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Design and Analysis of Hydraulic Arm with Gripper

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Abstract: In many fields, material handling is a major part of any process such as in industries for raw-material handling, and unloading of work-pieces, packaging and in household purpose etc. Material handling can be defined as transfer of material (such as components, bags, tools, work-pieces, assembly, etc) from one workstation to another or from a workstation to dispatch store. Manual material handling is limited as the load carrying capacity of a human is generally very small. Also fatigue and non-repeatability of a human are a limitation. Different material handling equipments are used in industries and workshops. Some of these are Electrical Over Travel (EOT) Cranes, Automated Guided Vehicles (AGV), Automated Storage and Retrieval System (ASRS), Palletizers, Side loaders, Fork-lifts, etc. However, these instruments are generally large in size and have limited application and/or travel. Hydraulic drive has an advantage over electric drive mechanism when power consumption and load capacity is considered. The aim of the project is to design a hydraulic arm with gripper that can be used for the purpose of material handling in various fields and be economical, flexible and easy to operate. The main objectives of the project are: (1) To select a suitable configuration of links for the equipment. (2) To design and analyze the links based on load considerations. (3) Make the system mobile so that work volume can be increased. (4) Reduce power consumption.
Keywords: Material Handling, Articulated Arm, Hydraulic drive, Gripper, Mobility

I. INTRODUCTION

As discussed, material handling is a crucial part of any industry. It accounts for 20-25% of total manufacturing cost. Conventional material handling equipments are generally used in large scale industries and often have a limitation travel/work-space. Such as the EOT crane has a limited travel in 3 directions. It can access a point within its cuboidal range set by it transverse and horizontal travel. Also some equipments prove uneconomical for small scale industries or workshops. The driving mechanism of these drives is generally electric or hydraulic. The electric drive has a limitation that continuous power is required to hold the component and has a limited load capacity. Contradictorily, hydraulic drive does not need continuous power for gripping and can take heavy loads easily. Using hydraulic circuits and a specific configuration of the system, the objective of material handling can be achieved. The system is made mobile by provision of wheels and a steering mechanism so that the work volume can be increased without any limitation, except some highly inaccessible areas from where the end effector cannot pass. The design of gripper (end effector) is also crucial so that various shapes and sizes of components can be lifted. A platform is provided so that the component can be kept on it and power consumption can be reduced. The basic aim behind the project is to develop a system that can become a solution for material handling in small industries and at the same time be economical, flexible and easy to operate.

II. LITERATURE REVIEW

1) *Robot Arm and Wrist Assembly (US06448217)[1]:* In 1982, William J. Langer designed a robotic arm and wrist assembly. It uses a forearm assembly that provides motion in three mutually perpendicular intersecting axes with rotation of axis of forearm. It includes mountings that permit low load on arm. The invention uses hydraulic system and rotary actuators for the wrist assembly. It includes mountings that permit low load on the arm and actuators. The movement of arm is achieved by using hydraulic power which actuates a double acting actuator which upon extension or retraction provides movement about a pivot point. To effect the rotation of the platform, a hydraulic motor is directly coupled to the platform. The major difficulties of excess load on arm and limited motion are overcome by use of flexure plates and tubular sections. The robotic arm is used for handling of tools and small equipments. It uses sensors, feedback loops, various hydraulic actuators and control valves that provide flexibility of operation.
2) *Compound Toggle Robotic Gripper (US06888145)[2]:* In 1986, Nihad Hamed and Hazem Hamed, developed a robotic gripper with toggle mechanism. The links are so designed that when actuator is powered, the jaws are in locking position so that if there

is a sudden loss of hydraulic-pressure, the jaws would still be in locked position and hence secure the work-piece. The gripper consists of two equally spaced jaws, one or both moving depending upon the design, and used as an end effector at the end of the arm. The gripper as discussed uses a compound hydraulic actuator and toggle mechanisms for opening or closing of the jaws of the gripper. The toggle links are connected to the linear actuator and other end is connected or forged into gripping jaws. When hydraulic power is supplied to the actuator, the extension or retraction of rod toggles the mechanism. The linkages force the jaws to open or close based on direction of motion of linear actuator rod.

