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Design & Optimization of Power Press Machine

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Abstract: Press working may be defined as a chip less manufacturing process by which various components are made from sheet metal. This process is also termed as cold stamping. The machine used for press working is known as PRESS. The main features of press are: a frame which supports a ram of a slide and a bed, as a source of mechanism for operating he ram in the line with normal to the bed. The ram is equipped with suitable punch/punches and a die block is attached to the bed. A stamping is produced by the downward stroke of the ram when the punch moves towards and into the die block. The punch and die block assembly is generally termed as a die set or simply as the die. Press working operations are usually done at room temperature.
Keywords: Mechanical Press frame, crack, stress concentration, FEM, numerical and experimental analysis.

I. CLASSIFICATION

A. Classification Based On The Source Of Power

1) *Fly Press:* Fly press or Ball press is the most simple of the presses and is operated by hand. The frame of the machine is rigid C shaped casting, which is subjected to the severe thrust exerted by a ram. The typical shape of the frame leaves the front open which facilitates the feeding of the sheet metal below the ram from the side of the machine. The screw of the press operates in nut which is incorporated in the two ends of the arm, which is bolted to the screw so that when the handle is turned it causes the screw to rotate within the nut. Attached to the lower end of the screw is the arm, which moves up and down the slides, provided at the extension of the frame. The connecting arrangement between the screw and the ram is such that when the screw is rotated, the ram slides up and down within the guide. The punch and the die constitute the press tool, the punch being the upper member is fixed to the lower end of the ram and the die which is the lower member of the press tool is fixed on a plate on the table known as the Bolster plate. The sheet metal to be formed is placed between the punch and the die. The press is operated by a sharp, partial revolution of the arm by pulling the handle and the kinetic energy is stored up in the two heavy balls mounted on the ram. As the arm is forced downwards, the resistance offered by the plate against deformation is overcome by the tremendous thrust exerted by the punch on the plate at the expense of the stored up energy and the material is formed to the desired shape.

2) *Power Press:* The constructional features of a power press are almost similar to that of the hand press, the only difference being, the ram, instead of driven by hand, is driven by power from a motor. The power press may be designated as mechanical or hydraulic according to the type of working mechanism used to transmit power to the ram. In a mechanical press, the fluid under the high pressure is pumped on one side of the piston and then on the other in hydraulic cylinder to drive the reciprocating movement. The punch is fitted on the end of the ram and the die is attached on the bolster plate. The flywheel mounted at the end of the crank shaft stores up the energy for maintaining a constant downward speed of the ram when the sheet metal is pressed between the punch and the die.

B. Classification Based On Design Of Frame

1) *Gap Press:* The gap like opening in the frame for feeding the sheet metal from one side of the press. The frame is integral with the base and provides a rigid construction.

2) *Inclined Press:* The inclined press is the most common types of press used in industries. The identifying characteristic of the inclined press is its ability to tilt back on the base, permitting the scraped or finished products to be discharged from the die by gravity without the aid of any type of handling mechanism. The press is not as rigid as a gap press owing to its construction.

3) *Adjustable press:* Has the mechanical arrangement for raising or lowering the table on which the die is fitted. This enables setting of different sizes of work. The press is not as rigid as the other type.

4) *Horn press:* The horn press has cylindrical horn like projection from the machine frame, which serves as the die supports. The horn may be interchanged for the different sizes of work. The press is intended for cylindrical work piece.

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5) *Straight side press:* The straight side press has two vertical rigid frames mounted on two sides which are intended for absorbing severe loads exerted by the ram. The machine is suitable for heavy work, but due to presence of side frames, the she metal cannot be fed from the sides.

II. PRESS TERMINOLOGY

A. Red

The bed is the lower part of press frame that serves as a table on which is a bolster plate is mounted.

B. Bolster Plate

This is thick plate secured to the press bed, which is used for locating and supporting the die assembly. It is usually 5- to 12.5 cm thick.

C. Die Set

It is unit assembly, which incorporates a lower and upper shoe, two or more guideposts and bushing.

D. Die

The die may be defined as the female part of a complete tool for producing work in a press. It is also referred to a complete tool consisting of a pair of mating members for producing work in a press.

E. Die Blocks

It is a block or a plate, which contains a die cavity.

F. Lower Shoe

The lower shoe of die set is generally mounted on the bolster plate of a press. The die block is mounted on the lower shoe. Also the guide posts are mounted on it.

G. Punch

This is the male component of the die assembly, which is directly or indirectly moved by and fastened to the press ram or slide.

H. Upper Shoe

This is upper part of the die set, which contains guidepost bushing.

