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# Design and Static Stress Analysis of Material Handling Tool Pallet/Skid

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***Abstract--In today's industries, material handling system is unitary of the significant system. The primary application of material handling equipment for storage and shipping of the products. Pallets are used mostly in storing heavy and large items in industries across the globe. Reason for using pallet is to ensure safe material handling and storage of the material. Designing is a field of making a part to be sustained in particular condition. Design of Pallet for crankshafts is designed precisely. If Pallet is not properly designed then it will fail to handling and storage. So that Pallet for crankshaft discussed in this work was designed with conventional CAD design practices having hollow rectangular cross section tubes and then analyzed statically with FEA software having gravitational loading of two crankshaft. The analysis was carried out to determine the induced stresses and deflections at various locations on proposed pallet. The pallet was analyzed by comparing different materials. Also by changing dimensions of tubes and by removing some fault in handling 55% weight is reduced and also cost is reduced by 45%.***
***Keywords - Material Handling, Pallet, Static Analysis***

## I. INTRODUCTION

Pallets had a massive impact on logistics, packaging and also on the transportation systems. Pallets have been the basic substantial component of the new strip material handling system since the 1940s. However the new palletization system has been progress in the recent periods but the palletization has relatively an old background. Somewhere about over 100 years. That's what it makes it such a vital part of a transportation chain, particularly from a material handling viewpoint. Pallets are used in different industries for different resolutions. But mostly, the purpose of pallet is in material storage, material handling of heavy parts and transporting cargoes. Pallets are usually made of wood, plastic and metals. A lot of research is being conducted on wood pallet and metal pallets. Basic way to moving unit load is that exercise of lifting devices under the bulk of the payload. Unit loads can be employed for picking up, storing and transporting. Therefore, for these unit load equipment's are used like pallets/skids. Pallets are required elements currently in any industry that handling large quantities of materials that provide themselves for loading. In industry, material handling system is the important part of processing product. Material handling system is the movement of the material or product in a short distance. This treatment occurs in plant or during shipping. Material handling system involves handling, control and storage of material or product.

## II. PROBLEM STATEMENT

Material handling system has several types. One of these is storage and transportation of material or product. For storage and shipping pallets (skids) are applied. Materials used for manufacturing the pallets are wood, plastic and metal. Wood pallets are cheaper than the other types of pallets but they have less life than others. These pallets are lifted by the forklift. This fork lift is designed at particular loading conditions. If the pallets are overloaded than while lifting there is a failure of the pallets and components get damaged. This failure takes place more in wood or plastic pallets. It is aimed to design metallic (M.S.) pallets for crankshafts.

## III. MATERIAL SURVEY

Wood, Polymer and Metals are used for the manufacturing the pallet in industries. Mostly wood is used for manufacturing the pallet due to low cost. Wood pallets were the original pallet material, and remain the most common pallet material. Wood pallets are common because they represent a good balance of the five design parameters Strength, Stiffness, Durability, Functionality, and Purchase Price. Wood pallets are easy to prototype. The most common polymer material for the pallet is Polyvinyl chloride (PVC). The polymer is about 3-6 times the price of wood per Kg. The most common manufacturing process is structural foam molding. General advantages are durable, cleanliness, germ free, weather resistance, and design possible. Metal pallets make up less than 1% of the market. Materials include carbon steel, stainless steel or aluminum. General advantages are strength, stiffness, durability, bug free, no pieces, clean, and recyclable. [10] Metal is used for designing and


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manufacturing the pallet because various factors showing in the table.

Table 1. Material Properties at various factors

| | Metal | Wood | Polymer |
|---|---|---|---|
| Heavy Load | Excellent | Poor | Good |
| Design Flexibility | Excellent | Good | Poor |
| Fire | Excellent | Poor | Good |
| Climate | Excellent | Good | Good |
| Cost | Good | Excellent | Poor |

Materials for metal pallet manufacturers consist of stainless steel, carbon steel and aluminum. Steel has various characters, among them Mild Steel is better for pallet manufacturing. Because,

The cost is less than other steel.
Easily available. High durability.
Manufacturing point of view the tubes of any cross section are readily available.
Easy to weld than other metals.

