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Design and Synthesis of Power Press Machine

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Abstract: Power press machine is essential in metalworking and fabrication, enabling precise cutting, shearing, punching, and notching operations. However, traditional cutting machines often come with high costs and limited portability, making them less accessible for small-scale and flexible manufacturing setups. This study focuses on the design and development of a compact and versatile power press that addresses these limitations.
The power press machine operates using a three-phase motor with an efficient power transmission system utilizing V-belt pulley. It incorporates an automated control mechanism, multiple worktables for diverse operations, and a lubrication system to enhance efficiency and longevity. The reciprocating motion of the slider block ensures precision in cutting and shearing tasks.
Designed for ease of maintenance and high operational accuracy, this power press reduces material wastage and labour costs while improving productivity. Its compact form factor makes it suitable for various industrial applications without requiring major modifications. The developed system provides a cost-effective and reliable solution for precision metalworking, contributing to enhanced manufacturing efficiency and process automation.

I. INTRODUCTION

Manufacturing industries rely heavily on metalworking processes such as cutting, shearing, punching, and notching to produce high-precision components.
These operations are essential in various sectors, including automotive, aerospace, construction, and fabrication. To perform these tasks efficiently, power press machines are commonly used due to their ability to apply controlled mechanical force for shaping and cutting metal sheets.
Traditional cutting machines, while effective, present several challenges, including high costs, limited portability, complex maintenance requirements, and energy inefficiency. Many of these machines require skilled operators, leading to increased labor costs and longer production times. Additionally, bulky and expensive industrial cutting machines are often inaccessible to small and medium-sized enterprises (SMEs) that operate on limited budgets.
To address these challenges, this study focuses on the design and development of a compact, cost-effective, and versatile power press machine. The proposed machine incorporates an efficient power transmission system, an automated control mechanism, multiple worktables for different operations, and a lubrication system to enhance efficiency and durability. By integrating these features, the developed power press aims to optimize productivity, improve cutting accuracy, and reduce material wastage, making it a viable alternative for modern industrial applications.

II. OBJECTIVES

The primary objectives of designing a Power Press is to create a versatile and efficient machine that can perform various operation including:
Punching: Create holes of different diameters and shapes in various materials.
Cutting: Cut materials using a reciprocating cutting tool with die.

III. RESEARCH METHODOLOGY

Design calculations play a crucial role in the research methodology of mechanical systems, ensuring that components are optimized for performance, durability, and safety. In this study, the design calculations focus on critical parameters like shear force, energy requirements, and dimensions of key components such as shafts, pulleys, and flywheels.

A. Design Calculation

Punching press with two shafts, one gear pair and one pulley pair. Punching time (t) is 1 sec cam shaft rpm is 60, motor power is 2 hp, stroke length is 30mm.

(1) Shear force required
SF=strength *area
SF=220*350
SF=77000 N
SF=7850 kg or 7.8 ton

(2) Energy for punching
E=force*thickness
E=(77000+0)/2) * 0.005
E=195.5 J

(3) Actual punching time
T= (1*5)/60
T=1/12 sec

(4) Idle punching time
T=1-(1/12)
T=11/12 sec

(5) Change in energy of flywheel (ΔE)
energy extracted from motor in time TR in
ER =1492*(1/11)
ER=373/3
ER =124.33 J
ΔE =192.5-124.33
ΔE =68.1667 J

(6) Mean speed of flywheel
Speed reduces from 1440 rpm to 60 rpm
SR= 1440/60 SR= 24
as machine has two shafts, so speed are reduces into steps,
24→6*4 SR1=6. AND SR2=4. & N=1450 RPM
∴ pulley/flywheel speed (N1) = N/SR1=1440/6
N1=240 RPM =N_{max}
Let coefficient of speed cs=0.12 ....for punching press
&Cs=ΔN/Nm
N_{min}= 212 83 rpm
&Nm=226.415rpm
& ωm=23.710 r/s

(7) Inertia of mass of flywheel
I=E/w²cs =68.1667/23.710²*0.12
I=1.0104 kg-m²
D1=90 mm
D2=D1*SR1=90*6
D2=540mm
R2=270mm. K2=R2/√2. .....for disk type flywheel
K2=190.279 mm
Parallelly, for ring type flywheel
K2=R2=270 mm