I. Punch Plate

The punch plate or punch retainer fits closely over the body of the punch and holds it in proper relative position.

J. Backup Plate

Backup plate or pressure plate is placed so that the intensity of pressure does not become excessive on punch holder. The plate distributes the pressure over a wide area and the intensity of pressure on the punch holder is reduced to avoid crushing.

K. Knock out

It is a mechanism, usually connected to and operated by the press ram, for freeing a work piece from a die.

L. Pitman

It is connecting rod, which is used to transmit motion from the main drive shaft down to the press slide.

M. Shut Height

It is the distance from top of the bed to the bottom of the slide with its stroke down and adjustment up.

N. Stroke

The stroke of a press is the distance of ram movement from its up position to its down position. It is equal to twice the crankshaft throw or the eccentricity of the eccentric drive. It is constant for the crankshaft and eccentric drives but is variable on the hydraulic press.

III. MAIN PARTS OF POWER PRESS:

A. Gears

1) *Driver Gear:* It is made up of cast iron. Its outer diameter is 41 mm. And it has 12 teeth.
2) *Driven Gear*: It is also made up of cast iron. Its outer diameter is 116 mm And it has 35 teeth.
3) *Flywheel:* It is made up of iron and its diameter is 120 mm.
4) *Bolster Plate:* It is made up of cast iron. Its dimensions are 118 mm *65 mm.
5) *Crank Shaft:* It is made up of high-speed steel. Its length is 135 mm, its diameter is23 mm.

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6) *RAM:* It is made up mild steel. Its dimension are 61 mm* 57mm *23 mm.
7) *Pitman*: It is made up of mild steel and its diameter is 25 mm.
8) *Base:* It is made up of grey cast iron and its length is 315 mm and height is 88 mm.
9) *Pulley:* It is made of cast iron and its diameter is 86 mm.
10) *Clutch:* It is used to control the reciprocating motion of the ram.

IV. PRESS OPERATIONS

A. Classification Of Press Operation

The sheet metal operation done on a press may be grouped in to two categories cutting operations and forming operations. In the cutting operation, the work piece is stressed beyond its ultimate strength. The stresses caused in the metal by the applied force will be shearing of the metal. In forming operation, the stresses are below the ultimate strength of the metal. In the operation, there is no cutting of the metal is done. but only the contour of the work piece is changed to get the desired product. The cutting operation includes: blanking, punching, notching, performing, trimming, shaving, slitting, and lancing etc. The forming operation includes: bending, drawing, redrawing, squeezing. The stresses induced in the metal during bending and drawing operation are tensile and during the squeezing operation it is compressive.

B. Description Of Press Operations

1) *Blanking:* Blanking is the operation of cutting a flat shape from sheet metal. The article punched out is called the "BLANK" and is the required product of the operation. The hole and metal left behind is discarded as waste. It is usually the first step of series of operation.
2) *Punching:* It is a cutting operation by which various shaped holes are made in sheet metal. Punching is similar to blanking except that in punching, the hole is the desired product and the material punched out in waste.
3) *Notching*- This is cutting operation by which metal pieces are cut from the edge of a sheet, stripe or blank.
4) *Perforating*- This is a process, by which multiple holes, which are very small and close together are cut in flat work material.
5) *Trimming*-This operation consist of cutting unwanted excess material from the periphery of a previously formed component.
6) *Shaving*- The edges of blanked parts are generally rough, uneven and unsure. Accurate dimensions of the part are obtained by removing a thin strip of metal along the edges. This operation is termed as shaving.
7) *Slitting*- It refers to the operation of making incomplete holes in a work piece.
8) *Lancing*- This is a cutting operation in which a hole is partially cut and then on side is bend down to form a sort of tab or louver. Since no metal is actually removed there will be no scrap.
9) *Nibbing*- The nibbing operation, which is used for only small quantities of components, is designed for cutting out flat parts from sheet metal. The flat parts range from simple to complex contour. This operation is generally substituted for blanking. The part is usually moved and guided by hand as the continuously operating punch cuts away at the edge of the desired contour.
10) *Bending*- In this operation, the material in the form of flat sheet or stripe, is uniformly strained around a linear axis, which lies in the neutral plane and perpendicular to the length wise direction of the sheet metal.
11) *Drawing*- This is a process of forming a flat work piece into a hollow shape by means of a punch, which causes the blank to flow into a die cavity.
12) *Squeezing*- Under this operation, the metal is caused to flow to all portions of a die under the action of compressive forces.

