iJRASET
International Journal For Research in
Applied Science and Engineering Technology

# INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

**Volume:** 11 **Issue:** XII **Month of publication:** December 2023

**DOI:** https://doi.org/10.22214/ijraset.2023.57501

# Design and Analysis of a Pick and Place Robotic Arm

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***Abstract: This paper focuses on the design and analysis of the basic robotic arm for pick and place operation which eliminates the usage of the shop floor area unlike other robotic arms. In industrial sector moving an object from one place to another is done multiple times in the production line as it has to go under several operations to reach to its final stage. Pick and Place robots are the most common robots in the industrial sector. This robot helps to pick an object and place it on the specified location directed by the operator. What are the advantages of a pick and place robot, and where it is applicable? The stress and strain developed in the robotic arm under the applied load. The displacement of the robotic arm is displayed with the maximum displacement position of the arm. Autodesk Fusion 360 tool is used to design the robotic arm and simulate the stress and displacement analysis.***
***Keywords: Area of reach, Link, Gripper, Degrees of freedom, End effector, Factor of Safety (FoS).***

## I. INTRODUCTION

The earliest robots as we probably are aware them were made in the mid 1950s by George C. Devol, a creator from Louisville, Kentucky. From Universal Automation, he developed and patented the reprogrammable manipulator known as "Unimate".
Engleberger obtained Devol's robot patent in the latter half of the 1960s. He had the option to transform it into a modern robot. Engleberger is referred to as "the Father of Robotics" in the industry for his efforts and accomplishments[1].
In the modern days the development of the science is gone far than expected. The world is achieving its goals and completing its task fast and with good accuracy. In order to do this, we need special equipment, here the scientists came up with the machine called robot. Robot is a machine that is capable to do everything that a human can do but in a fastest and safest way. Robots are designed as per their requirement. Robots are built with some input programme. Robots perform the task based on the programme designed to do the work. Robots are built to reduce the human efforts and to save the cost of labour. Robots can perform multiple tasks. Pick and Place robots are the most common robots in the industrial sector. Robots are used to perform unsafe, hazardous, and highly repetitive tasks. Robots can be controlled either by remote or software programme. Robotics is the interdisciplinary subject which includes mechanics, electronics, electricals, computer science.
Laws of a robotic arm:
There are three basic laws of Asimov that a robot should follow.
First law: “A robot may not injure a human being or, through inaction, allow a human being to come to harm.”
Second law: “A robot must obey orders given to it by human beings, except where such orders would conflict with the first law.”
Third law: “A robot must protect its own existence as long as such protection does not conflict with the first or second law.”[2].

## II. APPLICATIONS

*A. The area of usage of the robots has spread widely in this technical world. The pick and place robot are used in*

1) *Assembly line:* The pick and place robots are used in the assembly line to pick the object from its location and place it on the conveyor to undergo the assembly process.
2) *Packaging:* The pick and place robots are used in packing line to collect the objects from the assembly line or conveyor and place them into the packing box and send them to final packaging.
3) *Bin picking:* Bin picking process is picking the object from the bin which are arranged in a chaotic manner and place them in the desired location.
4) *Inspection:* Pick and Place robots are equipped with the cameras for visual inspection of the part. The object is inspected for any damages or any manufacturing defects.

### B. Different types of robots depending on their applications

1) Tele Robots: These are used where the robots can fill in the human position to do the work in the hazardous environment, nuclear power plants, and other dangerous situations. These are controlled by the human operator at a distance.
2) *Agricultural Robots:* These are potentially used for planting seeds, gathering reap. Some robots are put in the experimental field for picking apples straight from the trees.
3) *Industrial Robots:* These robots are utilized where a job involves high repetitive task, good accuracy and reliability. These robots are becoming a great substitute for the humans in the industries.
4) *Mobile Robots:* These are generally known as Automated guided vehicles (AGV's). These are just used to transport the materials from one location to another location.
5) *Service Robots:* These are used for the personal use and professional jobs outside the industrial sectors

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## III. LITERATURE REVIEW

Jain, R., Nayab Zafar, M., & Mohanta, J. C. (2019) [3]. One amazing building science that works with the planning, modelling, analysing, and application of robotics is robots. Robots are employed in daily life everywhere these days. Many different sectors and production processes employ a wide variety of robots. In manufacturing processes like arc-welding, spray painting, cutting, polishing, milling, drilling, assembly, pick and place, packing, palletizing, product inspection, and testing, robots are employed to provide the motion needed.

