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Design of High Pressure Double Acting Cylinder for Hydraulic Press Brake

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Abstract**: This project is aimed at the "Design of High Pressure Double Acting Cylinder for Hydraulic Press Brake" and implementing the results by modelling the figures using pro-E and analysing the design using Ansys software. The motivation for this project comes from the hydraulics, which is more efficient then other power transmission systems. Hydraulically driven machines like press brakes etc., are now able to generate more power and higher accuracies in speed, force and position control due to integration of electronics as control medium for hydraulic systems. Hydraulic systems use fluids as a source of power. Hydraulic systems are now extensively used in machine tools, material handling devices, transport and other equipments because of its simple design, high efficiency and few moving parts. A high force may be generated from a small input signal using a hydraulic system. Press brake is a special purpose machine whose function is to bend the sheet metal at required angle. However with relatively simple modifications the different operations like forming, blanking, notching, punching, piercing, straightening, embossing, trimming, etc., can be done apart from bending. Thus hydraulic systems are used for providing linear motion. By knowing the importance and complicity involved in working of a hydraulic system, created a need for designing a 'hydraulic cylinder' for press brake. A hydraulic cylinder is a device which converts fluid power into linear force or motion. The most significant feature of a hydraulic cylinder is its efficient motion control of heavy loads. This project basically deals with implementation of our basic design skills for the design of high pressure double acting cylinders used in a hydraulic press brake. The calculations have done taking into account various design considerations of hydraulic cylinder and press brake. They are as follows: design of piston, selection of pump, wall thickness of cylinder, design of cylinder head, design of packing box. The calculations were at first performed manually and later the 3D figures were drawn using Pro-E and results were analysed using Ansys software. This report comprises of two parts in which first part deals with basics of hydraulics and working of its components, the later part deals with design consideration of a double acting cylinder its modelling and analysis.**

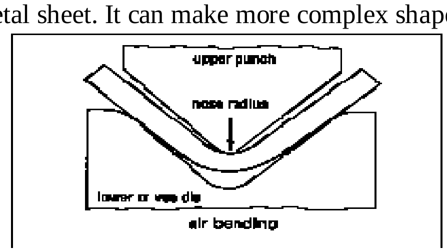
Keywords**: press, transmission systems, hydraulics, press brakes, special purpose machines, etc.,**

I. INTRODUCTION TO HYDRAULICS

Hydraulics is a topic in applied science and engineering dealing with the mechanical properties of liquids. Fluid mechanics provides the theoretical foundation for hydraulics, which focuses on the engineering uses of fluid properties. In fluid power, hydraulics is used for the generation, control, and transmission of power by the use of pressurized liquids. Hydraulic topics range through most science and engineering disciplines, and cover concepts such as pipe flow, dam design, fluidics and fluid control circuitry, pumps, turbines, hydropower, computational fluid dynamics, flow measurement, river channel behavior and erosion.
Free surface hydraulics is the branch of hydraulics dealing with free surface flow, such as occurring in rivers, canals, lakes, estuaries and seas. Its sub-field open channel flow studies the flow in open channels.

II. HYDRAULIC PRESS BRAKE

A press brake is a machine that can bend metal to nearly any shape or design. The press brake will "press" or shape the metal by force, using the power of the hydraulic motor to compress certain sections of the sheet metal and bend it into another shape. The press brake pushes metal into dies, which do most of the precision shaping. The press brake is different from a bending machine in that it does more than just put a curve into a metal sheet. It can make more complex shapes.



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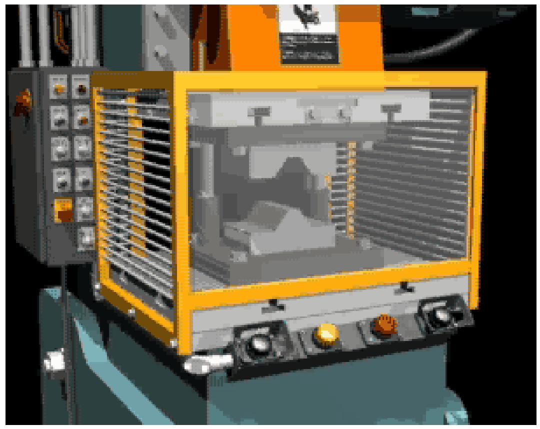
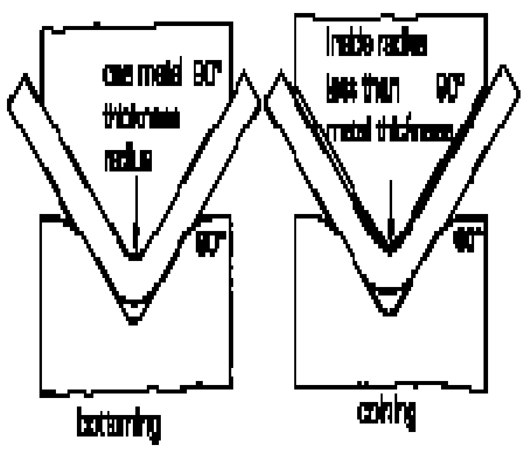
A Hydraulic Press brake molds metal sheets that are 1/16 to 1/4 inch thick. Other materials can also be shaped in them, however. It is important to note that the steel is not heated. The pressure and force of the press cause enough heat and friction to change the shape of the metal. This means that only metals with a malleable quality can be used in press brakes. This includes aluminium, soft steels, tin, pewter, copper, brass and other softer metal varieties. One common use for a press brake is to shape sheet metal into corrugated aluminium siding, for instance

A. Operation

Most press brakes are manually fed. The operator holds the work piece between the punch and die against the appropriate gauge, providing the pre-set dimension for the bend.



When the blank is properly positioned the machine is activated causing the ram to move toward the bed, and the work piece is formed between the die and punch. Then the ram returns, allowing for removal of the work piece. One type of press brake operation is air bending of sheet metal into a straight line angle. As shown in Figure 3, the punch pushes the work piece into the die cavity. Throughout the entire operation, the work piece touches only the tip of the punch and the two edges of the lower die. When the force of the upper die is released, the work piece "springs back" to form a final angle. The amount of spring back is directly related to material type, thickness, grain and temper. To minimize set-up time, most tools for air bending are made with the same angle in both the punch and die. Commonly an 80° or 85° die angle is used to allow for sufficient spring-back to obtain a 90° final angle.