V. SELECTION OF PRESS

The factor which should be considered while selecting a press for a given job are: the overall work size, the stock thickness and material, kind of operation to be performed, power required and speed of operation. For punching, blanking and trimming operation, usually the crank or eccentric type mechanism press is used. This is due to their small working strokes and high production rates. In operation, there is sudden release of load at the end of the cutting stroke. This sudden release of load is not advisable in hydraulic presses. So, hydraulic presses are not preferred for these operations. If however these are inevitable, then some damping devices are incorporated in the press design. For coining and other squeezing operations, which require very large forces, knuckle joint mechanical press is ideally suited. Hydraulic presses, which are slower and powerful, can also be used for these operations. Hydraulic presses are also better adapted to pressing, forming and drawing operations, which are basically slower processes.

VI. RATING OF A PRESS

A press is rated in tonnes of force that can be applied to the slide without undue strain and without affecting the structural strength of the press.

The tonnage of a mechanical press is determined by the size of the bearings of the crankshaft or the eccentric. It is given by the relation:

Tonnage capacity = shear strength of the crankshaft material * area of the crankshaft bearing..The tonnage capacity of a mechanical press is always given when the slide is near the bottom of its stroke, because it will be maximum at the point or with the crank turned through an angle of not more than 30 from the bottom zero position.
The tonnage capacity of a hydraulic press is given by:
Tonnage capacity = piston area * oil pressure in the cylinder. As noted earlier, the capacity of a hydraulic press can be varied by changing oil pressure. In double action crank presses, the tonnage of the inner slide determines the maximum drawing pressure, while the maximum blank holding pressure depends upon the tonnage of the outer slide. To keep the strains and the deflections of the press structure small, it is a usual practice to choose a press rated 50% to 100% higher than the force required for an operation.
In case of single, double and triple action hydraulic presses, the rams may all be driven from a central hydraulic accumulation fed by pump, or have individual drives from one or more pumps.

VII. REQUIREMENT OF A PRESS TOOL DESIGN

1) The dimensional accuracy and surface finish of stampings should confirm to the drawing and specific action.
2) The working parts of the press tool (die or punch) must be adequately strong, durable in operation and easily replaceable when worn out.
3) The die should ensure the required hourly output, easy maintenance, safe operation and reliable fastening in the press.
4) The die should be designed in such ways that as far as possible standard components are used for its manufacturing. As few special parts as possible should be used in its design.

VIII. DESIGN OF THE POWER PRESS

For designing the power press first of all we have calculated the cutting force, which will be required to cut the desired material. We have designed the press to cut an Aluminum sheet which is up to 0.5 mm thick and not more than 20 mm wide.

A. Design of punch:

We know that length of punch is given by:

Lm = 2 * (t + b)/ 8 * [E * b/(f * t)]0.5

Where,

Lm = length of shear (punch)
t = thickness of material to be cut
b = width of material
f = shear stress of punch material (which is 460 N/mm2 for medium carbon steel)
E = modulus of elasticity of the punch material

So we get,

Lm = 2 * (0.5 + 20)/8 * [1000*20/(460 * 0.5)]0.5
= 47.5 mm

For safety let us take the length of punch as 55 mm

B. Design of Die:

From the book "Metal Forming Processes" by G.R.Nagpal, we get the following data:

Die block thickness,

T = 15 mm for p = 250 mm

T = 25 mm for p = 75 - 250 mm

T = 30 mm for p larger than 250 mm

Where, p is the blanking perimeter.

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Now we have.

p = 2 * (b + t) = 2*(20 + 0.5), So p = 41 mm

Thus required thickness of the die block is 15 mm

C. Calculation of cutting force:

Now, Cutting force,

F = Lm * t * fs

Where fs is the So, we get

F = 55 * 0.5 * 300 =8250N

For the purpose of a safe design, let us take the design force as 4 times of the calculated force. Therefore we will design our press for a cutting force of 33 KN.

Now, work done per cut = F * p * t

Where,

F = required cutting force
p = penetration (in % which is equal to 60% for Aluminium)
t = thickness of the material
So, we get, work done = 33000 * 0.6 * 0.5
= 10 N-M (approximately)

We know that, Work done = Torque * angular displacement
So, Torque = Work done/ angular displacement

We have, Angular displacement = 45 degree or 0.7853 radians (for 3 mm shear and travel of ram 24 mm per stroke)

So we get,

Torque = 10/0.7853
= 12.73 N-M

Now let us take 75 - 100 strokes of ram per minute say 85 strokes per minutes. So the shaft connected to the ram have to rotate 85 times per minute.