Mourya, R., Shelke, A., Satpute, S., Kakade, S., & Botre, M. (2015) [4]. Modern robots, because of their extraordinary speed, accuracy and cost-adequacy in dull assignments, presently will generally be involved rather than manual laborers in computerized creation lines. These strong machines are not really independent, as in they require fundamental activities, for example, alignment and direction arranging to accomplish characterized undertakings. In the field of modern advanced mechanics, the connection among man and machine commonly comprises of programming and keeping up with the machine by the human administrator.

Lozano-Perez, T., Jones, J. L., Mazer, E., & O'Donnell, P. A. (1989) [5]. Task-level robot framework is one that can be told as far as undertaking level objectives, for example, "Handle section A and place it inside box B." This sort of detail stands out strongly from that is expected for existing modern robot frameworks, which demand a total determination of each movement of the robot and not just a depiction of an ideal objective. A significant quality of errand level details is that they are free of the robot playing out the undertaking, while a movement particular is married to a particular robot.

Farman, M., Al-Shaibah, M., Aoraiath, Z., & Jarrar, F. (2018) [6]. Utilizing robots over human work to perform exact and precise work is turning out to be more ideal, because of its better exhibition and negligible risks. An explained mechanical arm comprises of connections that interface a specific number of rotating joints in series to an end effector. The quantity of joints addresses the quantity of Levels of Opportunity or degrees of freedom (DOF) of the automated arm. The joints are normally activated utilizing servomotors, which give the vital force to turn the joints. Microcontrollers are utilized to convey the electrical messages expected for controlling the rakish movement of the servomotor shafts.

Humbert, G., Pham, M. T., Brun, X., Guillemot, M., & Noterman, D. (2015) [7]. A simple sort or queue in one direction is sufficient when using a single robot. The use of multiple robots necessitates more complex algorithms than a queue. The point is to estimate the quantity of robots concerning the quantity of items, boxes and transports. Optimization algorithms could be used to accomplish this. Research works connected with advancement calculations utilized in this mechanical application are various

Blanes, C., Mellado, M., Ortiz, C., & Valera, A. (2011) [8]. One of the requirements of any manufacturing automation is the ability to handle objects. Beneficial automated P&P offices should have low process durations per item. The gripper attributes, the robot highlights and the office format configuration, should be generally considered to get a sufficient way to deal with the plan of any control process. All the components that impact the plan of a mechanical control cell, which are the stages and the elements that should be enhanced to accomplish lower cycle times In P&P activities, grippers should have quick grasp activities with speedy and short developments, including quick tasks to get a handle on the item in a steady manner, and should work with the delivering effort to put the item. Products can be transported, gripped, and oriented by robots with an adequate end-effector (up to six DOFs).

## IV. METHODOLOGY AND MATERIALS

### A. Design

The overhead conveyor robotic arm design is made for the study of stress and displacement analysis under different materials. This design contains the robotic arm with the arm facing towards the ground. The general pick and place robots are placed on the ground.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 11 Issue XII Dec 2023- Available at www.ijraset.com