3) *Stäubli RS20 Robotic Arm[3],[4]:* In Johanson Technology, a company that manufactures capacitors, the capacitor wafers which are very delicate and small in size are required to be packaged from conveyor. Stäubli suggested a robotic arm for this purpose: Very compact 4-axis robot having a maximum load capacity of 1 kg, height range: 21-25 in , radial distance: 88-220 mm, and a vacuum type end effector.

III. PROPOSED MODEL

We selected articulated arm configuration for the assembly, additionally we provided an L(linear) and an O(orthogonal) type joint so that the degrees of freedom can be increased. L type joint is provided by four vertical bars and the table sliding along it. The table is actuated by hydraulic actuator(not shown in figure). O type joint is provided by sliding of the cross slide on which the arm is mounted. The links are operated by action of hydraulic actuators as shown. The end effector consist of gripper which is used for purpose of holding. The entire manipulator assembly is mounted on wheels and steering mechanism is provided. Platform is provided so during idle time there is no power consumption.

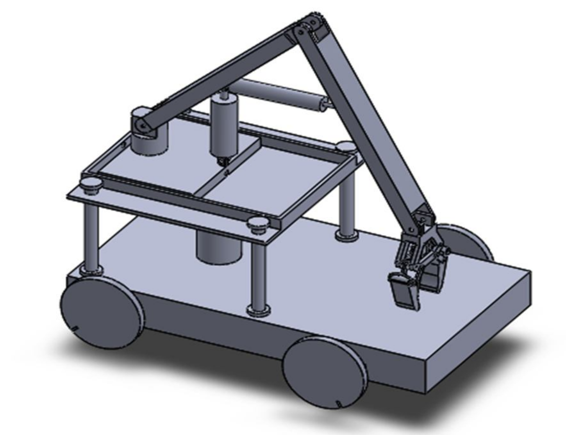

Fig. 1 Proposed 3D Model of the Assembly

A. *Assumptions*

1) The material used for the entire assembly is Structural Steel (E250)[5] with following properties:
   Density = 7850 kg/m^3
   Yield Strength s = 250 MPa
   Ultimate Strength = 460 MPa
   Poisson’s Ratio = 0.3
   Young’s Modulus = 200 GPa
   Bulk Modulus = 167.67 GPa
2) The material is assumed to be homogeneous and the stress induced is assumed to be within Hooke's limit. The bending that occurs due to load is assumed to be pure bending.
3) The dimensions of sections and columns, power, and torque required are calculated based on a load carrying capacity of 100 kg (approximately W=1000 N).
4) Length of both arm links is 500 mm.
5) The factor of safety is assumed to be 3-4.
6) *Analysis Approach:* The arm links work as a lever. Using the moment balance principle, the balancing force was found. In the analysis of the link, the junction where the cylinder rod supports the arm is considered to be fixed. Based on forces acting at the end of arm link, the stresses induced in it are found using FEA software ANSYS.

B. Calculations

From calculations, best location for hinge point is a:a' =1:1, b:b' = 1:2 for link-1 and a":a"'=1:0 for link-2 for which pressure requirement is minimum. The pressure range obtained is 9-40 bar.

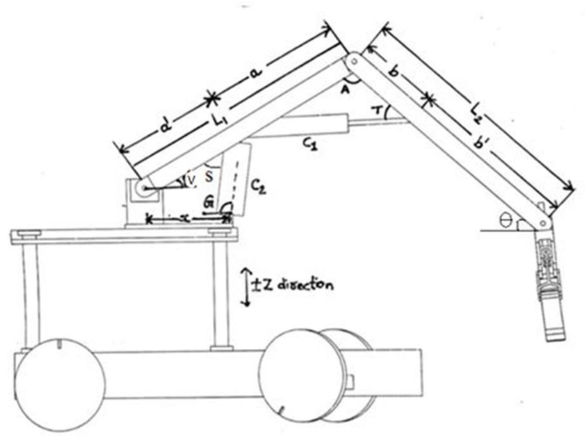

Fig. 2 Designation of angles and location of hinge points

1) *Section Determination:* Bending moment M = Wb'cosθ and section modulus Z= (M/s)

For maximum bending moment, cosθ =1 and W = 1000 N, b' =333.333 mm.