$M=I/ki^2 =1.0104/0.190279^2$.
M=27.90kg &
$M=I/ki^2=1.0104/0.27^2$
M=13.86 kg

(8) Diameter of pulley & gears
D1=90 mm. D2=500mm. Pulley
D3=100mm. D4=432mm. Gear

(9) Energy required to lift mass to 30mm
E'=mgh=10*9.81*0.03
E'=2.943 J

(10) Forces on plates of structures
S_{uc} = 240 Mpa, S_{uc}= 220 Mpa, S_{yt}=440 Mpa
let Fos = 2
(σac) allow = 240/2 = 120 Mpa
τ_{allow} 220/2 = 110mpa.
(σt)allow=220 MPa
Forces acting on each plate =77000/2=38500 N
P= 38500 N

(11) Dimensions of plate structure
min area (A) =F/ σac = 38500/120
A= 320.833 mm
let thickness of plate (t') be
t'= 18mm & L= A/t'= 320.833/18
L= 17.82 mm2

(12). vertical position (h1) of bearing in structure plate Shear area in structure plate
a1=RA/ τ_{allow} =38500/110
a1= 350 mm
a1=2(h1)*t
h1=a1/2t=350/(2*18)
h>10 mm
(13) Diameter of shaft (Tool Carrying Shaft)
(SF)=77000 N
1.(SF)max=38.5 kN
2.BM = Rb(l/2+x) – Fx &
(BM)max = Rbl /2= (33500 x 76) / 2
(BM)max=1463000 Nmm
3.Mt Torque or twisting moment
Mt = 77000 x radius
radius = 15mm
Mt=77000*15
Mt=115000 Nmm
Now, τallow =16/3.14*d3
d2≥44.1915mm d2≥5 or d2=50mm
& (σt)allow =16/3.14*d23
D2=42.54……… (Less Than Required)

(14) Cam diameter (Dc)
Dc =stroke length +shaft diameter
Dc =30+50
Dc =80 mm

(15) Diameter of shaft
as F4=F3 == T4/T4=T3/R3
T3= T4* R3/R4 =Mt*D3/D4
T3=288750 Nmm…….. torque transmitted by shaft (1)
& τallow =16 T3/3.14* d13
d13 =16t/3.14* τallow
d1≥23.733mm
Let, d1=30mm

(16) Force acting on bearing of shaft (1)
F3= T3/R3=288750/45
F3=6.416 KN………(force acting on bearing & Ts is torque transmitted through pulley)
1) Pulley 90 mm diameter
2) Pulley 500 mm diameter
3) Gear 100 mm pitch circle diameter
4) Gear 432 mm pitch circle diameter

(17) Bending moment on shaft (1)
MB1 = F3 × x
x = 130 mm……. from diagram
MB1 = 6.416 × 130 × 1000
MB1 = 844080 Nmm
τallow =16/πd1³ √(MB12+Mt12
110=16/ πd1³√ (844080)2+(288750)2
D1= 34.56 mm ∴ For safety purpose let d1=40mm

(18) Belt calculation
1) belt length (L)= 1970mm as B- 1970 mm as B- 80 inch
2) Distance of circle between Pulleys = 478mm
3) Power transmitted through belt =2HP=1492W
Max torque 250mm Radius Pulley get from motor = 54.9144. N, Tmax = 54194.43 Nm
Force on belt (FB)= Tmax/R=54914.43/250
FB = 219.65 N Or FB = 23 kg
Force on belt (FB) ≥ 70kg or 680.173 N
D = Tmn/ cosα
T = D cosα /mn =432 cos 15/6 = 65.8
D4 = 66 × 6 / cos α
D4=435.937≈ 437 mm
D3 = 15 × 6 /cos25 = 99.30 mm
b= πmn/sinα = 44.6
Motor ------> 2HP, 1440rpm, 3-phase
D1 = 90mm ; N = 1440rpm
D2 = 500mm ; mass of flywheel = 27kg
SR1 = D2/D1 = 5.55
Speed of flywheel (N1) = 1440/5.55