This consumes a space on the shop floor, to eliminate this problem we came up with an idea of placing the robotic arm on the overhead conveyor. This model consists of 6 degrees of freedom (DOF). The model contains a base, rotating base, flanges, links, supporting shafts, and the grippers. This design is modelled using Computer Aided Design (CAD) software Autodesk Fusion 360.
The following figure 1 illustrates the different components and their relative motions which helps to perform the assigned task of a robotic arm. Each component is responsible for completion of the task. Each component or a link has its own degrees of freedom (DOF) that represents the free motion of the joint depending on the DOF(s). The number 1 in the above figure is the base that is fixed in all the direction Ux,Uy,Uz, in terms of translation and rotational displacements. This is considered as a “fixed base” in this design. The number 2 in the above figure is representing the cylindrical base. This base is free to rotate about its z-axis in 360$^{o}$. This rotating base has a 1 DOF. The number 3 in the above figure are the flanges that are fixed to the rotating base, this does not have any free movement but these rotate along the rotating base in 360 degrees. These flanges are the L-Shaped bracket, these are used to hold the next link. These flanges can be fixed to the rotating base using bolts (M8X16mm)-4 No’s. The next components in the figure are link 1 that are directly connected to the flanges on the either side as shown in the figure. The links are also given 1 degree of freedom (DOF) which is the rotational movement about the x-axis. There is a supporting structural rod which help the links to move relative to each other and are helpful as the support to reduce the load carriage and the deformation of the links. This link helps in moving the end effector in forward and backward motion. The joint between the flange and the link 1 can be considered as shoulder joint as in human being. Now directly after the first link the link 2 is connected. The degree of freedom for this link is 1 DOF. The purpose of this link is similar to the link 1. The link is indicated with the number 5 in the above figure. This link 2 has a rotational motion about the axis parallel to the x-axis. This link is used to move the end effector in up and down direction. The joint between the link 1 and link 2 is identified as the elbow joint. The end effector is the main component in the pick and place robotic arm to move the object from one location to the other location. End effector has the highest degrees of freedom, it has 3 DOF. The 3 degrees of the freedoms are the rotational motions, they are Flexion/Extension, Adduction/Abduction, and Grasping respectively. Grasping is the action generally performed by the grippers provided at the end of the end effector and the robotic arm as shown in the figure numbered 6 and 7. The 3 rotational motions of the end effector are about respective coordinate axis (i.e., X-axis, Y-axis, Z-axis)

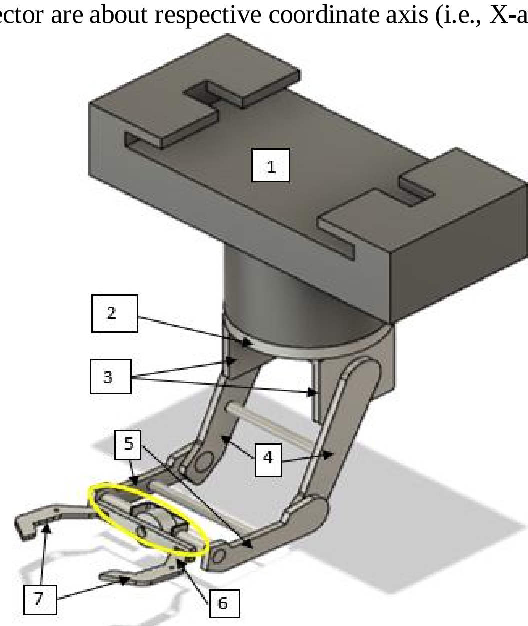

Figure 1. Robotic arm design

*B. Tools Used*

1) Fusion is a cloud-based CAD/CAM system for making products together. Combination instruments empowers client on improvement and emphasis of item thoughts and coordinated effort inside an item improvement group.
2) With its integrated concept-to-production toolset, Fusion 360 makes it simple and quick to explore design concepts. The design, function, and production of goods are the primary focuses of fusion. On utilizing the shape devices client can investigate structure and demonstrating apparatuses to make "completing elements".

3) Fusion 360 also makes it easier to bring together design teams to work on products together. All plans are put away in the cloud, and that implies group head and colleague generally access the most recent information Combination and furthermore tracks variants of the plan work.
4) Autodesk's Fusion 360, which combines CAM, structural design, mechanical simulation, and industrial design, is a design platform that enables cross-platform and cloud-based collaboration and sharing.
5) Fusion360 involves a few working conditions and modules: rendering, simulation, modeling, molding, surface patching, CAM, drawings, and other similar techniques [9].

## C. Materials Used.

In a designing a robotic arm material selection is the important aspect. The selection of the material depends on the properties likes hardness, density, strength, and the amount of maximum load that it has to carry. The material selected for this robotic arm are steel and aluminium 6061 as there are strongest materials. These materials are most commonly used materials in the industrial sectors.