From that z = 1333.332 mm^3 =1.333 cm^3

From standards of Jindal steel, the dimensions of C section are as : MC75 Indian channel Jindal steel[6]

(Total width=75 mm , Flange width=40mm,Thickness of web=4.8mm,Thickness of flange=7.5mm ,Z_{yy}=4.81cm^3, A=9.1cm^2 , Weight=7.14 kg/m)

$Z_{available}$ is 4.81 cm^3 and $Z_{require}$ is 1.333 cm^3. So, factor of safety = 3.6

2) *Determination of Column Dimensions:* By considering weight to be lifted, dimensions of links and two angles, we found out moment applied on column. We consider column as cantilever beam and moment is applied on free end and by knowing allowable stress of material (s_{all}=62.5 MPa) and factor of safety(FOS=4) required we obtained section modulus required by following bending equation:

M_b=933079 Nmm

$Z = \frac{M_b}{\sigma_{all}}$ $\quad$ $\sigma_{all} = \frac{\sigma_{yt}}{FOS}$

And by considering circular section we obtained diameter required for column,

For circular section,

$Z = \frac{\pi}{32} d^3$

We obtained d=33.5mm$\cong 35mm$

3) *Determination of Dimensions of Pin:* All the pins are subjected to double shear. Material of pin: Mild Steel (E250)

Using maximum shear stress theory:

$\sigma_{ys} = 0.5\sigma_{yt}$= 125 MPa

Taking factor of safety, FOS=4

$\sigma_{all} = 31.25\, MPa$

Now for double shear;

For pin at grabber, F=1000N

$$\sigma_{all} = \frac{F}{2\left(\frac{\pi}{4}d^2\right)}$$

Solving this we get d=4.513 $\cong 5mm$

Similarly, for pin at Arms, F=2000N

Solving, we get d=6.38 $\cong 7mm$

Standard bar stock of MS of 10 mm is available that can be used to make pins.

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C. Analysis

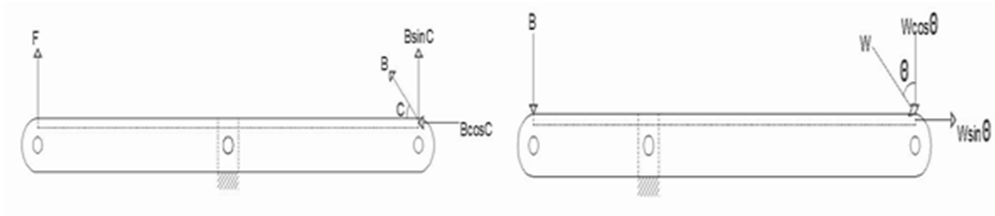


Fig. 3 Resolution of Forces

Angle 'A' between two links can be varied by varying the stroke length of cylinder C_1. 'A' varies from 55 º to 120º and stroke length of cylinder 'C_1' = 16 cm. Angle 'B*' between link-1 and horizontal can be varied by varying stroke of cylinder C_2. 'B*' varies from 30 º to 70 º and stroke length of cylinder 'C_2' = 7 cm.

The value of angle θ is determined by considering the maximum and minimum value of stress induced.

$$F_b = W\cos\theta \qquad F_t = W\sin\theta$$

$$\sigma_b = W\cos\theta\frac{l}{Z} \qquad \sigma_t = \frac{W\sin\theta}{A}$$

$$\sigma = \frac{W\sin\theta}{A} + W\cos\theta\frac{l}{Z}$$

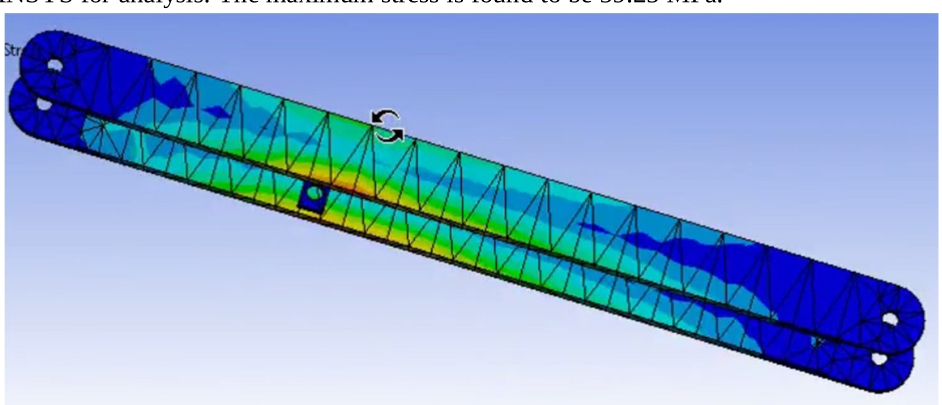
By differentiating above equation, we get maximum stress at 0º and minimum stress at 90º. So, value of θ varies from 0º to 90º.

