller (GOC) has been designed, developed and manufactured by Mitsubishi Electric India and is aimed to meet the optimal automation needs of the Indian and overseas market. GOC find its applications in varied sectors like Packaging, HVAC, Textile and other applications in SPM. Key attributes of this PLC:

1) I/O Capacity – 48
2) Communication Options – Serial RS232, Serial RS422/485, Ethernet.
3) Display – Graphical LCD, 128 X 64 pixels
4) Data logging via SD Card (upto 32GB).

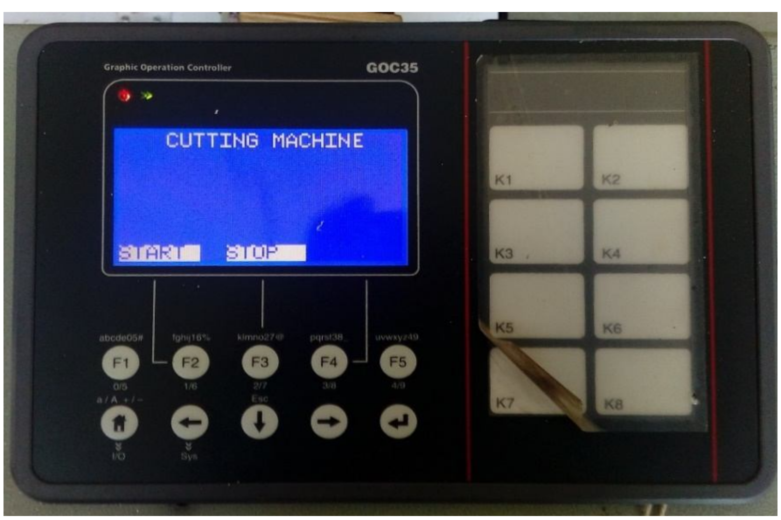

Fig 2. Graphic Operation Controller

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C. Conveyor

Conveyor is the major part of material handling system which main purpose is to transport material from one point to another, thereby reducing human efforts and reducing lead time on shopfloor. This conveyor consists of total seven rollers of mild steel. Sprocket and chain arrangement is used for conveying action. DC motor is used to put or give motion to sprockets. The dimensions of conveyor are 0.6 X 0.3 X 0.6 m. Torque of this motor is 8N-m which is high as to carry the load. Due to high torque, speed of the motor is less which is 45 rpm. This motor is also operating between 0 to 12V.

Fig 3. Roller Conveyor

D. Electro-pneumatic system

Electro-pneumatic system comprises of pneumatic circuit which is controlled by electronic components. In this project, double acting cylinder is used which has air pressure limit of 0.1MPa to 0.9 MPa. Cylinder has bore of 32mm and stroke of 50mm. 5/2 Direction control valve is used for control the position of piston of cylinder. To control the position of piston, solenoid is used to replace pushbutton or other manual arrangements.

Fig 4. Solenoid of Direction Control Valve.

IV. CALCULATIONS AND WORKING

A. Calculations

1) Chain and Sprocket

Data: Power = 10W, $N_1 = N_2 = 45$RPM

Step 1: Service Factor:

$K_S = K_1. K_2. K_3. K_4. K_5. K_6$

$K_1 = 1.25$………………… (Variable Load)

$K_2 = 1.25$……………..…. (Fixed Distance)