### 1) Stainless Steel

Stainless steel is an iron and chromium alloy. While stainless must contain at least 10.5% chromium, the exact components and ratios will vary based on the grade requested and the intended use of the steel. The below table 1 shows the properties of the steel.

Table 1 Properties of Stainless Steel.

| MATERIAL | PROPERTIES | VALUES |
|---|---|---|
| STAINLESS STEEL | Density | 8.000E-06 kg/mm^3 |
| | Young's Modulus | 193000.00 MPa |
| | Poisson's Ratio | 0.3 |
| | Yield Strength | 250.00 MPa |
| | Ultimate Tensile Strength | 540.00 MPa |
| | Thermal conductivity | 0.016 W/ (mm C) |
| | Thermal Expansion Coefficient | 1.040E-05 /C |
| | Specific Heat | 477.00 J/(Kg C) |

### 2) Aluminum 6061

6061 is commonly used for the following:

- Development of airplane structures, for example, wings and fuselages, more generally in homebuilt airplane than business or military airplane. 2024 compound is to some degree more grounded, however 6061 is all the more effortlessly worked and stays impervious to erosion in any event, when the surface is rubbed.
- Yacht construction, including small utility boats.
- Car parts, like the frame of the Audi A8 and the Plymouth Prowler

The below is the table 2 showing the properties of aluminum 6061 material.

Table 2. Properties of Aluminum 6061

| MATERIAL | PROPERTIES | VALUES |
|---|---|---|
| ALUMINUM 6061 | Density | 2.700E-06 kg/mm^3 |
| | Young's Modulus | 68900.00 MPa |
| | Poisson's Ratio | 0.33 |
| | Yield Strength | 275.00 MPa |
| | Ultimate Tensile Strength | 310.00 MPa |
| | Thermal conductivity | 0.167 W/ (mm C) |
| | Thermal Expansion Coefficient | 2.360E-05 /C |
| | Specific Heat | 897.00 J/(Kg C) |

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
*ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538*
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*3) Cast Iron*

Cast iron is essentially an alloy of iron and carbon with silicon, manganese, sulphur, and phosphorous, all of which have significant effects on the alloy's structure and properties. The eutectic softening temperature for cast iron differs somewhat with silicon content and for the most part falls somewhere in the range of 1135°C and 1150°C. The properties of the cast iron are shown in the Table 3.

Table 3. Properties of Cast iron.

| MATERIAL | PROPERTIES | VALUES |
|---|---|---|
| Cast Iron | Density | 7.150E-06 kg/mm^3 |
| | Young's Modulus | 120000.50 MPa |
| | Poisson's Ratio | 0.30 |
| | Yield Strength | 758.00 MPa |
| | Ultimate Tensile Strength | 884.00 MPa |
| | Thermal conductivity | 0.021 W/ (mm C) |
| | Thermal Expansion Coefficient | 1.200E-05 /C |
| | Specific Heat | 450.00 J/(Kg C) |

## V. RESULTS AND ANALYSIS

The results for the stress and displacement analysis of the pick and place robotic arm when different load conditions are applied are as follows. In every load case same load is applied on the end effector gripper surface on the same point. In this paper we consider a loads of 60N,70N, 80N and 85N.

### *A. Load of 60N*

The stress developed in the robotic arm when a load/force of 60N is applied is shown in the figure 2(a),2(b), and 2(c).

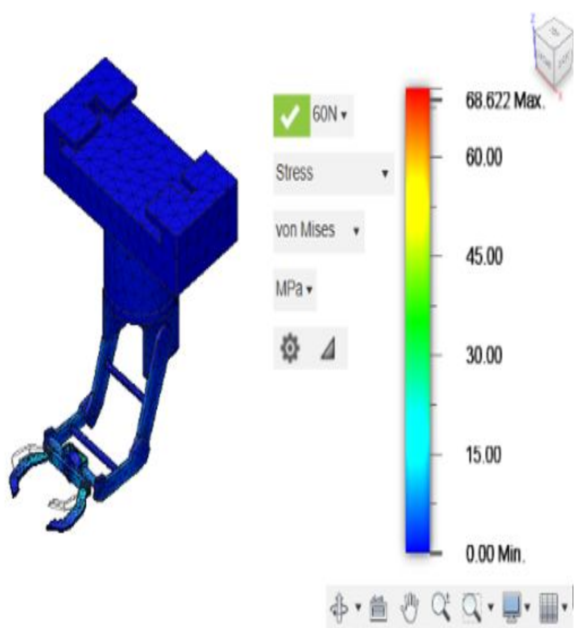


Figure 2(a). Stress in Aluminum 6061 at 60N.