Mild Steel is used having grade C40 as per the company data, Material properties inputs for pallet design,

Table 2. Material Properties of M.S. C40

| Sr. No. | Material Properties | Values |
|---|---|---|
| 1 | Density | 7800 Kg/m$^3$ |
| 2 | Young's modulus (E) | 210 GPa |
| 3 | Ultimate tensile strength | 550 MPa |
| 4 | Yield tensile strength | 320 MPa |
| 5 | Poisson's ratio | 0.3 |

## IV. DESIGN OF PALLET FOR CRANKSHAFT

The Pallet frame required to support various components has been designed by predictable design procedure. The weights of the components mounted on the frame were considered as loads for designing. According to the crankshaft specification concept model is generated for designing the pallet for crankshaft.

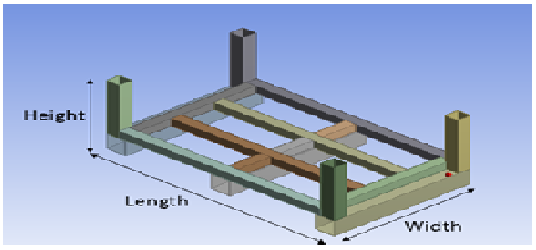


Fig.1 Concept Model


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Design Considerations for pallet for two crankshafts.

Length of the Pallet = 1700 mm

Width of the Pallet = 978 mm

Height of Pallet = 664 mm

Considering above values and on the basis of the size of product to be placed on pallet. Size is taken as 1700 mm × 1000 mm ×700 mm.

Pallet frame is a structural assembly containing of beams of various cross sections and dimensions. The sections used may be of equivalent dimensions and cross sections. The rectangular hallow cross section is selected because of weight consideration, easily available and easy to manufacturing as well as welding.

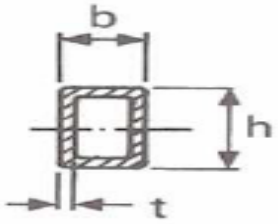


Fig.2 Rectangular Hollow Cross section

Considering the different dimensions of cross-section and doing trail error method following cross-section is selected for a horizontal rectangular hallow tube on which crankshaft has two resting points. By using Strength of material formula, considering simply supporting beam.

$$\frac{M}{I} = \frac{\sigma}{y}$$

Factor of safety = 3

$$\sigma = (M*y)/I$$

$$\sigma_{all} = (\sigma*3)$$

$$y_{max} = \frac{W*a\,(3L^2 - 4a^2)}{24EI}$$

*A. Selection Of The Pallet Columns (Legs)*

The legs of the table will be subjected to the buckling load that is TransForce to them from the beam. We will consider a rectangular hollow cross-section of the beam.

The formula for calculating critical buckling load is,

$$P_{cr} = \frac{\pi^2 EI}{Le^2}$$

The formula for calculating critical buckling load is,

$P_{cr}$ = 4359 KN (For 1 column)

Total weight on one column = 6.375 KN (For 1 column)

From above results column is safe under buckling load because the critical load is greater than the actual load on one column.

*B. Selection Nylon Pads*

To avoid the metal to metal contact nylon pads are used. In this pallet nylon pads are used to avoid the contact between the crankshaft and horizontal tube on which crankshaft is placed.



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Table 3. Nylon Pads at different positions

| Nylon Pads | Diameter (mm) |
|---|---|
| At one end | 111 |
| At middle | 140 |
| At other end | 170 |

### *C. Selection Of Clamp*

For holding the component or for closing the door of pallet toggle clamp is required. Toggle is placed on the front surface of the pallet. In this pallet for closing the door 540 Kg capacity required. The PAH – 331 clamp is selected for this pallet having capacity 150 kg to 3000 kg. [9]

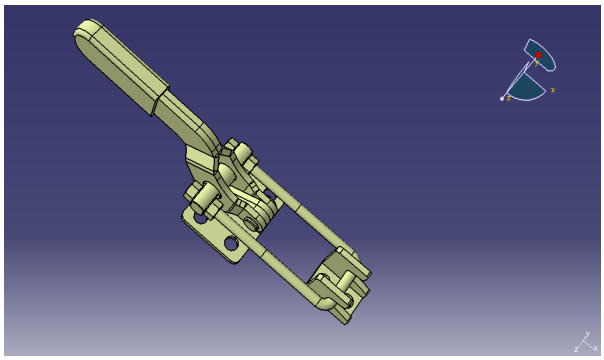

Fig. 3 PAH – 331 clamp [9]

## V. MODELLING

After comparing actual and critical buckling load and selecting the cross section as well as standard parts like nut bolt, clamps and pins as it will provide better stability to the structure of the pallet. Now which all these inputs we are able to model the pallet.