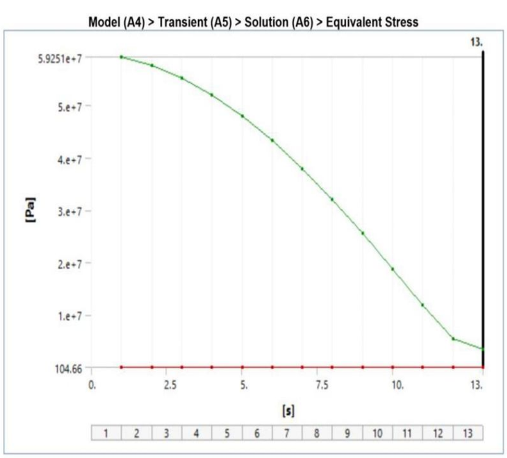
Weight of body to be lifted is W = 1000 N. This weight is resolved in two components,

i) Wcosθ - which is perpendicular to Link-2

ii) Wsinθ - which is along the Link-2

Balancing force 'B' was found using moment balance. It is perpendicular to Link-2. Varying θ we get different value of forces which are entered in ANSYS for analysis. The maximum stress is found to be 59.25 MPa.





Time [s]	Minimum [Pa]	Maximum [Pa]
1.	2171.9	5.9251e+007
2.	2113.4	5.7692e+007
3.	2023.6	5.5275e+007
4.	1904.	5.2038e+007
5.	1756.2	4.8027e+007
6.	1582.6	4.3305e+007
7.	1385.6	3.794e+007
8.	1165.7	3.2015e+007
9.	923.63	2.5614e+007
10.	673.04	1.8836e+007
11.	426.19	1.1984e+007
12.	171.98	5.4553e+006
13.	104.66	3.4291e+006

Fig. 4 Variation of Stress in Link-2

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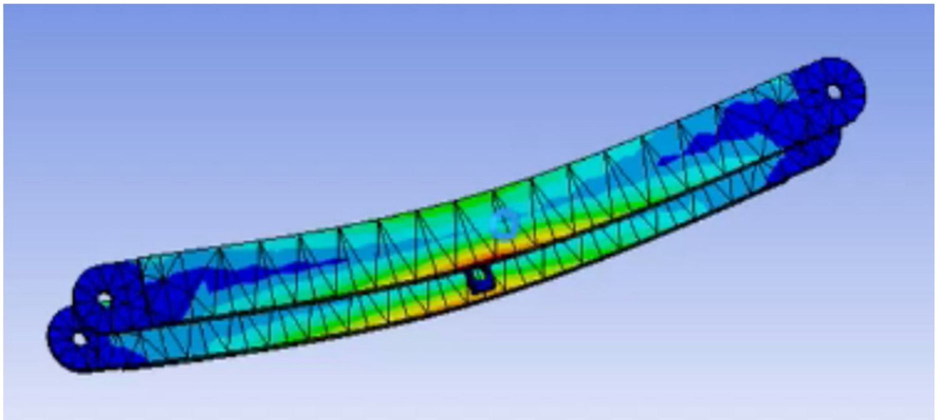
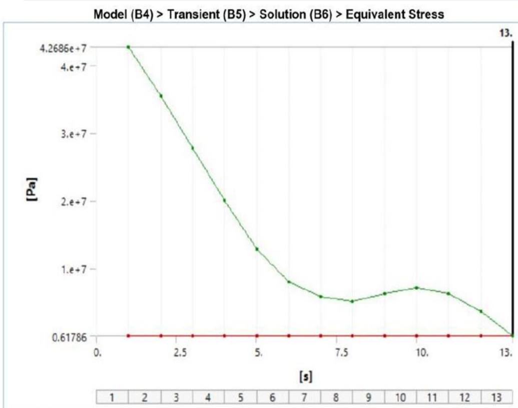
Angle C is angle between the balancing force B and Link-1. Resolving the balancing force B we get,

i) BcosC which is along Link-1

ii) BsinC which is perpendicular to Link-1

Balancing force for this is found out using moment balance. It is perpendicular to Link-1. Varying C we get different value of forces which are entered in ANSYS for analysis. The maximum stress is found to be 42.68 MPa.