In situations requiring dimensional accuracy and angular precision, another forming process is required. This process is called "Coining" or "Bottoming." Coining requires having a punch and die manufactured to the desired final bend angle and forcing the work piece completely into the die. Coining reduces spring-back, however this process is limited by the tonnage capacity of the press brake.

Press Brake

III.DESIGN CONSIDERATIONS FOR HYDRAULIC CYLINDER

There are a number of other considerations when selecting the appropriate hydraulic cylinder for a task besides the bore size. Failure to consider these other design aspects may result in a cylinder that is not suitable to an application or will suffer a short service life.

A. These design considerations include

1) Rod Diameter based on required column strength.
2) Appropriate Mounting Style for the application.
3) Cylinder Side Loading and Bearing Requirements.
4) Materials of Construction.
5) Seal Materials.
6) Port Locations, Size and Type.
7) Cylinder and Rod Coatings.
8) Type of Hydraulic Fluid to be used.

IV.DESIGN CALCULATIONS OF PRESS BRAKE AND CYLINDER

A. Design Calculation Of Press Brake

1) Specification

a) Tonnage of press brake= 200 tons.
b) Cylinder size=Ø250mmxØ235mm.
c) Cylinder bore diameter, D=Ø250mm=Ø25cm.
d) Piston rod diameter, d=Ø235mm=Ø23.5cm.
e) Number of cylinders =2.
f) Return tonnage = 10% of the tonnage (assumed) =20 tons.
g) Pressure = 200kg/cm^2 (assumed).

Cylinder Area Calculation:

Pressure calculations:

Tonnage=200 tons.

Working pressure= $\frac{Tonnage}{Area\ of cylinder}$

Area of cylinder, A= $\pi D^2/4$

$= (\pi \times 25^2)/4$

$= 490.87\ cm^2$.

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Area of two cylinders or Piston area = 490.87x2 = 981.74 cm^2.

Working pressure= $\frac{200 \times 10^3}{981.74}$

=203.71 kg/cm^2 = 204 kg/cm^2.(say)

Hence diameter of the piston rod is 235mm.

Area of piston rod = $\pi d^2/4$

= $(\pi \times 23.5^2)/4$

=433.7 cm^2.

Rod area = 433.7x2 = 867.97 cm^2.

Return area = Piston area - Rod area

= 981.74 - 867.97

=114.26 cm^2.

Return pressure = $\frac{Tonnage}{Return\ Area}$

= $\frac{200 \times 10^3}{114.26}$ =175kg/cm^2.

Assumed speed ±10% of tonnage.

Fast advance = 20mm/sec.

Pressing = 5mm/sec.

Fast return = 50mm/sec.

Discharge for fast advance, Q_{fa}= $\frac{20 \times 60 \times 981.74}{10 \times 10^3}$ = 118 lpm.

Discharge for pressing, Q_{pr}= $\frac{5 \times 60 \times 981.74}{10 \times 10^3}$ = 29.4 lpm.

Discharge for fast return, Q_{fr}= $\frac{50 \times 60 \times 981.74}{10 \times 10^3}$ = 34.27 lpm.

Selection of Pump:

For fast advance, Q_{fa} a prefill valve pv=50 is selected which can provide a flow rate of almost 118 lpm.

For pressing, Q_{pr} and fastreturn, Q_{fr} Rexorth A2F 20- 12 pump(2 no.s) are selected which can offer a flow rate

= 17.4x2=34.8 lpm.

Use of Rexorth A2F 20- 12 pump = $\frac{12 \times 1450}{1000}$ =17.4 lpm.

= 17.4x2 = 34.8 lpm.

Discharge from pump, Q_{pump} = $\frac{34.8 \times 10^4}{60 \times 981.74}$ = 5.9mm/sec^2

= 6mm/sec^2.

Power = $\frac{Q \times Pressure}{Constant \times \eta}$ = $\frac{34.8 \times 204}{600 \times 0.9}$ = 13.14 kW.

= 15kW (say).

B. Cylinder calculations of press brake:

1) Specification

a) Tonnage of Press Brake = 200 tons.

b) Stroke = 750mm.

c) Working pressure = 204 kg/cm^2

d) Type: Double Acting

e) Speeds:

f) Fast advance = 20mm/sec.

g) Pressing = 5mm/sec.

h) Fast return = 50mm/sec.

i) Gross lifting capacity = 38 tons.

Outer Diameter of the Cylinder: W=r x K in inches

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Where,

W = wall thickness.

r = internal radius.

δ =Tensile stress = 15000 psi

s = 15000 psi if cylinder diameter is < 30".

s = 14000 psi if cylinder diameter is > 30".

P = maximum system pressure in psi.

K = 0.21 (from hydraulic standard for casting of 15000 psi).

$$K=\frac{\sqrt{(S+P)}}{\sqrt{(S-P)}}-1$$

S = 15000 psi

P = 204 x 14.22

= 2901 psi

$$K=\frac{\sqrt{(15000+2901)}}{\sqrt{(15000-2901)}}-1$$

K = 0.216.

$$W=\frac{250}{2}\times 0.216 =$$

= 125 x 0.216 = 27mm.

Cylinder assembly for a 203.7kg/cm^2 Operating pressure:

For 204kg/cm^2 pressure in cylinder assembly test pressure of cylinder = 1.5P=1.5 x 204

=306kg/cm^2.

Test pressure in psi = 306 x 14.22 = 4351.32 psi.

$$K=\frac{\sqrt{(S+P)}}{\sqrt{(S-P)}}-1$$

$$=\frac{\sqrt{(15000+4351.32)}}{\sqrt{(15000-4351.32)}}-1$$

= 0.348

W = r x K

= 125 x 0.348 = 43.5mm.

Outer Diameter of Cylinder = Inner Diameter + 2W

= 250 + 2(43.5)

= 337mm

Cylinder Head

t = r x z

Where,

$$z = 0.81\times\frac{\sqrt{P}}{\sqrt{s}}$$

$$= 0.81\times\frac{\sqrt{2901}}{\sqrt{15000}} = 0.356$$

Taking the value of z = 0356 for 15000 psi.

t = 125 x 0356

= 44.5mm.

Taking the additional 50mm extra material for the prefill valve for safety.

Calculated thickness + prefill valve mountings

= 44.5 + 50 = 94.5 = 95.