N1 = 259.459 rpm
Shaft (1) dia. = d1 = 40mm, L1 = 360 mm
D3 = 100mm, module (m) = 6mm, width (b) = 50mm
N2 = N1 = 259.459 rpm.
SR2 = 259.459/60SR2 = 4.324
Therefore D4 = D3 × SR2
D4 = 100 × 4.324
D4 = 432 mm, module (m) = 6mm, width (b) = 50 mm Helix angle (Ø) = 15^o
d2 = 50mm ; L2 = 250 mm
• cam diameter = 80 mm
• structure plate thickness = 18 mm
• torque carrying capacity of clutch = 1155000 Nmm
• tool plate thickness = 20 mm Belt B-80 3 no.s
cam shaft or shaft (2) bearing ----->NU 1010 ECP single row cylindrical roller bearing

B. CAD Model of Various Components

The components are design in SOLIDWORK software. The different types components which are used in the power press machine are given below:

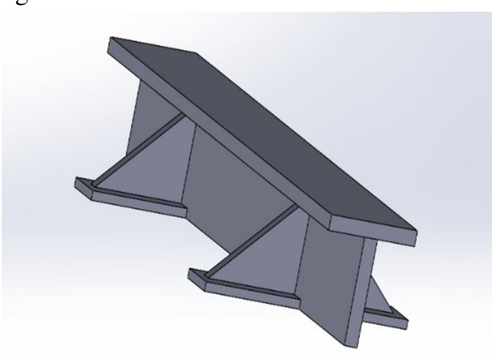