Now we know that,
Power = 2 * pi * N * T /60

= 2 * 3.142 * 85 * 12. 73/60

= 113 W Say 120 W

Now the motor, which we have purchased from the market having power 120 Watts, was having the following specification:

Power = 120 Watts
Voltage = 12 Volts
Current = 10 Ampere
No. of revolution = 1500 r.p.m.

In order to reduce the a.c. supply voltage we have used a step down transformer of 12 Volts.

D. Design of Gears:

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As the r.p.m. of the motor are high, we have connected a pulley, having diameter about 6 times that of the diameter of the pulley on the motor shaft, to the pinion shaft. This has reduced the r.p.m. of the pinion shaft 6 times as compared to the motor shaft. So, we get, r.p.m. of pinion shaft, Np = 260 r.p.m.

Now assuming the pitch line velocity 0.5 m/sec. We get,

V = pi * Dp * Np/60

Where Dp is the diameter of the pinion

V = 3.142 * Dp * 260

So, Dp = 38.50 mm

Now let Dg = diameter of the gear.

Let us a velocity ratio of 3:1 so that the r.p.m. of the gear will be equal to the r.p.m. of the shaft which is connected to the ram i.e. 85 r.p.m.

So, we get Dg = 3 * Dp
= 115.5 mm

Now tangential force, Ft = P * Cs/v

Where, P = power of the motor
Cs = service factor(which is equal to 1 for a 8 - 10 hour working condition)

V = pitch line velocity, So, Ft = 120 * 1/0.5,
Ft = 228 N

Taking 2 - 4 times of the load for safe design we take Ft = 912 N

Now applying Lewis equation

Ft = sigmad * Cv * Fp * pi * y * m

Where,

sigmad = allowable static stress
Cv = velocity factor
Fp = face width of the pinion
m = module

Taking sigmad for cast iron as 47 Mpa

Cv = 3/(3 + v) For v upto 12 m/sec

= 0.85

So,
912 = 47 * 0.85 * 9m * pi * 0.78 * m

m = 3.25 mm

Now number of teeth on the pinion,

Np = Dp/m

= 39/3.25

= 35

So we get the number of teeth on the pinion as 12 and the number of teeth on the gear as 35.

Now face width of the pinion will be,

Fp = Ft / (sigmad * Cv * pi * m *)

= 912 / (47 * 0.85 * 3.412 * 0.078 * 3.25)

= 27 mm (approximately)

similarly we get the face width of gear as 17.47 mm.

Now taking the greater value of face width we take,

Fp = Fg = 27 mm.

E. Design of pinion Shaft:

Normal load acting between the tooth surface,

Wn = Ft / cos fiv

= 912/ cos20 (As the pressure angle is 20 degree for 20 degee full depth system)

= 970 N

Now, Weight of the pinion,

Wp = 0.00118 *Tp * fp * m2

= 4.03 N

Now, resulting load acting on the pinion will be,

Wr = rot (Wn2 + Wp2 +2 Wn * Wp* cos fiv)

= 973.78 N

Now bending moment on the shaft due to the resultant load,

M = Wp * X

Where X = overhang (assuming it as 100 mm)

M = 97378 N-mm

Twisting moment on the shaft

T = Ft * Dp / 2

T = 17556 N-mm

Now equivalent twisting moment,

Te = rot (M2 + T2)

= 989478 N-mm (approximately)

Taking material of the shaft as alloy steel whose safe stress is 345 N/mm2

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So,

Te = pi * sigma * (Psd)> /16

Ps = 11.34 mm

Where, Psd = pinion shaft diameter

For the diameter of safety let us take the pinion shaft diameter as 22 mm.

F. Design of gear shaft:

Normal load acting between the teeth surfaces,

Wn = Ft / cos fiv

= 912 / cos 20

= 970 N

Weight of the gear ,

Wg = 0.00118 Tg * fg * m2

= 12 N

Now, resulting load acting on the gear will be,

Wr = rot (Wn2 + Wg2 + 2 * Wn * Wg * cosfiv)

Wr = 981 N

Now, bending moment on the shaft due to resultant load will be,

M = Wr * X

Where X is the overhang (assume it as 160 mm)

So, M = 186960 N-mm

Twisting moment on the shaft,

T = Ft * Dg / 2

= 52668 N-mm

Now equivalent twisting moment will be,

Te = rot (T2 + M2)

= 165560 N-mm

Also,

Te = pi * sigma * (Gsd)> / 16

So, we get

Gsd = 13.47 mm

Where Gsd is the gear shaft diameter. For the purpose of safety let us take the diameter of gear shaft as 24 mm.