Packing Box

Area of packing box $=\frac{\pi}{4}(D^2-d^2)$

$=\frac{\pi}{4}(28.5^2-23.5^2)$

= 204.2 mm^2.

Load = Area x Working Pressure

= 204.2 x 204 = 41656.8 kg

= 42 tons.

Maximum Load = 204.2 x 306 = 62485.2 kg

= 62 tons.

Bolts Calculation

Number of bolts, n = 16 (assumed).

Size of the bolts = M 24(assumed).

Minor Diameter, d = 20.319

Area of bolts = n x $\frac{\pi}{4}$ d^2

= 16x $\frac{\pi}{4}$ x $(20.319)^2$

= 5188.173mm^2.

Pressure = $\frac{Tonnage}{Area\ x\ n}$ = $\frac{42 \times 10^3}{\frac{\pi}{4} \times (20.319)^2 \times 16}$ = 8.09kg/mm^2.

Stress = $\frac{Load}{Area}$ = $\frac{41656.8}{5188.173}$ = 8.029kg/mm^2.

Maximum allowable tensile stress of M24 bolt = 12.9 kg/mm^2.

Since the stress on the bolts is less than the maximum allowable tensile stress the design is safe.

Result:

Wall thickness of the cylinder = 43.5mm.

Outer diameter of the cylinder = 337mm.

Cylinder head thickness = 94.5mm.

Area of Cylinder	981.251mm^2
Operating Pressure	203.82 kg/cm^2
Maximum Pressure	306 kg/cm^2
Flow Rate Fast Advance	117.75 lpm
Flow Rate Pressing	29.45 lpm
Flow Rate Fast Return	34.27 lpm
Power of Pump	13.15 kW

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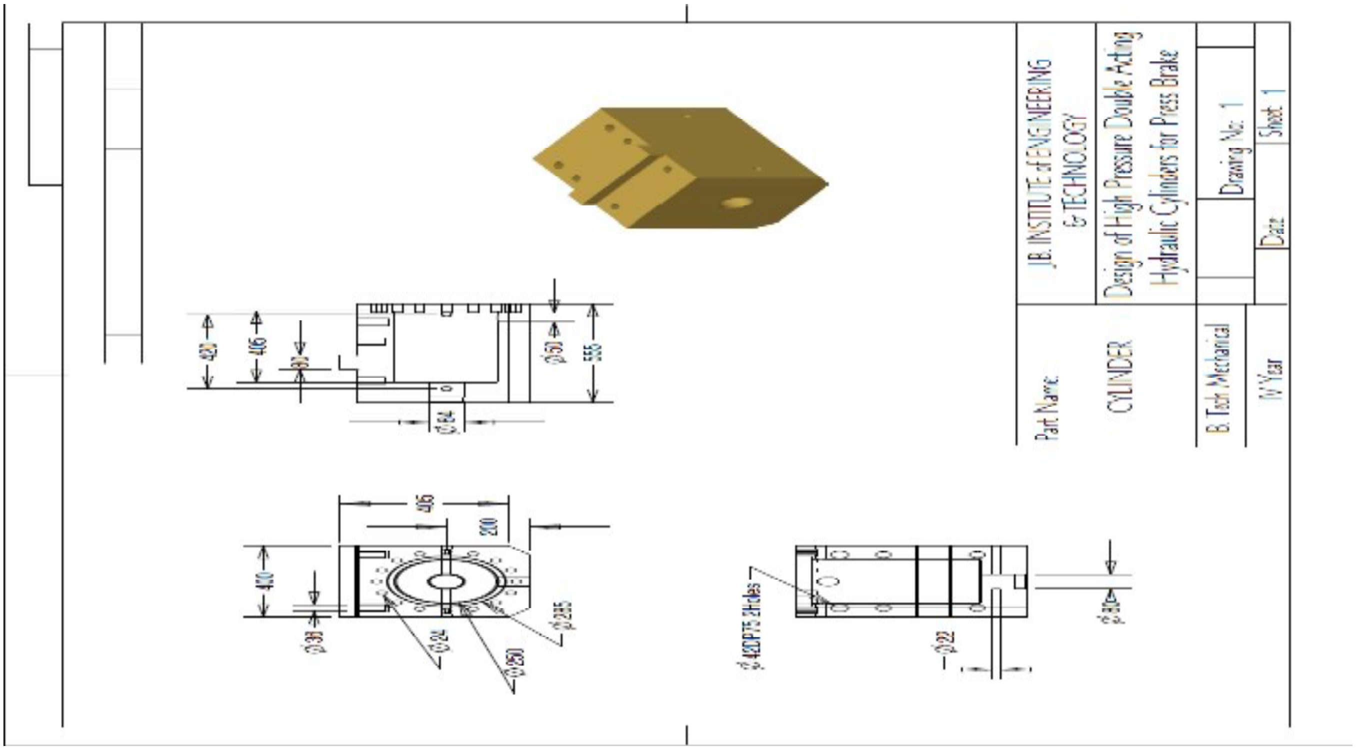
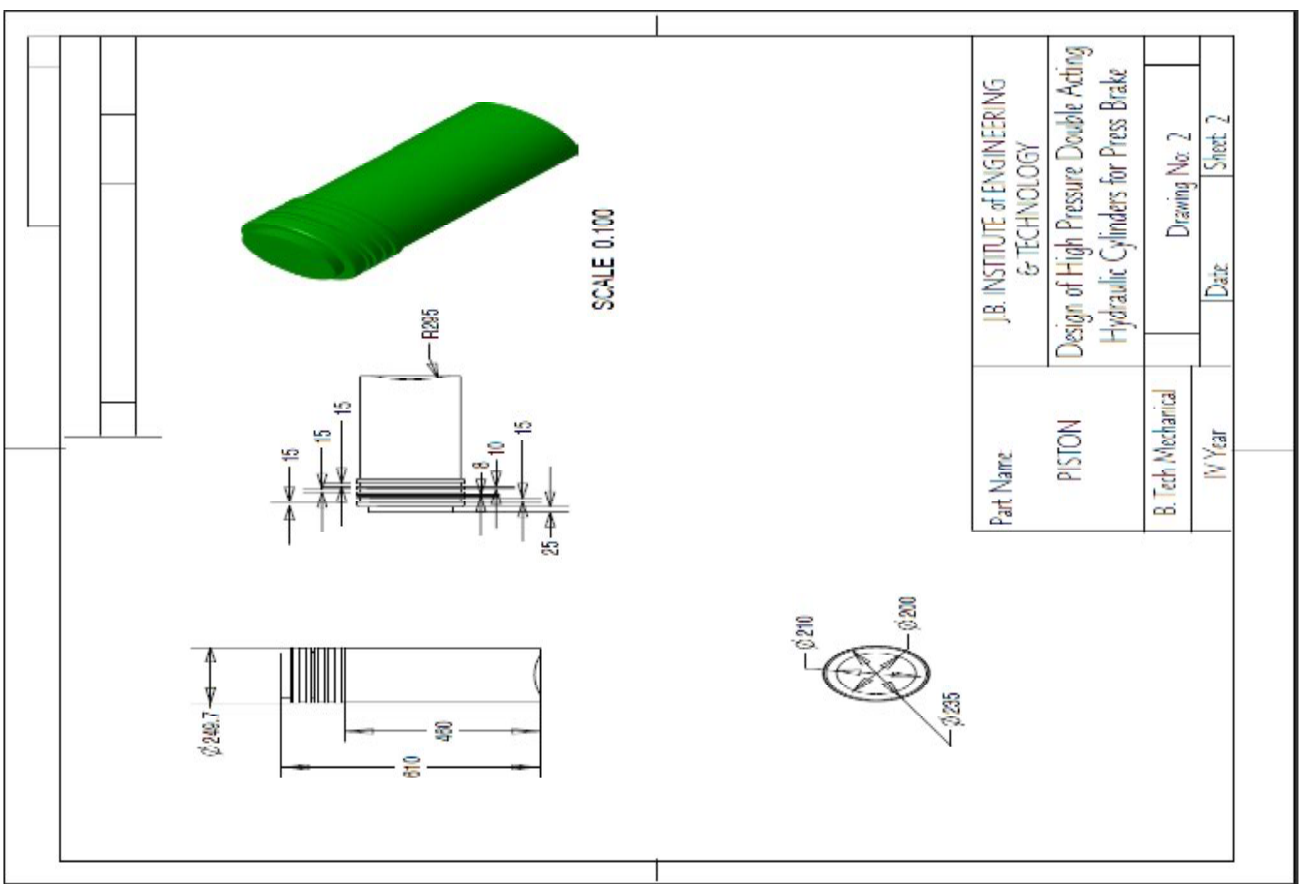
V. MODEL FIGURES USING PRO-E SOFTWARE