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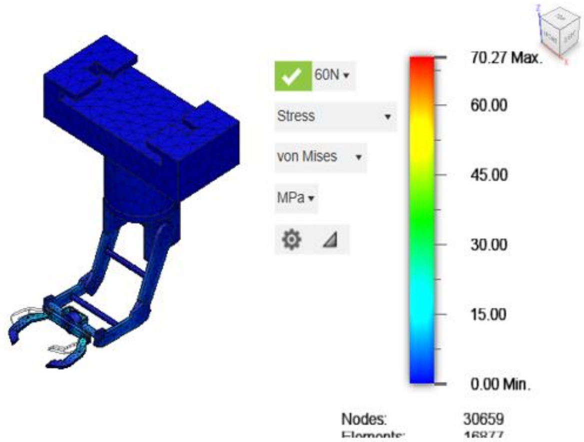


Figure 2(b) Stess in Stainless Steel at 60N.

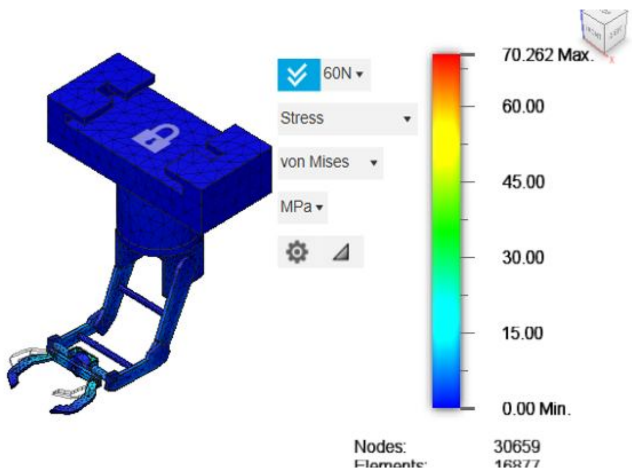


Figure 2(c) Stress in Cast iron at 60N.

*B. Load of 70N*

The stress developed in the robotic arm when a load/force of 70N is applied is shown in the figure 3(a),3(b), and 3(c).

In the second load case, you applied a load of 70N at the same. This allows for understanding the amount of stress increased throughout the model for all three materials

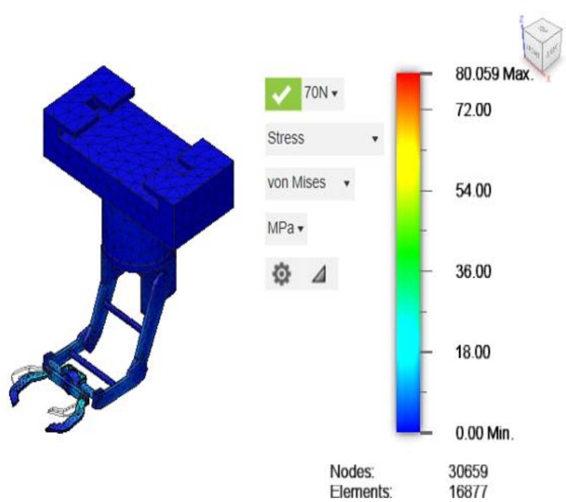


Figure 3(a) Stress in Aluminum 6061 at 70N.