Fig.1. Base

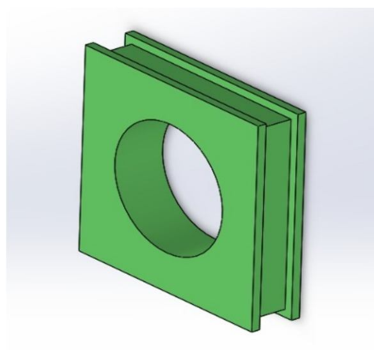


Fig.2 Slider

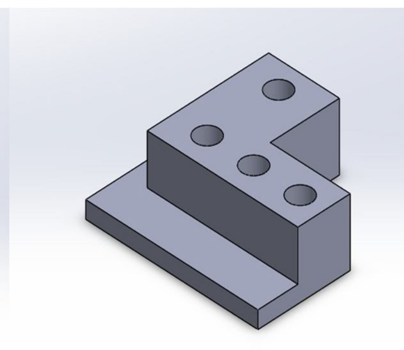


Fig.3 Notch Die

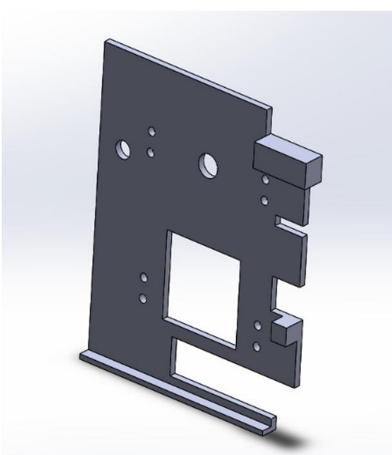


Fig.4 Structure plate left

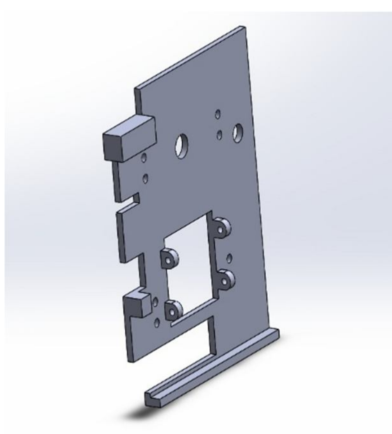


Fig.5 Structure plate right

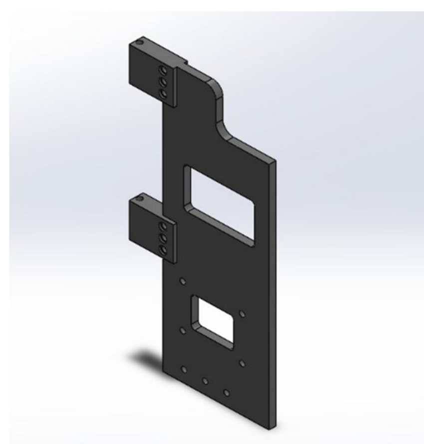


Fig.6 Tool plate

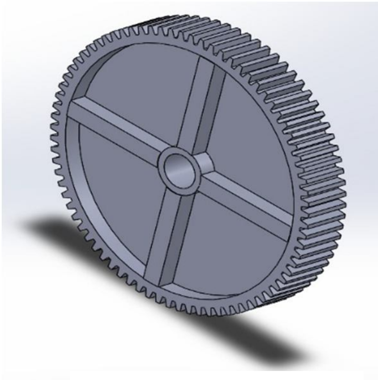


Fig.7 Spur gear

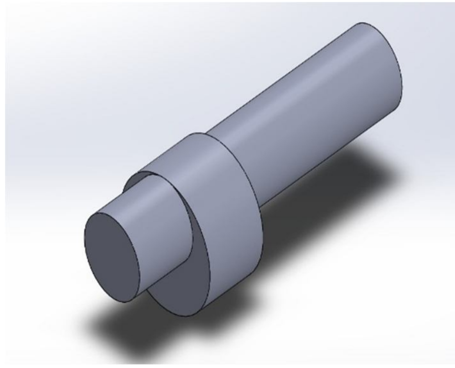


Fig.8 Driver gear pully

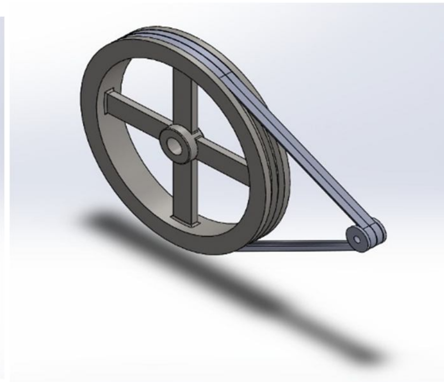


Fig.9 Flywheel and pully

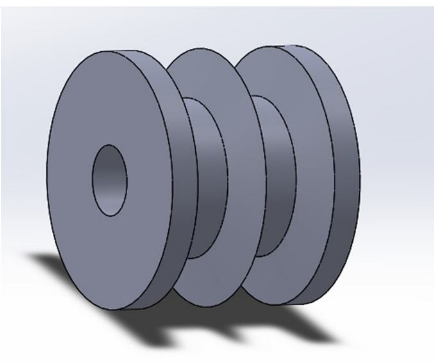
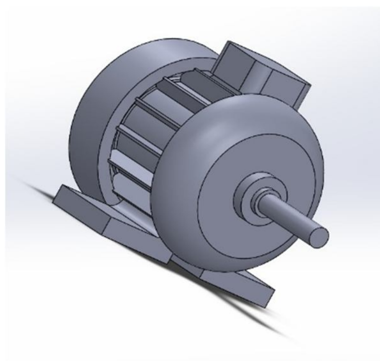


Fig.10 Cam shaft


ZFig.11 Motor pully

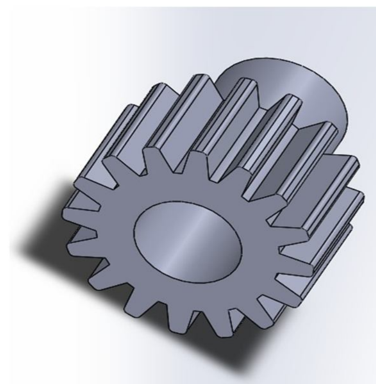
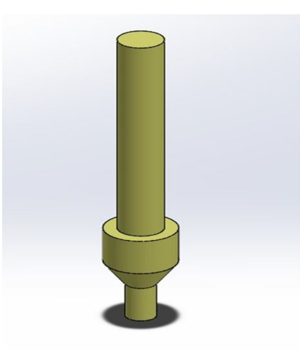