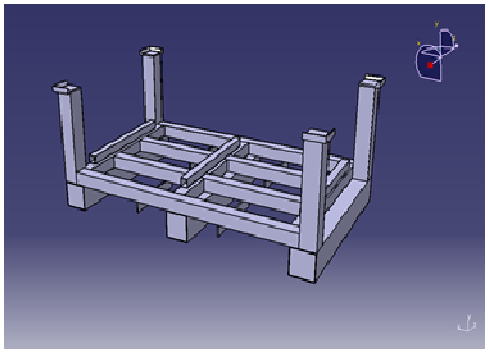

Fig.4 Pallet 3D structure

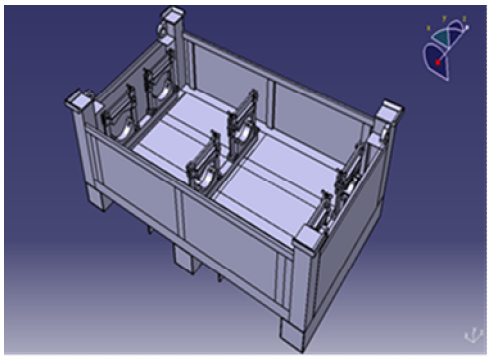

Fig.5 Pallet Assembly for crankshafts

## VI. STATIC STRESS ANALYSIS

After completion of the CAD model of the pallet for crankshaft the static analysis is done. The analysis of pallet is carried out on ANSYS Workbench 12.0. Inputs for static analysis having static load 5400 N, Structure of pallet is uniform and also materials used in the pallet is uniform throughout. A material used in the pallet is M.S. The following table shows the material properties


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Table 4. Mild Steel Properties

| Sr.No. | Properties | Value | Unit |
|---|---|---|---|
| 1 | Density | 7800 | $Kg/m^3$ |
| 2 | Young's Modulus | $210*10^3$ | MPa |
| 3 | Poisson's Ratio | 0.3 | - |
| 4 | Tensile Yield Strength | 320 | MPa |
| 5 | Compressive Yield Strength | 320 | MPa |
| 6 | Ultimate tensile strength | 550 | MPa |

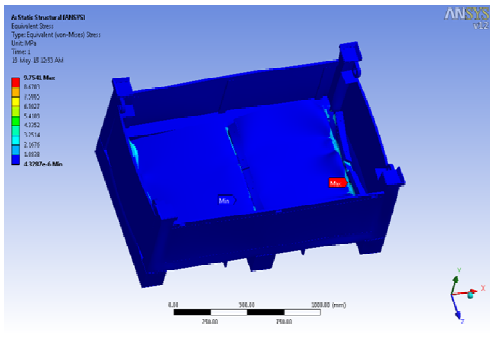

Fig.6 Von-Mises Stress in pallet

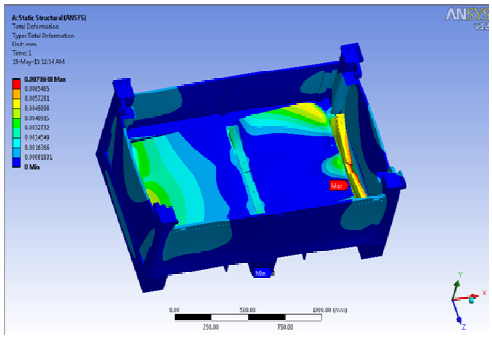

Fig.7 Total Deformation in Pallet

From Figure 6 it is concluded that maximum and minimum stress on pallet structure.