K_3 = 1……………………. (Optimum Center Distance)
K_4 = 1……………………. (Up to 60^o)
K_5 = 1……………………. (Drop Lubrication)
K_6 = 1……………………. (Single Shift)
Step 2: No. of teeth on driving and driven sprocket:
$Z_1 = Z_2 = 18$, where Z_1 is number of teeth on driving sprocket and Z_2 is number of teeth on driven sprocket.
Step 3: Pitch selection
Pitch = 12.7………………. (For < 200 RPM)
Step 4: P.C.D. of sprocket
$d1=\frac{P}{sin\frac{180}{Z1}} = \frac{12.7}{sin\frac{180}{18}} = 73.14$, where d_1 is diameter of driving sprocket and d_2 is diameter of driven sprockets.
But $Z_2 = Z_1$
$\therefore d_1 = d_2 = 73.14$ mm
Step 5: Chain Velocity

$$V = \frac{\pi d_1 n_1}{60000}$$
$$= \frac{\pi \times 73.14 \times 45}{60000}$$

= 0.172 m/sec
Step 6: Selection of chain based on overall joint
$A_1 = 11$mm
$\therefore A = 0.21$cm^2
Step 7: Chain Specification
Chain No. = R1230
Pitch = 12.7mm
Bearing Area = 0.2cm^2
Weight per unit length = 0.3kgf/m
Breaking load = 820kgf
Step 10: Check for actual F.O.S

$$[n] = \frac{Q}{\sum P}$$

$\sum P = Pt + Pc + Ps$, where P_t is tangential force due to power transmission in kgf, P_c is centrifugal tension in kgf and P_s is tension due to sagging of chain in kgf.

$$Pt = \frac{102.N.ks}{V}$$
$$= \frac{102 \times 10 \times 10^{-3} \times 1.5625}{0.134}$$
$$= 11.89\text{kgf}$$

$$Pc = \frac{W.V^2}{g}$$
$$= \frac{0.3 \times 0.172^2}{9.81}$$
$$= 9.04 \times 10^{-4} kgf$$
$$Ps = k.W.a$$
$$= 6 \times 0.3 \times 0.9$$
$$= 1.62$$

$$\therefore \sum P = 11.89 + 9.04 \times 10^{-4} + 1.62$$

= 13.51

$[n] = \frac{820}{13.51} = 60.69$

n_{min} = 7………………… (For < 50 RPM)

$\because [n] > n_{min}$

Hence selection of chain is ok.

2) Roller design

Rollers can be manufactured manually in workshop or directly available in the market. The selected roller of outside diameteris 32mm and inside diameter is 29mm. Thus the weight of roller is given by,

Roller wt. = (D² d' x1 x 7.850 106 x 4

= π x (322 29') x 400 x 7.850 /108 x 4

= 0.45 Kg

Design of roller: Material MS

E = 2.10* 10^5 Mpa, p= 7700 Kg/m3, Syt = 250 Mpa

Considering uniformly distributed load & FOS = 2

Allowable Stress (σ_{all}) = Syt/Fs =250/2=125 Mpa

Maximum Stress Calculation for given condition

W = material to be transport

= 5 PVC pipe = 4kg

= 0.57kg

D1= Outer diameter of roller = 35 mm

D2 = Inner diameter of roller = 32 mm

W = Width of roller = 28.5cm

y = Distance from neutral axis = 0.035/2 = 0.0175

Considering uniformly distributed load,

= (4*9.81*0.4)/8

Maximum Moment (Mmax) = W*L/8

Mmax = 1.962 Nm

Moment of Inertia (I) = π (D_1^4-D_2^4)/64

= π (0.035^4 - 0.032^4)/64

= 2.22×10^{-8}m4

Maximum bending stress (σ_b) = Mmax y/I

= $1.962\times 0.0175/2.22\times10^{-8}$

σ_b = 1.55 Mpa

Checking Factor of Safety for design

σ_{all} /σ_b= 125/1.55

FOS = 80.65

As Calculated FOS is greater than assumed Fs,

Therefore, Selected Material is safe.

B. Symbols and Functions:

GOC PLC requires Codesys software for ladder logic programming. Some of the common symbols used in ladder logic programming.

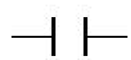

Fig 5. Normally Open Contact

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In normally open contact, current or any signal does not pass until a switch is pressed so that switch is actuated or contacts are closed.