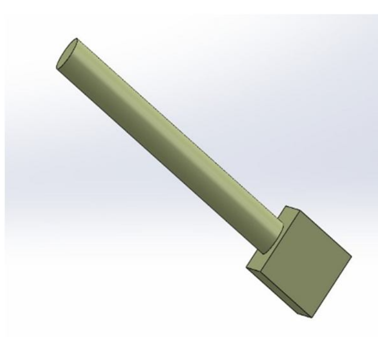
Fig.12 Motor

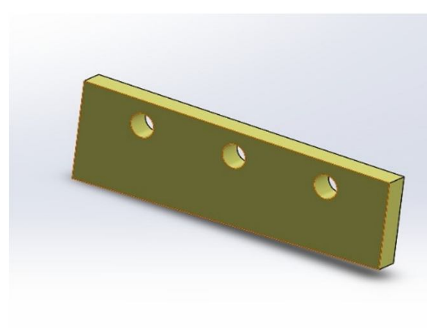
Fig.13 Hole punch

Fig.14 Notch punch

Fig.15 Shear punch







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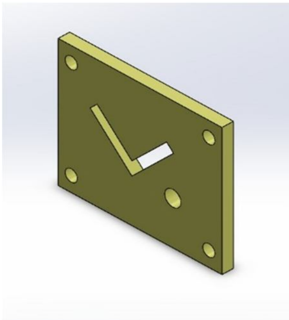


Fig.16 Angle punch

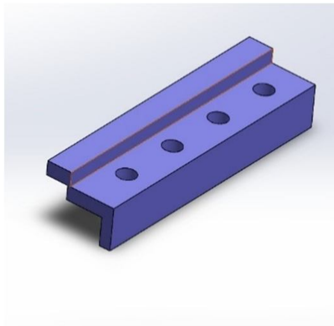


Fig.17 Shear die

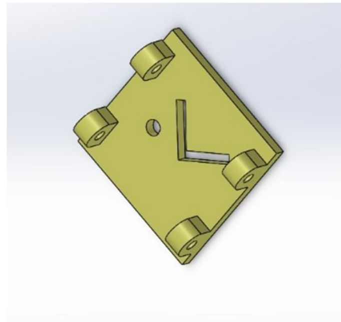


Fig.18 Angle die

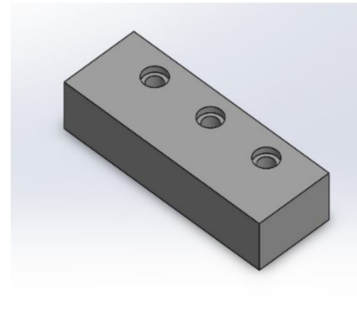
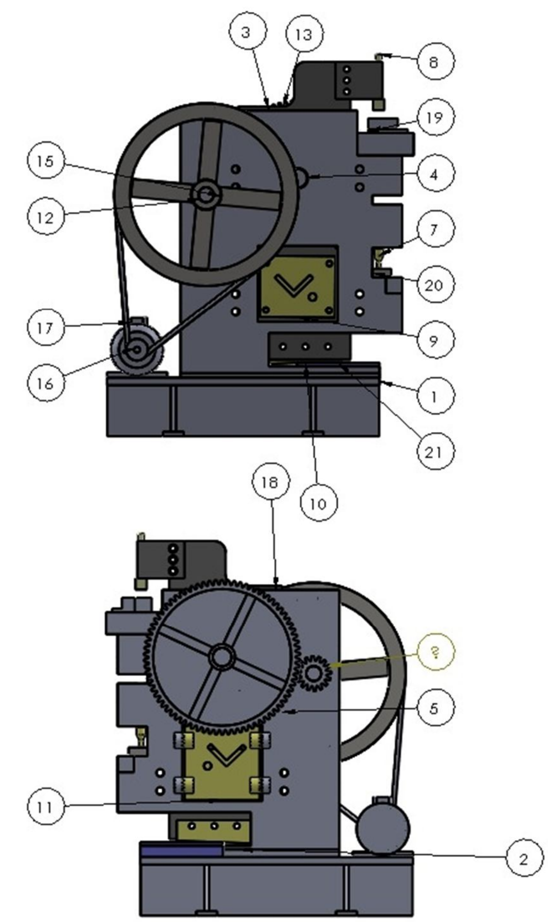


Fig.19 Hole die

C. Final CAD Design



ITEM NO.	PART NAME	QTY.
1	Base_Structure	1
2	Structure_Plate_Right	1
3	Structure_Plate_Left	1
4	Cam_Shaft	1
5	Tool_Plate	1
6	Slider	1
7	Hole_Punch	1
8	Notch_Punch	1
9	Angle_Punch	1
10	Shear_Punch	1
11	Angle_Die	1
12	Pully_Shaft	1
13	Helical_Gear	1
14	Driver_Gear_Pulley	1
15	Flywheel	1
16	Motor_Pully	1
17	motor	1
18	Belt2-1	2
19	Notch_Die	1
20	Hole_Die	1
21	Shear_Die	1