Table 5. Equivalent Stresses in Pallet

| Stress | Part Name | Value |
|---|---|---|
| Maximum Stress | Resting tube | 9.7541 MPa |
| Minimum Stress | Ground tube | $4.3287*10^{-6}$ MPa |

A material used in the pallet have yielded stress 320 MPa and maximum stress is less than yield stress so it implies that design of pallet is safe. Total deformation is maximum at the resting tube 0.0073648 mm which is negligible.

## VII. ANALYSIS OF DIFFERENT MATERIAL AND COMPARISON WITH THE M.S.

Pallet is analysed by different material like PVC and Wood. By using these materials pallet deflection is checked and compering the results with the M.S. material. Giving the material inputs geometry is imported. After that loading conditions and boundary conditions are given.

### *A. Analysis By Using Pvc (Polyvinyl Chloride)*

Static Analysis is carried out at load 5400 N.


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Table 6. PVC Properties [1]

| Sr.No. | Properties | Value | Unit |
|---|---|---|---|
| 1 | Density | $1.42*10^6$ | $Kg/m^3$ |
| 2 | Young's Modulus | 2999.2 | MPa |
| 3 | Poisson's Ratio | 0.4 | - |
| 4 | Tensile Yield Strength | 51.71 | MPa |
| 5 | Compressive Yield Strength | 66.19 | MPa |

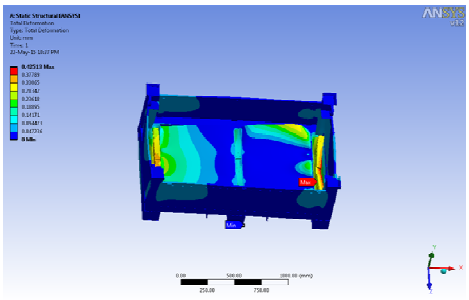

Fig.8 Total Deformation in PVC Pallet

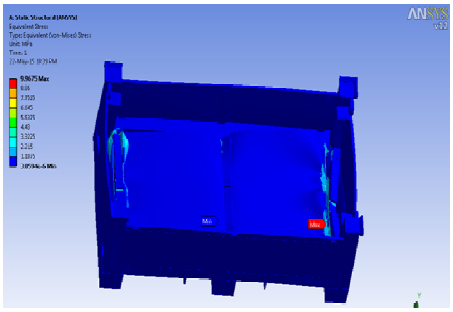

Fig.9 Equivalent Stress in PVC Pallet

*B. Analysis By Using Polyethylene*

Static Analysis is carried out at load 5400 N.

Table 7. Polyethylene Properties [1]

| Sr.No. | Properties | Value | Unit |
|---|---|---|---|
| 1 | Density | 930 | $Kg/m^3$ |
| 2 | Young's Modulus | 1100 | MPa |
| 3 | Poisson's Ratio | 0.4 | - |
| 4 | Tensile Yield Strength | 22.063 | MPa |

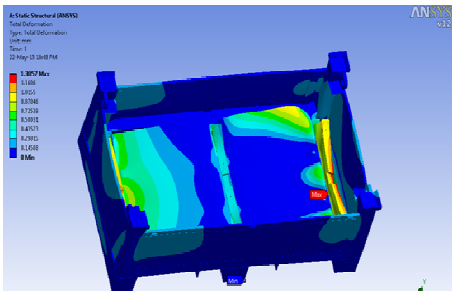

Fig.10 Total Deformation in Polyethylene Pallet

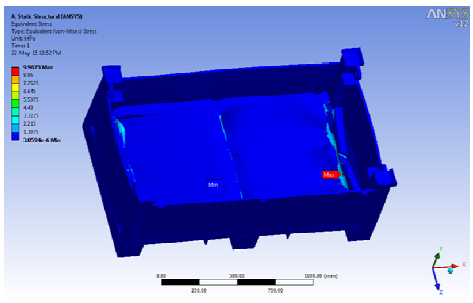

Fig.11 Equivalent Stress in Polyethylene Pallet



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Table 8. Comparison with M.S.

| Materials | Maximum Deformation (mm) | Maximum Stress (MPa) |
|---|---|---|
| M.S. | 0.0073648 | 9.7541 |
| PVC | 0.42513 | 9.9675 |
| Polyethylene | 1.3057 | 9.9675 |

M.S. have minimum deflection than PVC and Polyethylene, M.S. have more durability than Polyethylene and PVC and in cost factor PVC have more cost. So for manufacturing the pallet M.S. is preferred.

