Design and Analysis of Lifting Carriage of 4T Overhead Stacker Crane

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Abstract:- The Overhead Stacker Crane is a hybrid device that combines the features and constructions of "Industrial Forklifts" and "Electric Overhead Cranes." Stacker cranes are equipment with varied levels of automation that are used to store materials. They travel along the aisles of the operating areas, where they enter, position, or extract the material. This type of crane is widely used in assembly shops, production stores, warehouses, etc. Each application needs customizing. The lifting carriage of different overhead stacker crane design is studied in this study. The new design has two advantages: the lifting carriage is bracketed to the mast of the overhead stacker, and the new lifting mechanism is more compact. The most common structure configurations are single-mast and twin-mast constructions. Single-mast structures are used for investigation in our research. A live example has been chosen, and several design engineering stages have been implemented, with the goal of achieving compliance with safety-related standards as well as possible enhancements for future consideration. All the concerned parts have been 3D modelled, analyzed using classical means as well as advanced means of FEA. The goal of using design engineering concepts is to provide a verified design with documentation that can be manufactured with or without indicated improvements. Static analysis of identified parts is performed using both hand calculation and the FEA approach.

***Keywords**:- Overhead Stacker Crane, Forklift, Analysis, FEA.*

I. INTRODUCTION

Material handling is the function of moving the right material to the right place, at the right time, in the right amount, in sequence, and in the right position or condition to minimize production costs. Hoisting equipment is usually powered equipment used for lifting and lowering unit and varying loads intermittently. In certain equipment while lifting and lowering, shifting of the load can also be accomplished, within an area known as the reach of the equipment. The primary function of hoisting equipment is transferring through lifting and lowering operations.

Material handling equipment used in a warehouse to lift pallets is not the same as that used to lift the axle of a tractor. In such scenarios, two separate fork sizes are used for each case. The time required to change the lifting equipment and adjust the tines is high. This is the specific customer requirement for a stacker crane design, which comprises a customized lifting carriage for lifting the pallet and keeping the pallet in the warehouse and retrieving it as per the requirement. The specific requirement of the lifting carriage is that the lifting carriage should support a payload (pallet) of a maximum of 4000kg. The lift arms on the lifting carriage are not fixed; the distance between them can be adjusted as per requirement. It is required to design for the abovementioned requirements along with validation through stress analysis. Only a safe design can be taken forward to the fabrication and deployment stages.

II. LAYOUT OF THE OVERHEAD STACKER CRANE

As shown in figure 1 below carriage can slide up and down on the mast. Detailed assembly of carriage is also shown in figure 2. It consists of carriage, pulley mounting, bracket, tine.

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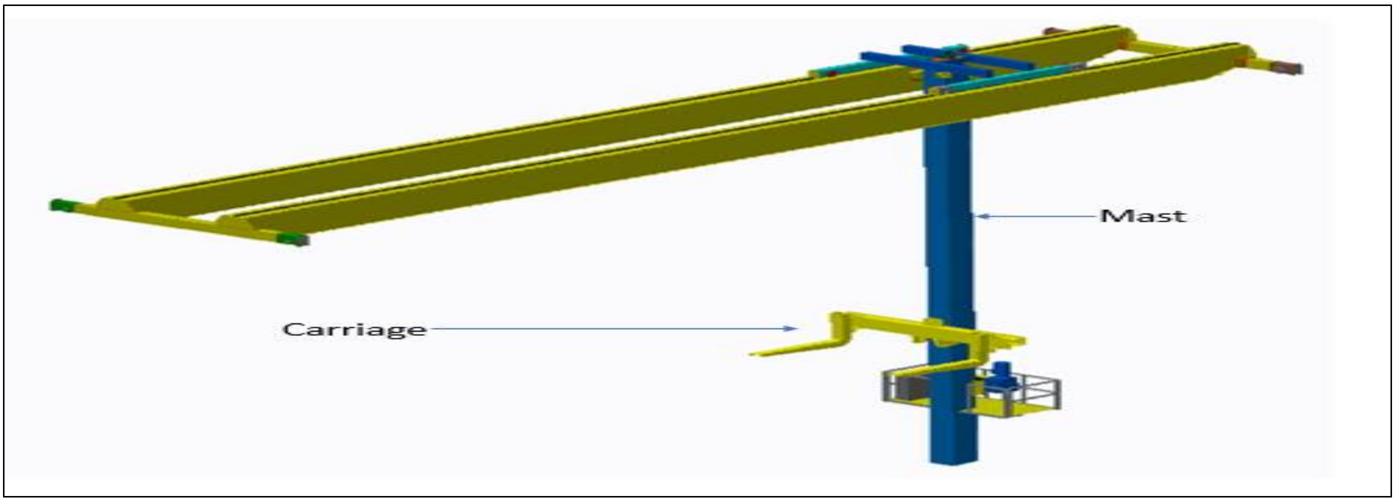