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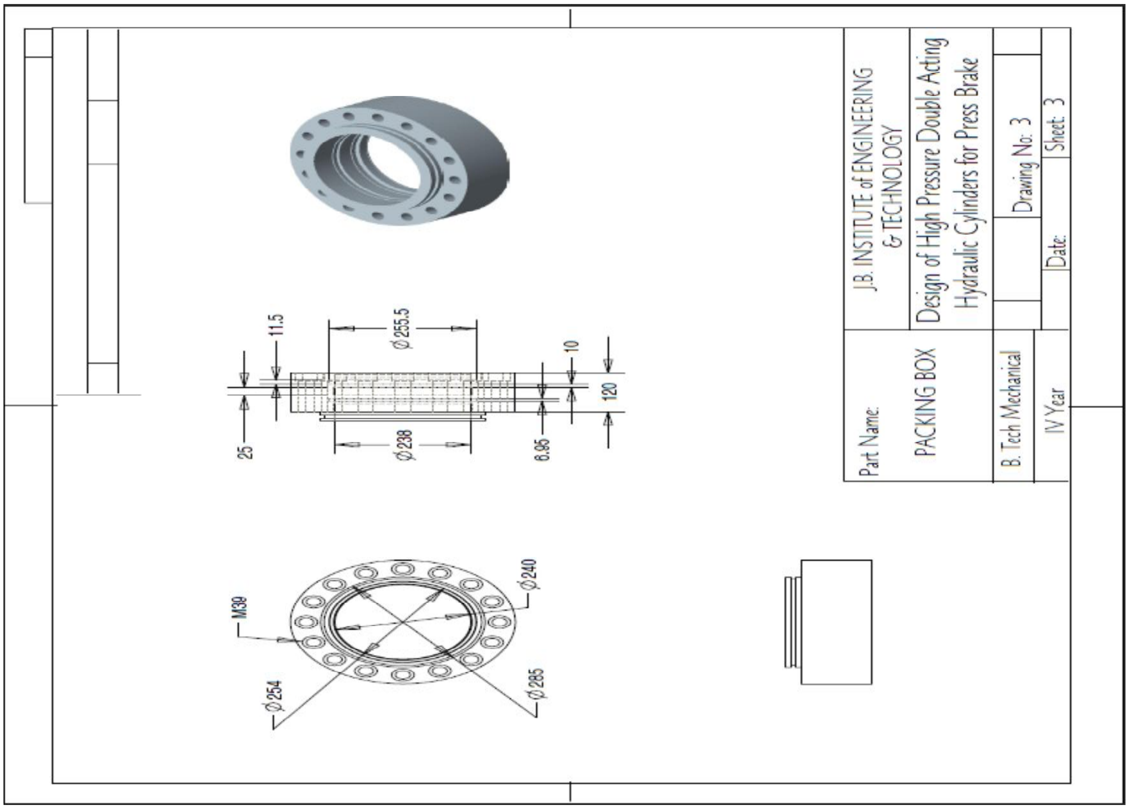