Time [s]	Minimum [Pa]	Maximum [Pa]
1.	1564.5	4.2686e+007
2.	1245.7	3.5439e+007
3.	918.02	2.7785e+007
4.	599.57	2.0109e+007
5.	312.45	1.2789e+007
6.	127.59	8.0507e+006
7.	18.552	5.8502e+006
8.	201.19	5.11e+006
9.	223.86	6.2116e+006
10.	179.58	7.1476e+006
11.	126.64	6.2943e+006
12.	68.64	3.655e+006
13.	0.61786	32905

Fig. 5 Variation of Stress in Link-1

The observed stresses are below the allowable yield strength. Thus, the design is safe. We obtain a factor of safety of about 4.2 which is required in material handling equipments.

D. Selection of Motor

We first calculated total weight of mechanism including weight to be lifted in ANSYS and we assumed the weight is concentrated at centre of four guide columns. Based on above stated situation, we obtained reaction force at two front wheels and two rear wheels. Then we took coefficient of friction between road and wheel as 0.4 and found out the tangential force.

We have radius of wheel according to our requirement (100 mm). So based on tangential force and wheel radius we found out starting torque required.

We considered speed of mechanism is 150 rpm we obtained motor power required.

Our Requirements:

Torque:	64 Nm
Speed:	150 rpm
Power:	1 kW

Following are specification of motor we selected:

MY1020Z (600 W, at rated speed 480 rpm with sprocket)[7]

Torque:	65 Nm
Speed:	150 rpm (after reduction)
Power:	1.2 kW

E. Selection of Power-Pack

We design diameter of cylinders based on load to be lifted and maximum pressure in all cylinder is within limit of 45 bar. Based on selected standard cylinders diameter and speed required for actuation we found out total volume flow rate required in mechanism and that was 7.2 lit/min

Based on above mentioned requirement we select power pack of following specification:

BUCHER DC Power Pack (50 bar, 20 lit/min) by Hydrofit [8]
Flow rate: 8 lit/min
Max. Pressure: 45 bar

F. Cost Estimation

Considering the cost of metal, hydraulic actuators, DC motors, power-pack, DCVs, hydraulic pipes, and other miscellaneous components, overall cost of the project can be estimated to be around Rs. 1,20,000. The project is hence economical given that the initial cost is lower as compared to conventional material handling equipments.

IV. CONCLUSIONS

Current material handling system such as EOT, Cranes, Robotic arms, ASRS, etc. have limitations like higher cost, large space and power requirement. Our hydraulic arm combines the high load carrying capacity of hydraulic system in conjunction with a robust mechanism. It has a drive mechanism to reach any space. It also has higher load carrying capacity as compared to servo motor driven robots. They would work with great efficiency at place where precision is not required but load capacity required is higher. Following are the advantages of our project:

A. Increased flexibility of accommodating various shaped components.
B. Reduced power consumption.
C. Mobility
D. Additional degrees of freedom that increase work volume.