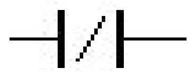

Fig 6. Normally Closed Contact

In normally closed contact, current or any signal passes through until switch is pressed so that contacts are opened and circuit breaks.

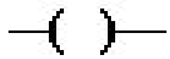

Fig 7. Relay coil

It is a relay coil denoting output part of ladder logic programming. It is used to actuate motor coils, etc.

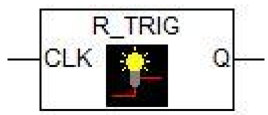

Fig 8. Rising edge detector

It is a rising edge detector used to detect the rise in pulse or any kind of output voltage that is produced by sensors.

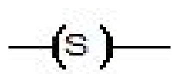

Fig 9. Set coil

It is a special type of coil used in programming. Once this coil is energized it no longer dependant on action that energized it. To de-energize it another provisions are used.

Fig 10. Reset coil

It is similar to set coil. Only difference it sets ‘off’ on giving signal whereas set coil sets ‘on’ on giving signal.

Fig 11. Timer

This symbol is used to denote timer used in programming.

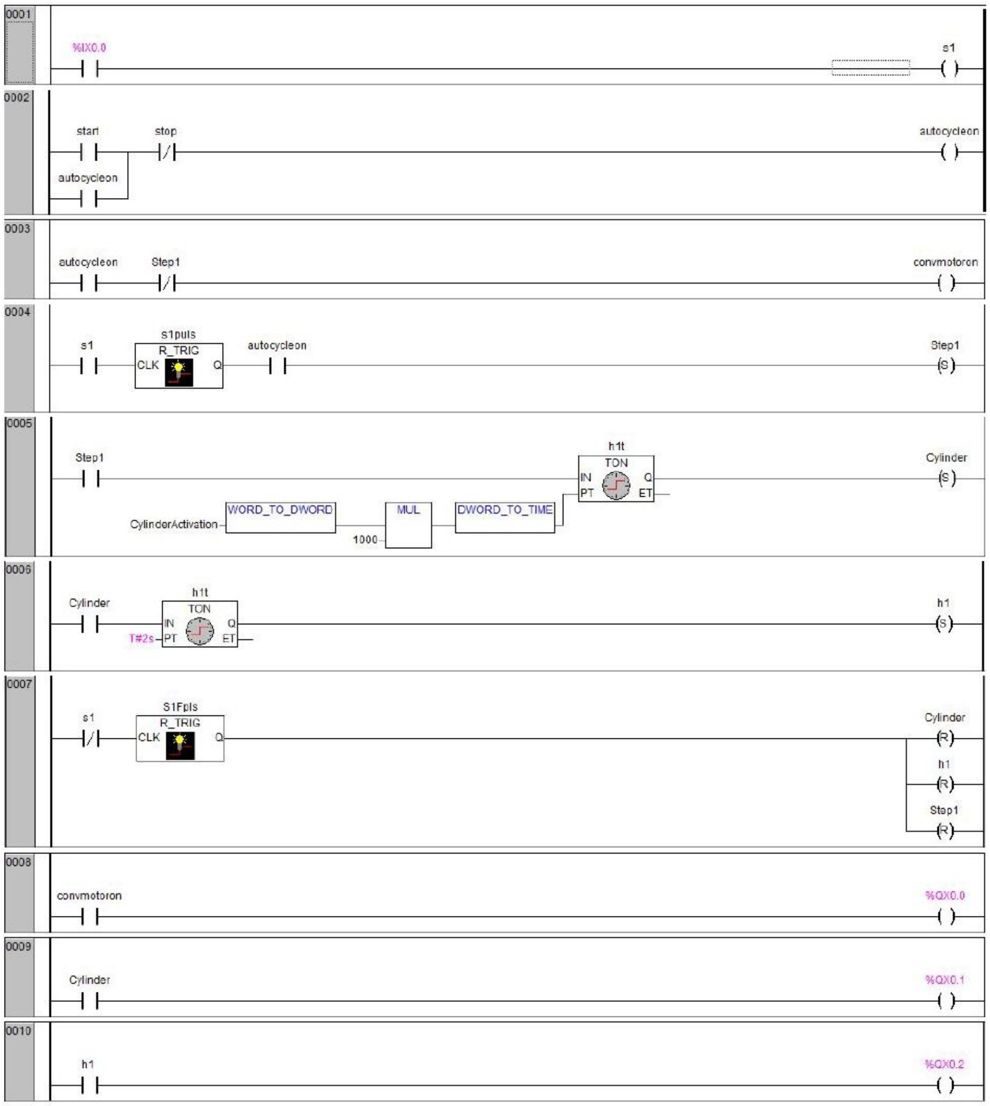

Fig 12. Ladder Logic

Connections

1) In network (0001): input I00 of PLC is defined as input from capacitive sensor (s1).
2) In network (0002): start and stop button on plc are defined by NO and NC contacts respectively. Output coil 'autocyleon' is used as relay coil.
3) In network (0003): step1 is termed as NC contact and motor of conveyor is termed at output side as 'convmotoron' which is relay output.
4) In network (0004): rising edge detector is used to detect the rise in signal or we can say that NO contact of sensor becomes NC when material gets in contact with sensor.
5) In network (0005): timer is used in contact with set coil of solenoid of direction control valve.
6) In network (0006): a delay of 2sec is given to the hacksaw motor 'h1' which is again relay output after coil of direction control valve operated.
7) In network (0007): rising edge detector function is used with NC contact of sensor. Solenoid coil is defined as reset coil followed by hacksaw motor h1 and step 1.
8) In network (0008): Output Q00 of PLC is defines as 'convmotoron'.

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9) In network (0009): Output Q01 of PLC is defined as solenoid coil of direction control valve by name 'cylinder'.
10) In network (0010): Output Q02 of PLC is defined by hacksaw motor h1