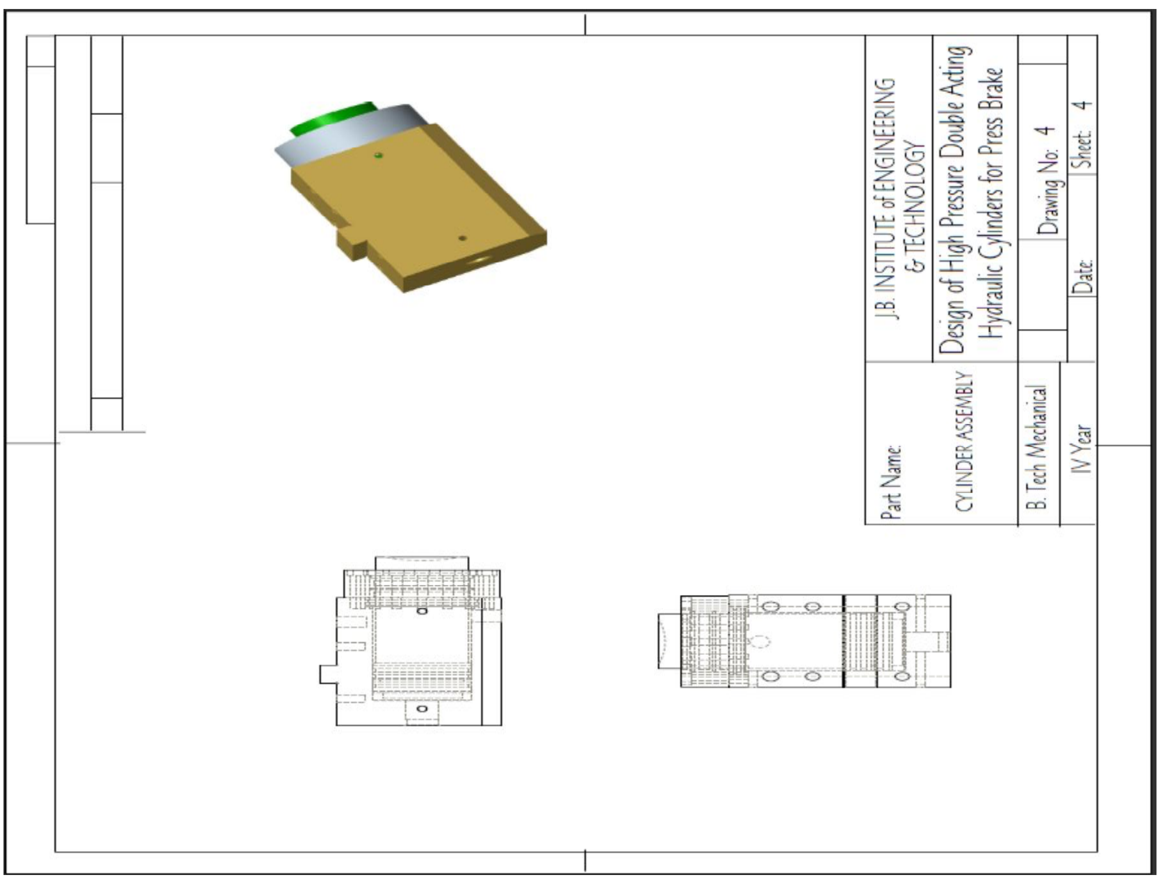

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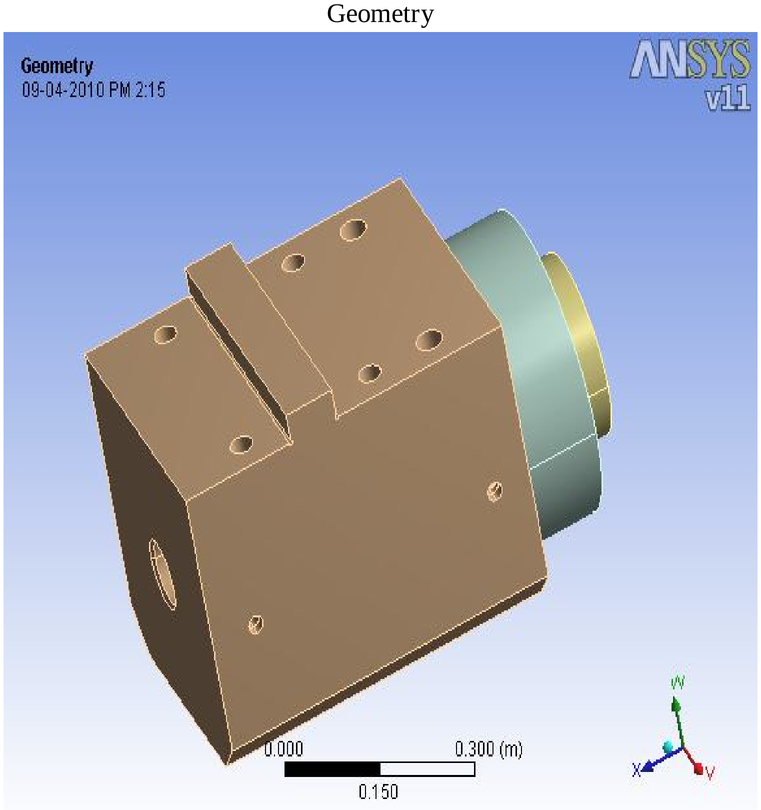
VI. ANALYSIS OF DESIGN USING ANSYS SOFTWARE

A. Description of Material used for analysis of Design

Stainless steel is considered for the analysis of design because of the following properties:

Structural	
Young's Modulus	1.93e+011 Pa
Poisson's Ratio	0.31
Density	7750. kg/m³
Thermal Expansion	1.7e-005 1/°C
Tensile Yield Strength	2.07e+008 Pa
Compressive Yield Strength	2.07e+008 Pa
Tensile Ultimate Strength	5.86e+008 Pa
Compressive Ultimate Strength	0. Pa
Thermal	
Thermal Conductivity	15.1 W/m·°C
Specific Heat	480. J/kg·°C
Electromagnetics	
Relative Permeability	10000
Resistivity	7.7e-007 Ohm·m

Geometry



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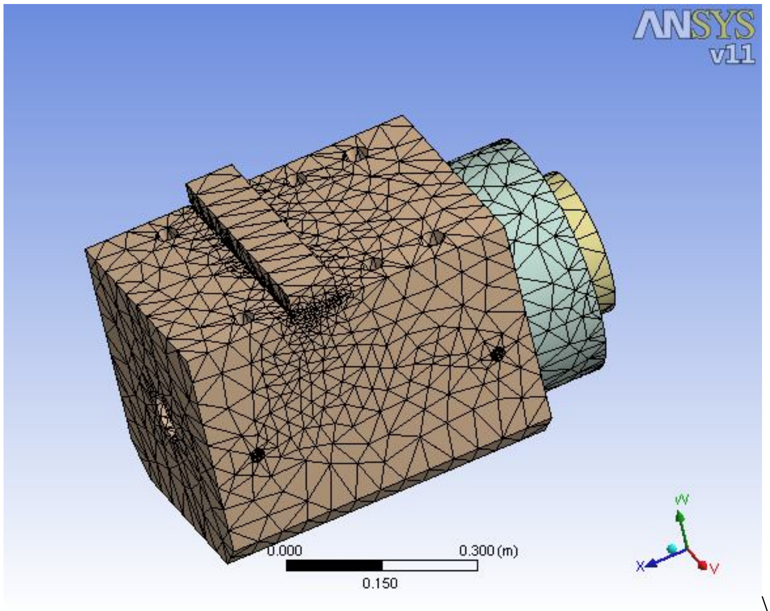
Mesh