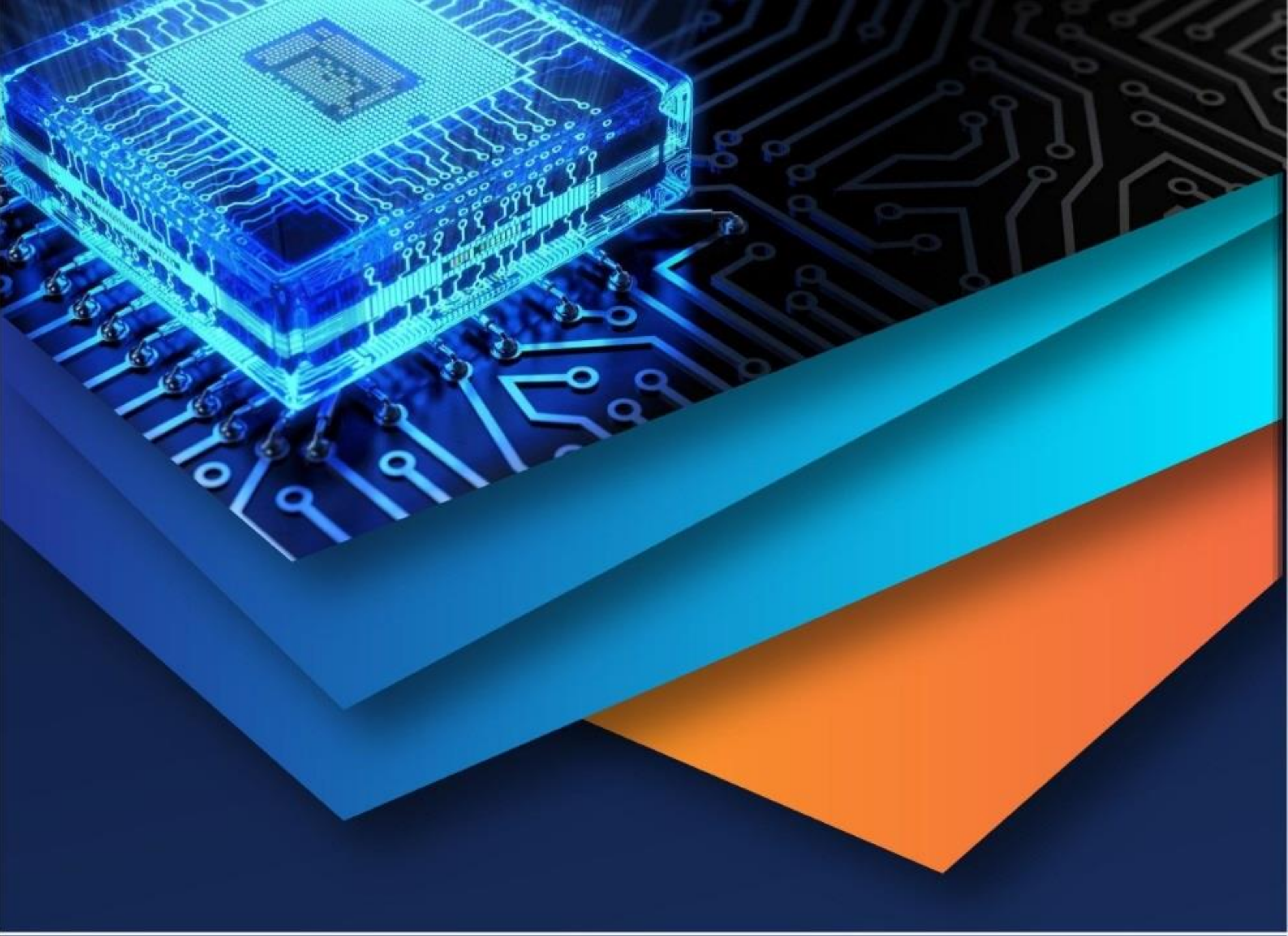
Following are the applications:

1) Can grip or pick things in industrial purpose.
2) In assembly lines of mega factories to assemble various parts of products.
3) In small scale garages, to lift mechanical components (up-to some suitable size).
4) Stacking and reclaiming of materials.
5) To lift goods from lower plane to higher plane

The project thus can be used in industrial sector and prove to be cost-effective in the long run.

REFERENCES

[1] https://patents.google.com/patent/US4496279A/es
[2] https://patents.google.com/patent/US4728137A/en?oq=US06888145
[3] SELECTION OF MATERIAL HANDLING EQUIPMENT FOR FLEXIBLE MANUFACTURING SYSTEM USING FAHP, *International Journal of Recent advances in Mechanical Engineering (IJMECH) Vol.5, No.1, February 2016, Authors: Surinder Kumar and Tilak Raj*
[4] DESIGN AND IMPLEMENTATION OF AN AUTOMATED PICK AND PLACE SYSTEM FOR JOHANSON TECHNOLOGY, INC., *California Polytechnic State University, Author: Alex M Felker*
[5] IS 2062 (Structural Steel)
[6] IS 808:1852 (Jindal steel)
[7] MOTOR OF REQUIRED TORQUE AND RPM.; *Website: www.robu.in (Model Number: MY1020Z*
[8] HYDROFIT; *Model Number: BUCHER DC Power Pack*



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