## VIII. MANUFACTURING OF PALLET

Pallet have a frame structure includes the rectangular hollow tube. By welding all tube pallet structure is completed. There are many types of welding according to the application. For manufacturing pallet structure welding is used. Nylon pads are manufactured by the water jet cutting operation where the nylon blocks cut into the required dimensions like length, width and radius of nylon pad on which the crankshaft is rested. According to the diameter of crankshaft nylon pads are manufactured.

Fig.12 Pallet Structure

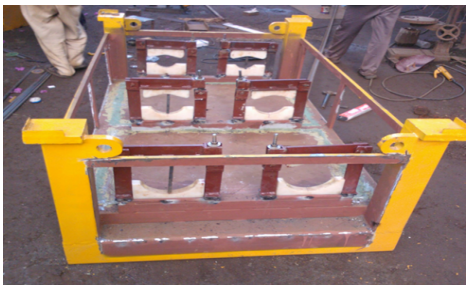

Fig. 13 Pallet Assembly

After completion of nylon pad it is attached to the pivot clamp and pivot clamp attached to the bottom tube. There are six pivot clamps at six resting points of two crankshafts. Following figure shows the complete assembly of pallet.

## IX. WEIGHT REDUCTION OF PALLET

The manufactured pallet is having some problems in loading the crankshaft and for transporting from one place to another due to its heavy weight. So the heavy weight is main problem and it can be reduce by removing the problematic parts and by changing the dimensions of the hollow rectangular tubes where the stresses and deflections are minimum or at negligible value. Existing Pallet have total weight 310 Kg.

### *A. Supporting Column Tubes*

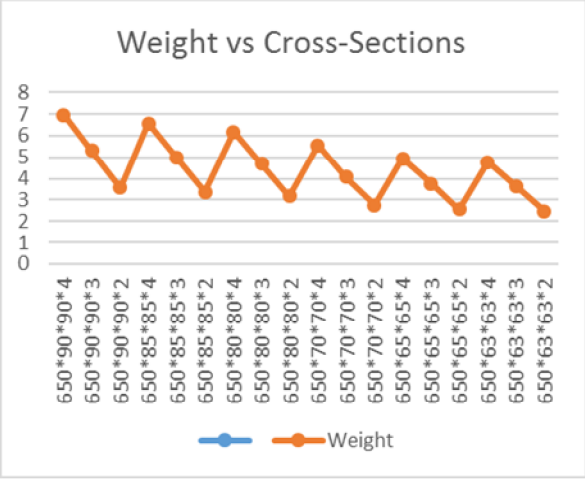


Fig.14 Weights of various cross sections for supporting column tube

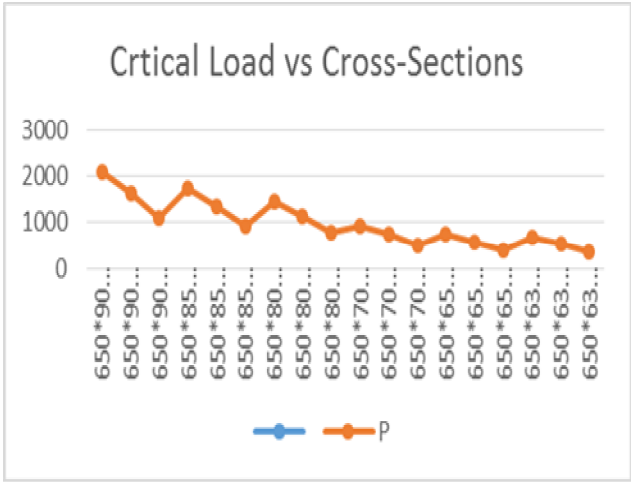


Fig.15 Critical Load at various cross-sections for supporting column tube



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From above results column is safe under buckling load because the critical load is greater than the actual load on one column. So modified column tube for pallet having dimension 63 mm × 63 mm × 2 mm × 650 mm.