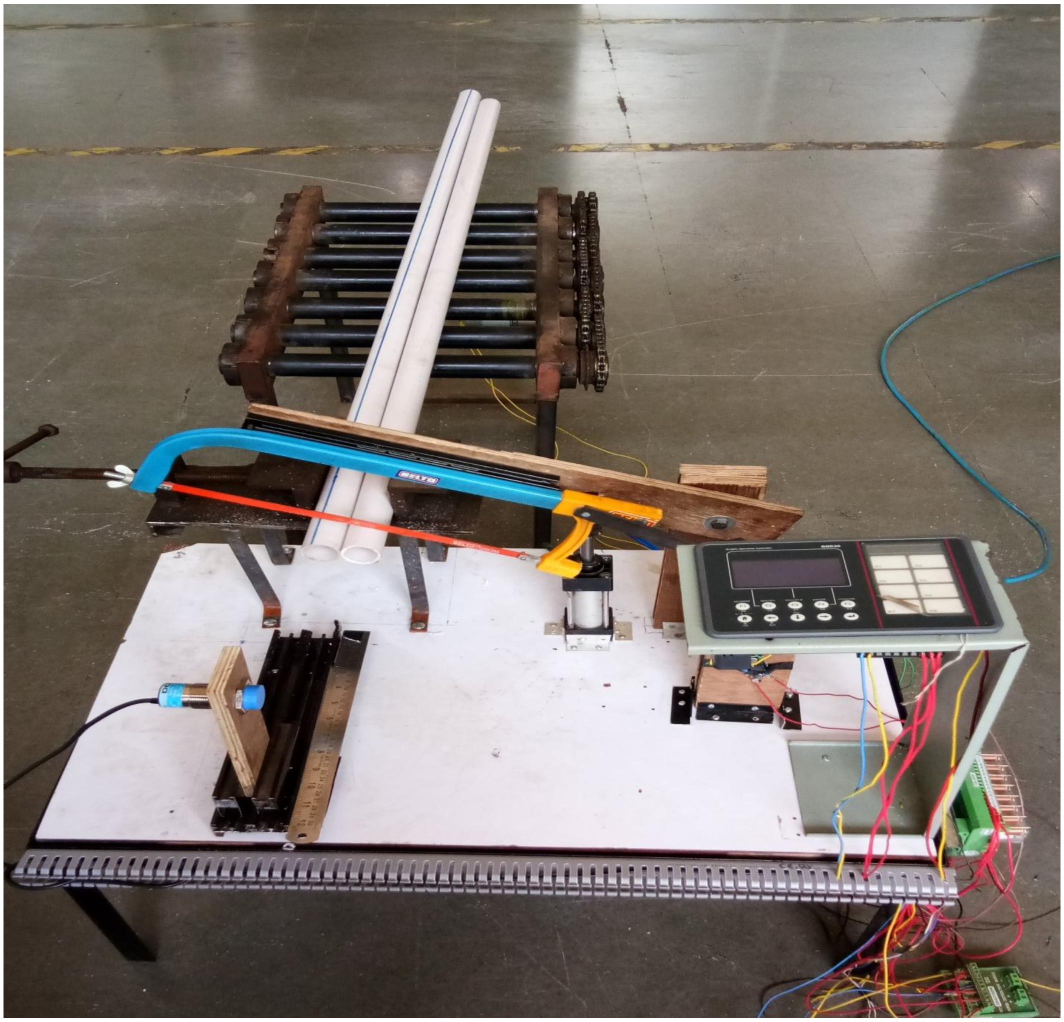

Fig 13. Setup of PLC Operated Cutting Machine

Working:

1) In first cycle, after giving 24V DC supply to PLC and then pressing start button , conveyor motor operates. This feeds or moves material forward until it is reached to its position to start cutting.
2) Capacitive Sensor is fixed at the required position so that when material that is being moved forward touches it, it sends signal to the PLC as input to it.
3) After input is given to the PLC by sensor, conveyor motor is stopped and hacksaw motor turned ON.
4) As soon as hacksaw motor is started ON, double acting cylinder comes to bottom position bringing hacksaw frame downwards for cutting action.
5) After cutting of material is done, hacksaw is stopped and double acting cylinder is brought to top position.
6) Again, conveyor is started and cycle is repeated. To stop the cycle in between, user can press the stop button on PLC.

V. CONCLUSION AND FUTURE SCOPE

Automatic power hacksaw machine gives high productivity in short time period in comparison with the conventional hacksaw machines. The major advantage of this machine is that intervention of labor is reduced to maximum level. In this rapid emerging industrial era, the use of power Hacksaw machine is wide. Time and labor plays a major role in production process this can be overcome by using this type of automatic machines. The automatic hacksaw machine can be made use of at any of the industries like pump manufacturing industries that involve bulk amount of shafts that have to be cut frequently.

Due to variable speed of hacksaw achieved by using voltage regulator or any other means to control speed of DC motor, speed for particular material can be used. Material handling for conveying material to be cut can be improved in a such way that; material after getting cut can be conveyed to workstation or shop floor for further machining. PLC contributes high flexibility in order to add or remove any feature to this machine. Logic that is build can be manipulated as per requirement and same can be tested and followed within time limit.

VI. ACKNOWLEDGEMENT

We would like express our warm thank you to fabricators of the setup. Following that we would also appreciate and convey our sincere thanks to Mr. Pankaj Nandrekar-Deputy Manager – Application at Mitsubishi Electric India Pvt. Ltd for guiding us with PLC part and suggesting us right PLC by giving his valuable time. Similarly, from bottom of our hear we acknowledge entire team of Chavare Engineering Pvt. Ltd for helping us with PLC, its working and programming. Last but not least, this would have not been possible without valuable guidance, help from teaching as well as non teaching members of department of mechanical engineering, and our friends.