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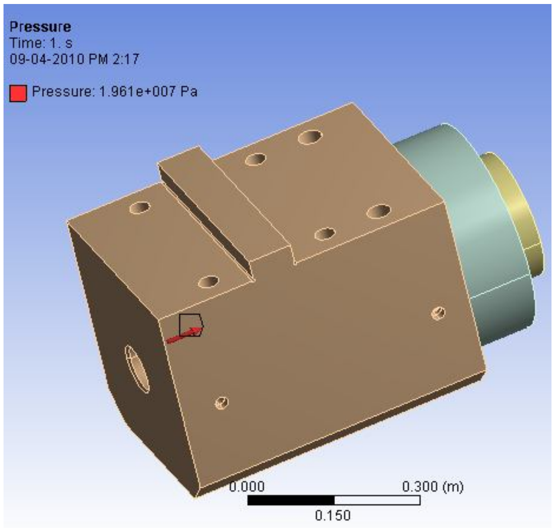
The Geometry is meshed using mesh tool in Ansys workbench.

Object	*Mesh*
Element Type	4 node Triangular
Statistics	
Nodes	59075
Elements	33543

Pressure



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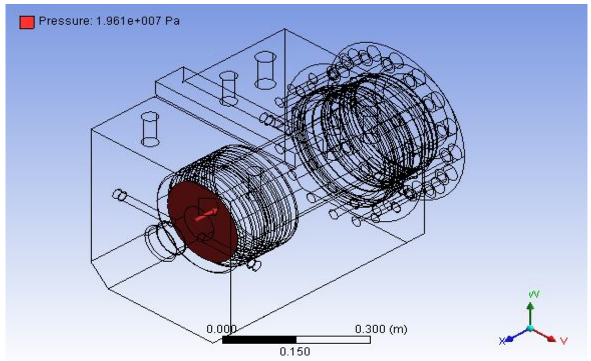
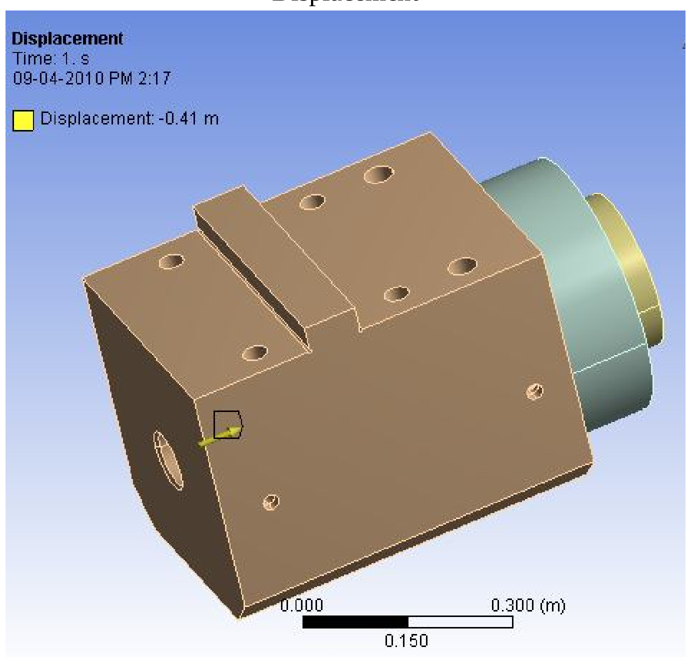
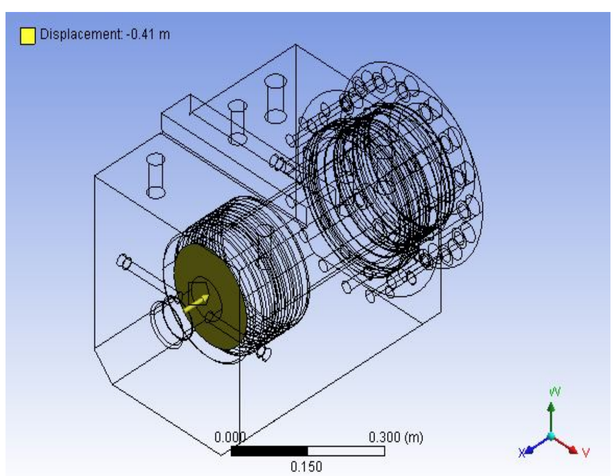


Working pressure about 19.61Mpa (200 kg/cm^2) in Z-direction on piston face.

Displacement





Displacement of 410mm (0.41m) is applied on piston face in Z-direction.

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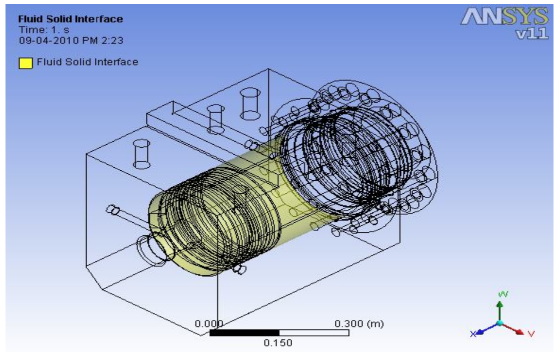
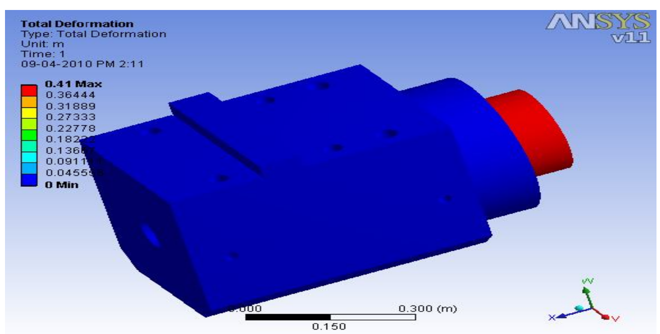
Fluid Solid Interface



he above figure shows the contact between the fluid and components of Geometry when the fluid is supplied to the cylinder at a pressure o 19.61Mpa (200 kg/cm^2).
After the pressure is applied on the following analyses were carried on the geometry by taking the cylinder face as fixed support. B.