*B. Resting Tubes Of Crankshafts*

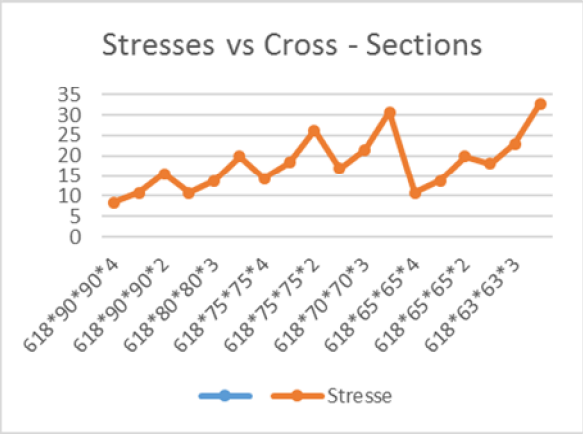


Fig.16 Stresses at various cross-sections for resting tube

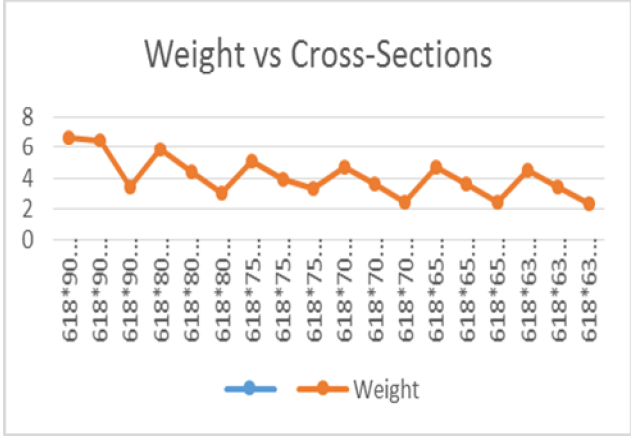


Fig.17 Weights of various cross-sections for resting tube

The allowable stress value is less than the yield stress 320 MPa so design for resting tube is safe. Modified resting tube have dimensions 63 mm × 63 mm × 2 mm × 618 mm.

After modifying the parts and dimensions of the existing pallet. By using these modified dimensions, we are able to model the modified pallet in CATIA.

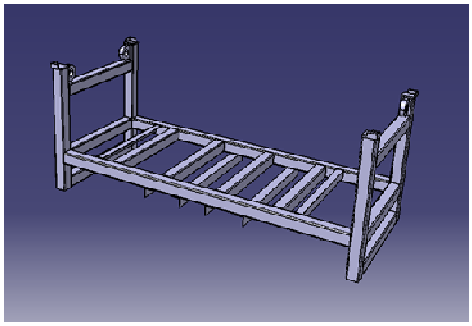

Fig.18 Modified Pallet Structure

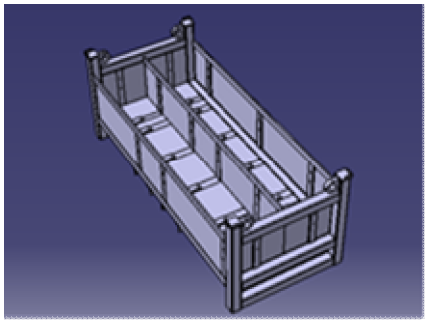

Fig.19 Modified Pallet Assembly

By doing assembly by considering same material of existing pallet Mild Steel, weight of the modified pallet is 140 Kg. The existing pallet have 310 Kg weight, so there is reduction of 170 Kg weight that means there is 55% weight reduction is done.

Also there is a reduction in the cost, 310 Kg pallet have 15500/- rupees and modified pallet have cost 7000/- rupees. So there is a 45% cost is reduced.

## X. CONCLUSION

The work developed an illustration of pallet for two crankshafts in this design, modelling, analysis for giving operating condition and weight reduction. Gradual reduction in sectional dimensions gave significant reduction in weight. Mild Steel material was used by comparing other materials considering heavy load, environmental factors and cost for manufacturing the pallet. Also the stress, factor of safety and deflection lie within permissible limits of yield for the given loading conditions. These results are compared with different materials for pallet by performing Finite Element Analysis and it is detected that Mild Steel have minimum deflection than others. The maximum deflection is 1.3057mm of polyethylene pallet. Pallet is so heavy and there is problem while handling, so weight is reduced by changing dimensions and removing uncomfortable parts in the pallet. Implementing these things weight of the pallet is reduced by 55% and it is safe under same loading conditions and also there is


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reduction in cost of the pallet, cost of pallet reduced by 45%.