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IX. FUTURE MODIFICATION

There are lots of modifications which are possible in our press. In future, according to our requirements, we can change the tool and die of the press to perform the desired operation. By changing the tool we can perform operations like punching a hole, blanking different shapes, bending, trimming, nibbing, slitting etc.

We can also change the velocity ratio of the press by changing the gears. This will help us to perform operations on metal sheets with different thickness and of different materials. We can also change the motor of the press, by keeping in mind the capacities of the component, which will allow us to generate different amount of power and thus will enable us to perform other operations as well. By changing the pulley of the press, we can vary the number of revolutions per minute of the press without changing the motor or the gears. Change in the number of revolutions will obviously change the number of strokes of the ram.

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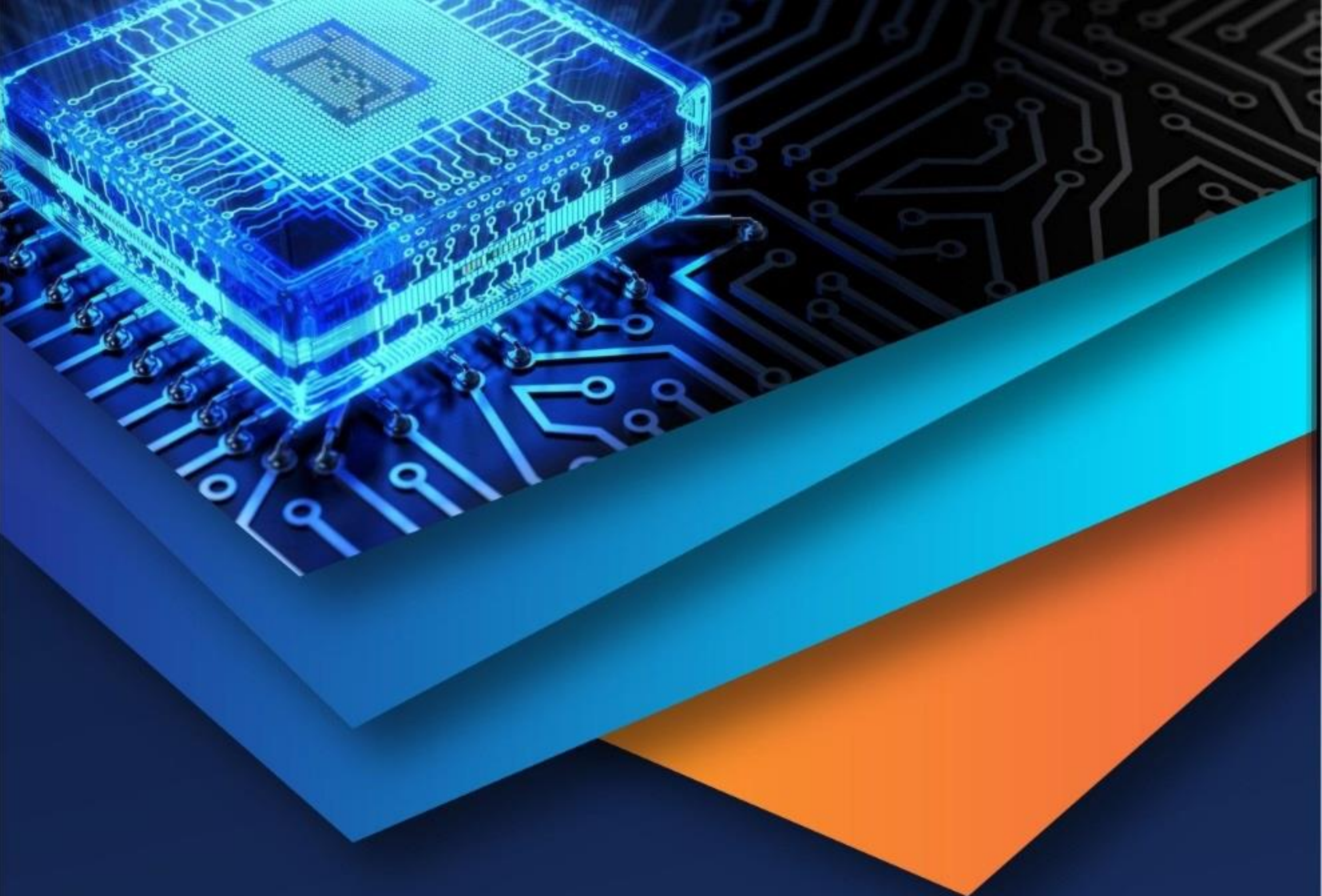

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