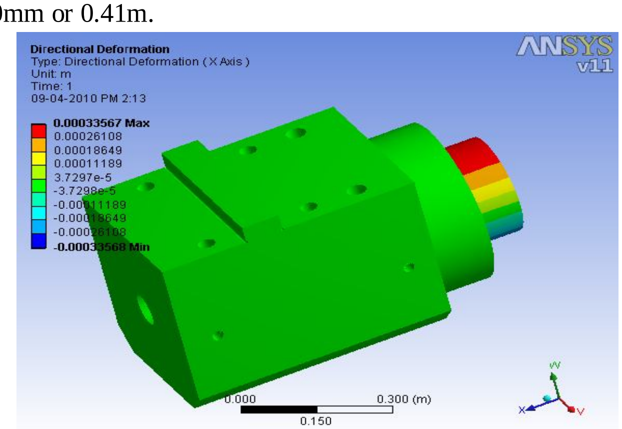
B. The different analyses are

1) Total Deformation
2) Directional Deformation
3) Equivalent Stress (Von-Mises Stress)
4) Equivalent Strain (Von-Mises Strain).
5) Safety Factor.



Total Deformation

Total Deformation is carried to show the movement of piston through the cylinder when pressure is applied.
Length of the Stroke of Piston is 410mm or 0.41m.



Directional Deformation

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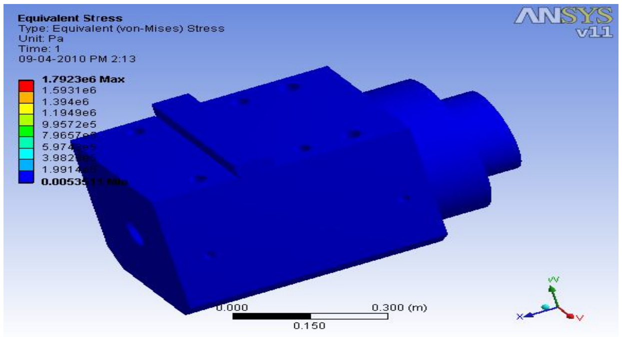
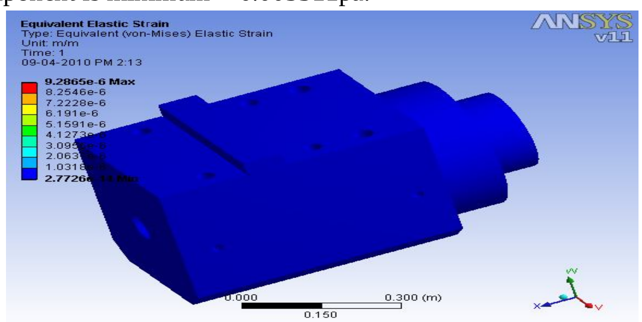
Direction Deformation is analyzed to find out the deformation of geometry in X-direction when pressure is applied.
Deformation of Cylinder and Packing Box =-3.7298x10^{-5} m or -0.0032798x10^{-5}mm.
Deformation of Piston = 0.00033567m or 0.00033567 x 10^{-3}mm.



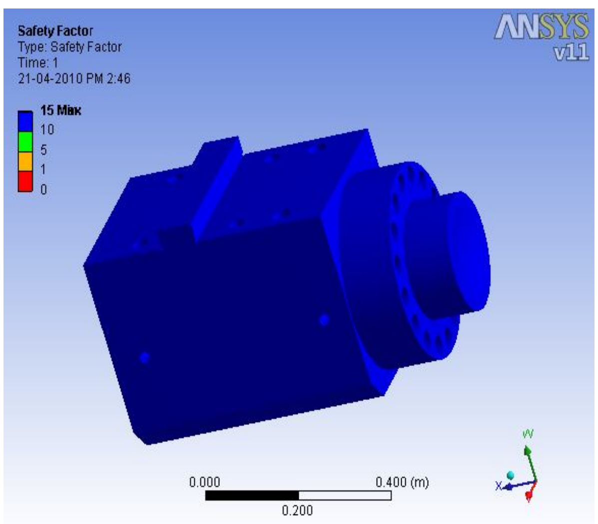
Equivalent Stress

Minimum Equivalent Stress is 0.005311pa.
Maximum Equivalent stress is 1.7923x10^{6}pa.
Equivalent Stress acting on the Component is minimum = 0.005311pa.



Equivalent Elastic Strain

Maximum Equivalent Strain is 9.2865x10^{-6}.
Minimum Equivalent Strain is 2.779x10^{-6}
Equivalent Strain acting on the Component is Minimum = 2.779x10^{-6}



Safety Factor

According to the analysis conducted in Ansys for the design:

Maximum factor of safety is 1.5
Minimum occurs on cylinder.

VII. DISCUSSION AND SUGGESTIONS

A. Cylinder tubes with 8f-52 material (suitable for higher pressure up to 300 kg/cm^2) are not available indigenously (occurring naturally in a particular region). These tubes have to be imported and are costly. Thus, as a cost effective design, we have designed the cylinder by casting it locally and thus reducing the cost by at least 35%.

B. Here at the piston end we have used gliding seal for scaling and sliding for sliding motion of the piston in place of piston rings and bronze brushes, piston rings and bronze brushes are costly and these materials are indigenously selected. Piston rings and bronze materials have to be imported, as they are not available in India. Dealers and companies are there in India who manufacture glydrings and slydrings that are less expensive compared to piston rings and bronze brushes. The cost is approximately reduced by 30%.

C. The design of hydraulic cylinder has considered only an overpass. It can be incorporated and developed by considering even the interchanges and also pedestrian conditions.

D. The hydraulic system considered here is only justified for some machines only. Even the system can be developed for every certain period and the design can be changed accordingly. The cylinder design can be updated by incorporating the standard considering the international standards used.

E. Thus, it can be concluded that study of hydraulic cylinder is not limited to a particular area, it can be improved to any extent by developing the knowledge base to the required extent.