Fig.20 Final CAD Design

IV. SCOTCH YOKE MECHANISM

The power press machine operates using a scotch yoke mechanism coupled with a V-belt pulley system to achieve efficient power transmission and precise metalworking operations. The machine converts rotary motion from the flywheel into reciprocating motion of the slider block, enabling punching, shearing, and cutting processes with high accuracy

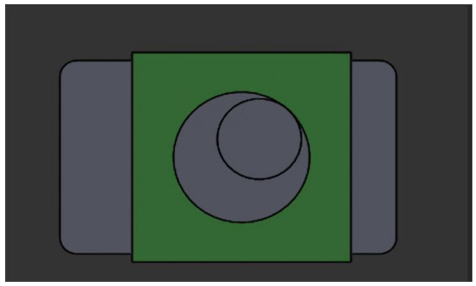


Fig.21 Scotch yoke mechanism

V. RESULTS

The following data provides the design of power press machine. The result are given below:

1) Shear Force Capability: Handles a shear force of 77,000 N.
2) Flywheel Design: Operates at a mean speed of 226.415 RPM with an inertia of 1.0104 kg·m².
3) Energy Efficiency: Requires 195.5 J for punching operations.
4) Compact and Portable Design: Plate thickness: 18 mm; Lightweight and portable.
5) Component Dimensions: Shaft diameter: 50 mm; Cam diameter: 80 mm.
6) Speed and Power Transmission: Utilizes a scotch yoke mechanism and V-belt pulleys for power transmission.
7) Reduction in Setup Time: Minimizes material alignment and holding setup times.
8) Versatility: Performs punching, cutting, and shearing operations.
9) Cost Savings: Reduces dependency on hydraulic mechanisms and minimizes material waste.
10) Improved Safety: Includes robust components and safety features.
11) Idle and Punching Time: Punching time is 1/12 seconds; idle time is 11/12 seconds.
12) Pulley and Gear Dimensions: Pulley diameters: D1 = 90 mm, D2 = 500 mm; Gear diameters: D3 = 100 mm, D4 = 432 mm.

VI. DISCUSSION

The results and calculations provide valuable insights into the design and performance of the multifunctional power press machine. Below is a detailed discussion in simple language:

1) Shear Force Capability: The machine can handle a shear force of 77,000 N, showing its ability to cut or punch strong materials like square bars, round bars, and angle bars. The energy required for punching is calculated as 195.5 J, which is relatively low for such operations.
2) Component Dimensions: The shaft diameter (50 mm) and cam diameter (80 mm) are optimized to handle operational stresses. These dimensions ensure the durability and reliability of the components during continuous use.
3) Speed and Power Transmission: The scotch yoke mechanism and V-belt pulleys ensure smooth and efficient power transmission. This reduces dependency on hydraulic systems, making the machine simpler and less expensive to maintain.
4) Compact and Portable Design: The machine is designed with compact dimensions and a lightweight structure (plate thickness of 18 mm). This makes it easy to move and suitable for industries with limited workspace.

VII. CONCLUSION

The development of a compact, efficient, and cost-effective power press machine successfully addresses the challenges of traditional metalworking systems.

The designed machine demonstrates high shear force capability (77,000 N), precise power transmission using a scotch yoke mechanism and V-belt pulleys, and improved energy efficiency (195.5 J for punching operations). With a mean flywheel speed of 226.415 RPM and optimized component dimensions, the system ensures stable performance and durability. Its compact and portable design, along with multiple functionalities such as punching, cutting, and shearing, enhances versatility while reducing operational costs and material waste.

Additionally, the incorporation of robust safety features, minimized setup time, and an efficient idle-to-punching cycle (11/12s idle, 1/12s punching) further improves productivity and operator safety. The machine’s reduced reliance on hydraulic mechanisms makes it an energy-efficient and cost-saving solution for modern industrial applications.