## XI. ACKNOWLEDGEMENT

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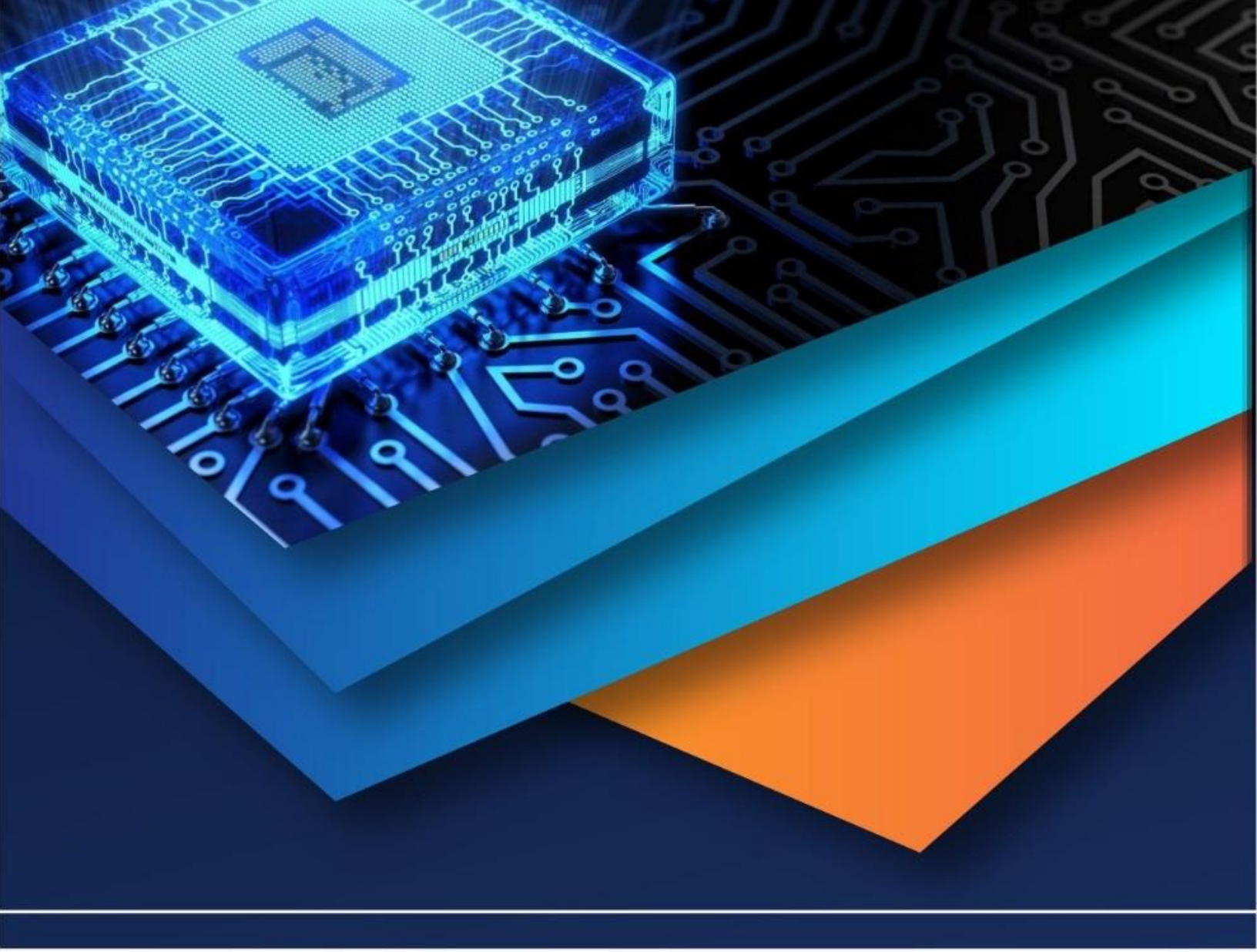

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