VIII. CONCLUSION

Finally at the end of our project report which dealt with the Design of Hydraulic Cylinder manually by using the set of conventional formulae and later the model figures were generated by using Pro-E software and analysis were done by applying the working pressure on component by considering Stainless Steel as material for different aspects on the Hydraulic Cylinder Assembly by using Ansys software. After the analysis safe results were obtained.

This project report also focuses on the Hydraulic System its working and classification and their details such as components of Hydraulic Cylinder and their specification and the application of Hydraulic Cylinder in Special Purpose Machines like Presses and Press brake.

A. VALUES OF COMMON HYDRAULIC FLUIDS

Properties	Petroleum Oil	Oil Emulsion	Water Glycol Synthetic Fluid	Straight Synthetic
Specific Gravity	0.876	0.948	1.073	1.148
Kinematic Viscosity @ 37.8^{o}c @ 54.4^{o}c	48.5 -	107.5 67	41/45.2 26	47 -
Viscosity Index	100	143	160	-

B. Technical Data of Packing Seals

Type	Code no.	O-Ring Material	Operating Pressure (Mpa)	Operating Temperature (^{0}c)	Mating Material Surface	Size Range of Piston Diameter (mm)	Standard No.

Glyd Ring	T46NA	Turcite NBR-70 Shore A	Up to 80Mpa	-45^{0}c to 200^{0}c	Steel, Hardened steel, Chrome Plated Cast Iron.	250	ISO 7425/2
Glyd Ring	T46	Turcon NBR-70 Shore A	Up to 60Mpa	-30^{0}c to 100^{0}c	Steel, Hardened Steel,	200	ISO 7250
Slyd Ring	T47	Zurcon, Turcite	Up to 50Mpa	-30^0 to 150 ^{0}c	Hard Chromed Steel, Cast Iron	420	ISO 10766
Slyd Ring	C380	Luytex	Up to 50Mpa	-35^{0}c to 150^{0}c	Stainless steel, Hard Chromed CI, Steel	150	ISO 10766
Step seal	S270	Zurcon	Up to 80Mpa	-45^{0}cto200 ^{0}c	Cast Iron, Mild Steel	270	ISO 80500

C. Technical Data of Wiper or Scraper

Wiper or Scraper	DA17	NBR-90 Shore A	Speed Up to 5m/s	-30^{0}c to110^{0}c	Standard Material	250	ISO 1700

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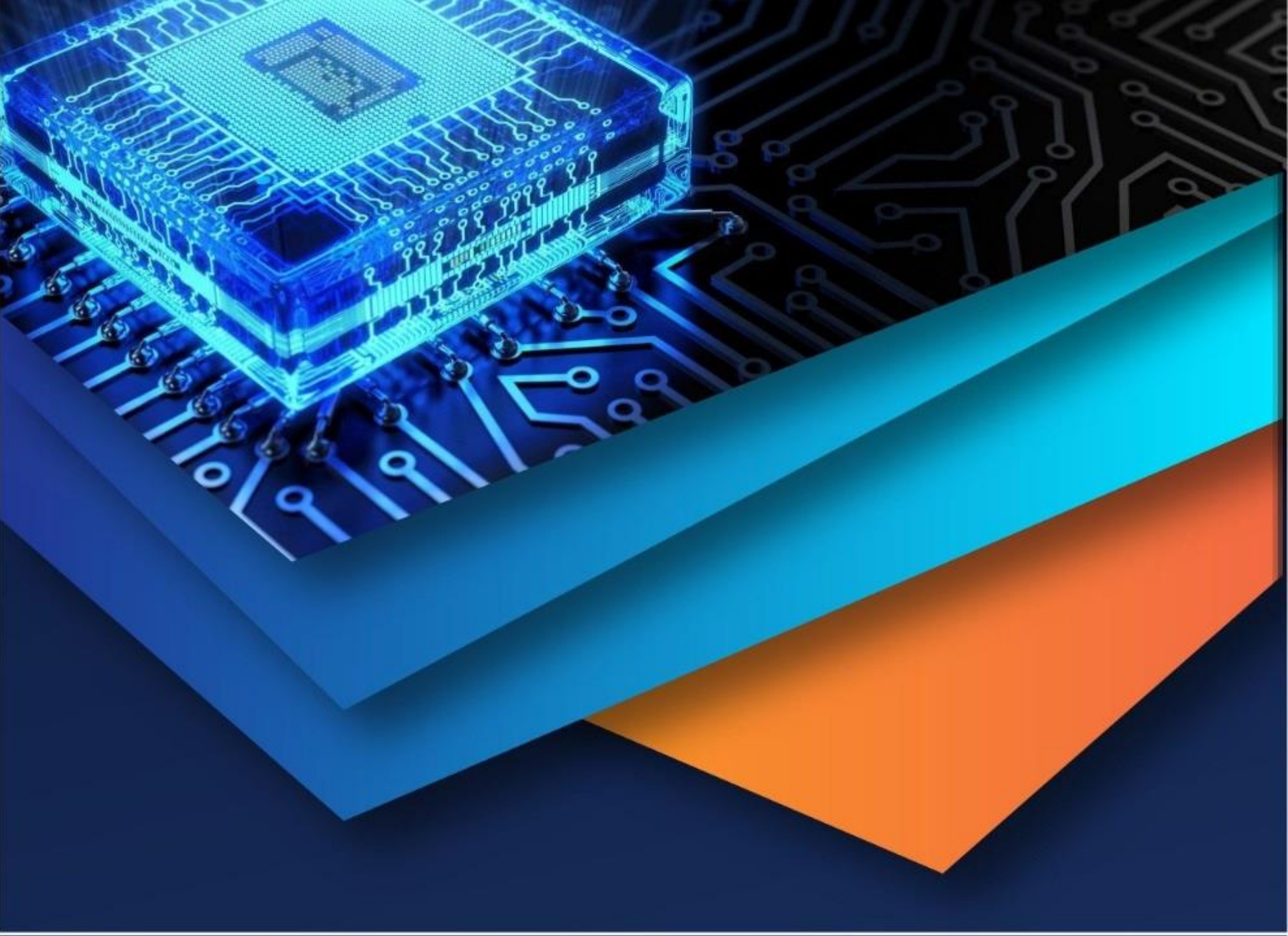
[8] Catalogue of Shane Bond Company
[9] Catalogue of Bosch Rexorth Company
[10] Catalogue of Polyhydron Company



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IMPACT FACTOR: 7.129

IMPACT FACTOR: 7.429