Overall, the results validate the effectiveness of the proposed power press in enhancing precision, reducing costs, and improving operational efficiency. Future work may focus on further optimizing the design through advanced automation, improved material selection, and enhanced safety mechanisms to expand its industrial applicability.

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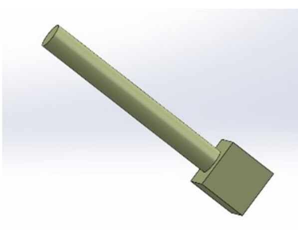

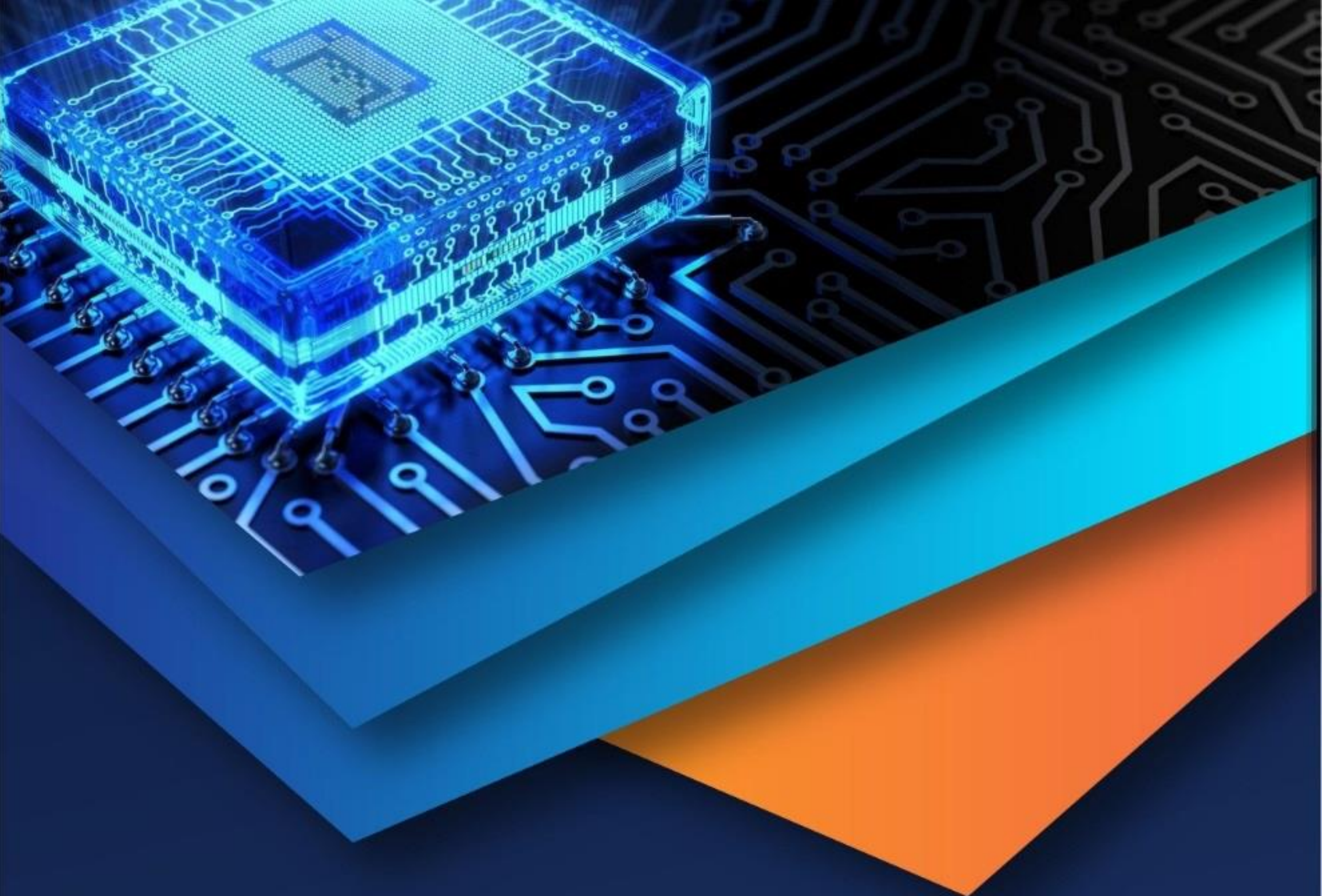

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