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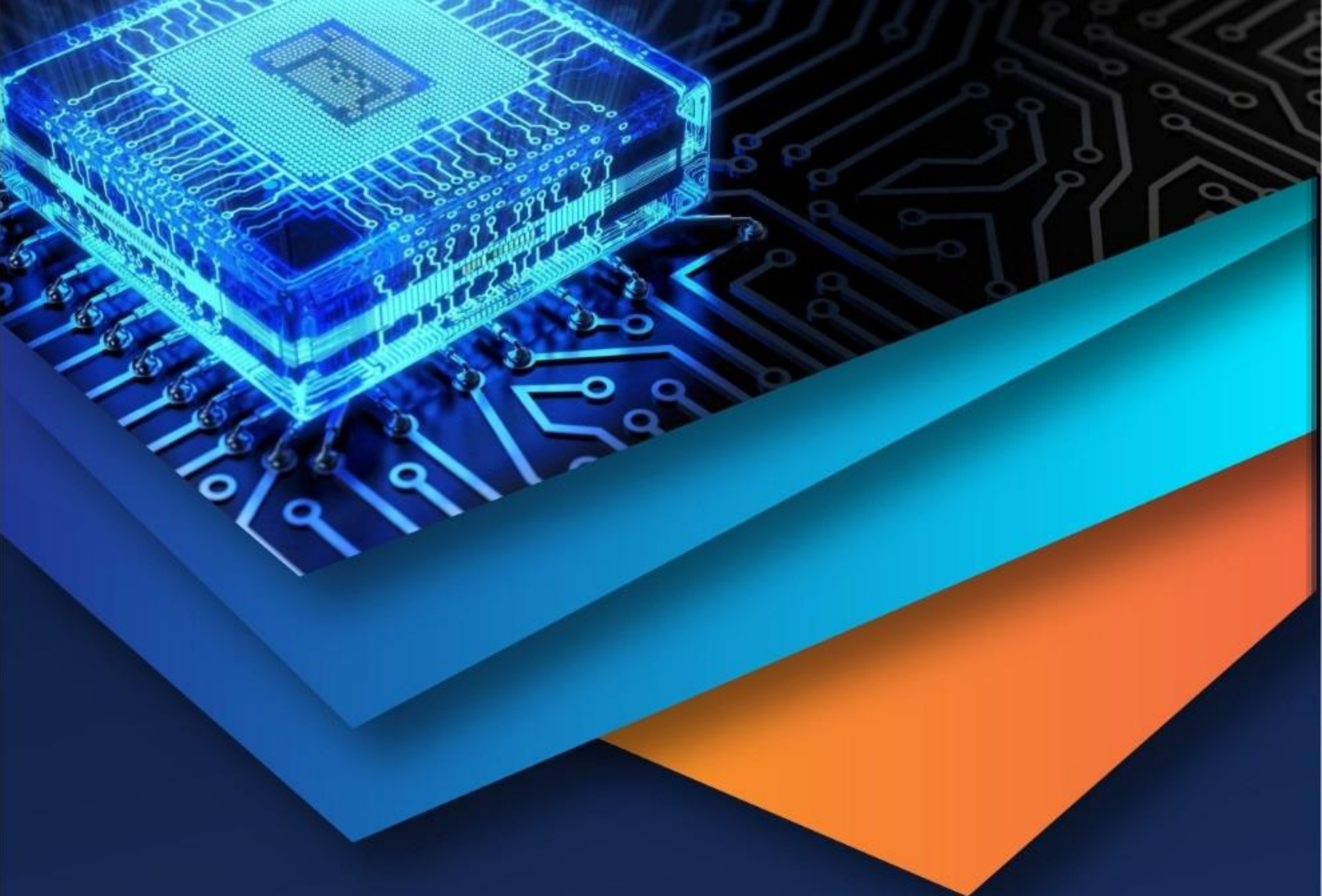

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