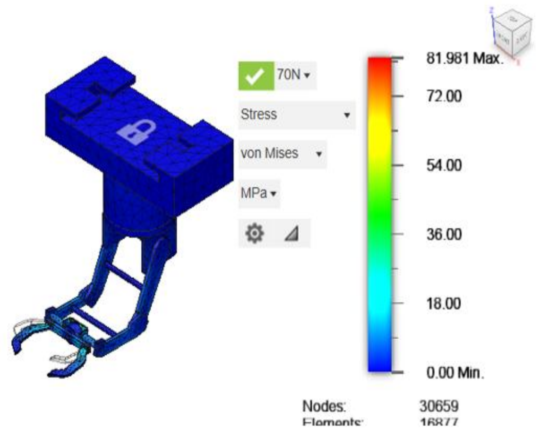


Figure 3(b) Stress in Stainless Steel at 70N.


Figure 3(c) Stress in Cast iron at 70N.

### *C. Load of 80N*

Now, for the load case 3 we apply a force of 80N vertically downwards onto the surface of the gripper. This is the maximum load that this model can carry based on our factor of safety limitation. In this case the factory of safety reaches close to the minimum limit which indicates if we apply more force.

The below figures 4 is the simulation results of the robotic arm at 80N of load on the gripper end.

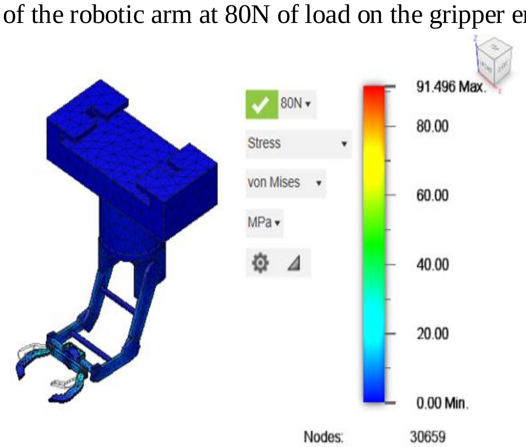


Figure 4 Stress in Aluminum 6061 at 80N.

We observe that this is the maximum stress that the robotic arm can carry when studied under different loads. The robotic arm fails after the load of 80N. The displacement and stress in the robotic arm are shown in the following figure 5 and figure 6 respectively.

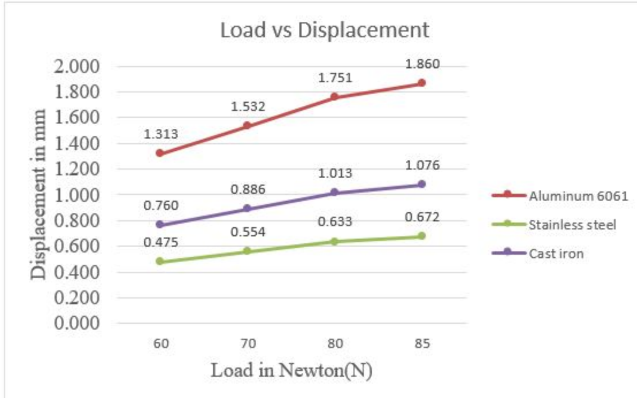


Figure 5. Load vs Displacement graph.

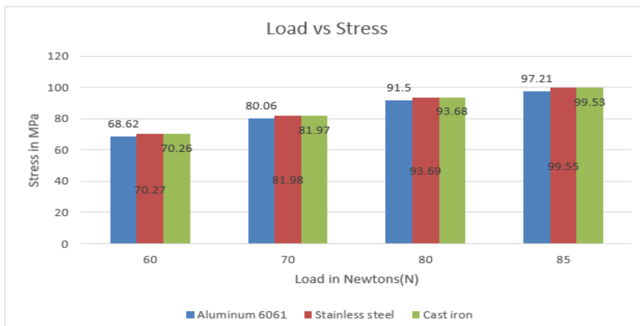


Figure 6 Load vs Stress graph.

## VI. CONCLUSION AND FUTURE SCOPE

This paper centres around the design of a pick and place robotic arm that makes the tasks easy to complete and with a good accuracy. Unlike other pick and place robotic arm this is arranged on the overhead conveyor so that it does not occupy any extra workspace area/ shop floor. This model is designed for only small loads. After applying the different loads (60N, 70N, 80N,85N) on the robotic arm with different materials (Aluminum 6061, Stainless steel, Cast iron). We observed that the stress developed in the stainless steel is more when compared to Aluminum 6061 and Cast iron.

We also observed that the components Stainless steel and Cast iron can fail fastly. From the results we conclude that the Aluminum 6061 is the best option for us to use in terms of stress factor and the cost factor.

This research can be more developed using different materials and different manufacturing processes which can be helpful in cost optimization and better strength.

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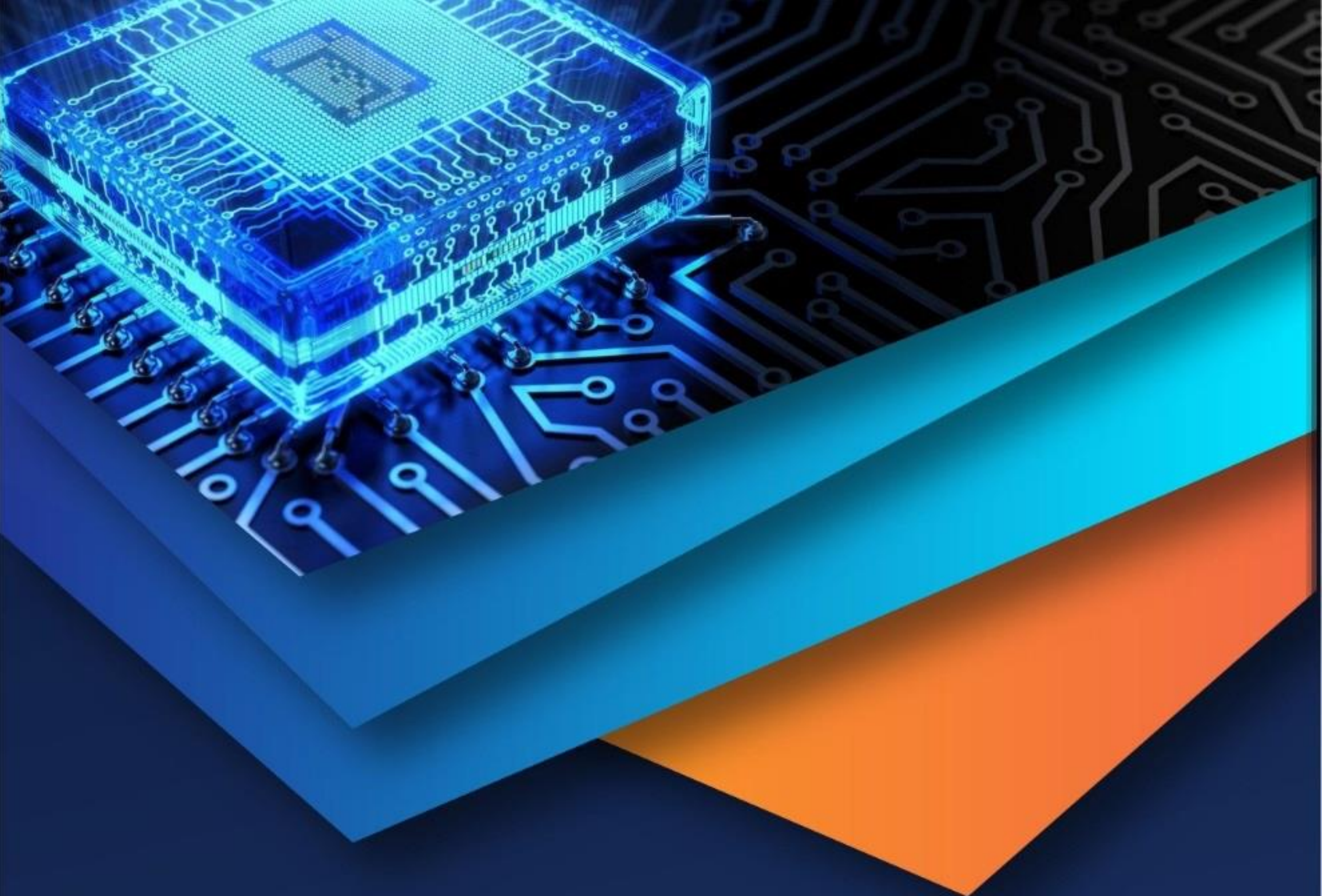

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