Fig 1: Overhead Stacker Crane

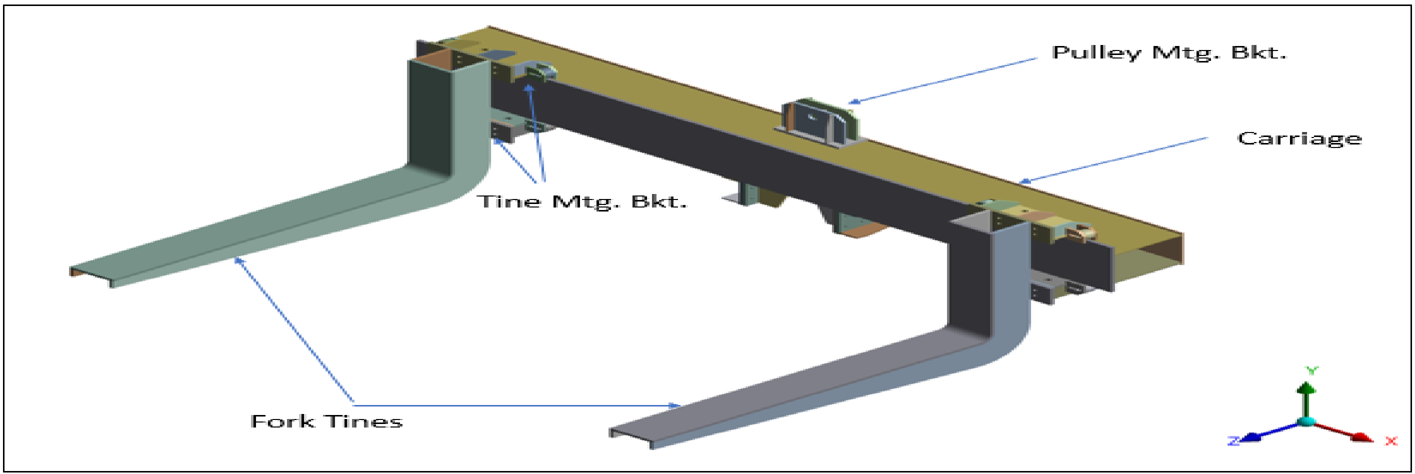

Fig 2: Lifting Carriage

III. TECHNICAL PARAMETERS OF OVERHEAD STACKER CRANE

The stacker cranes of various categories, design, and configuration according to the functions designed. The stacker crane which is area of interest of this study has following specifications:

Sr. No.	Parameter	Specification
1	Capacity, kg	4000
2	Span, meter	1.9
3	Hoist type	Electrical, wire type
4	Hoisting Speed, FPM	6-25
5	Mast Rotation, RPM	120
6	Hoist brake	125% in working condition
7	Rack height, ft.	24.60
8	Fork length, ft.	4.26

IV. DESIGN CALULATIONS OF FORK TINE

Tine is designed for supporting payloads. The stacker crane performance and job security rely on the forklift tine strength and stiffness. Fork tine is rigid hanging on the carriage.

- *Arrangement/Loads/Symbol used for Fork Tine:*

The crane is being designed for a payload of 4 tons (4000kg). This payload acts on the fork tine through CG of the loads, shown as shownn in the below figure.

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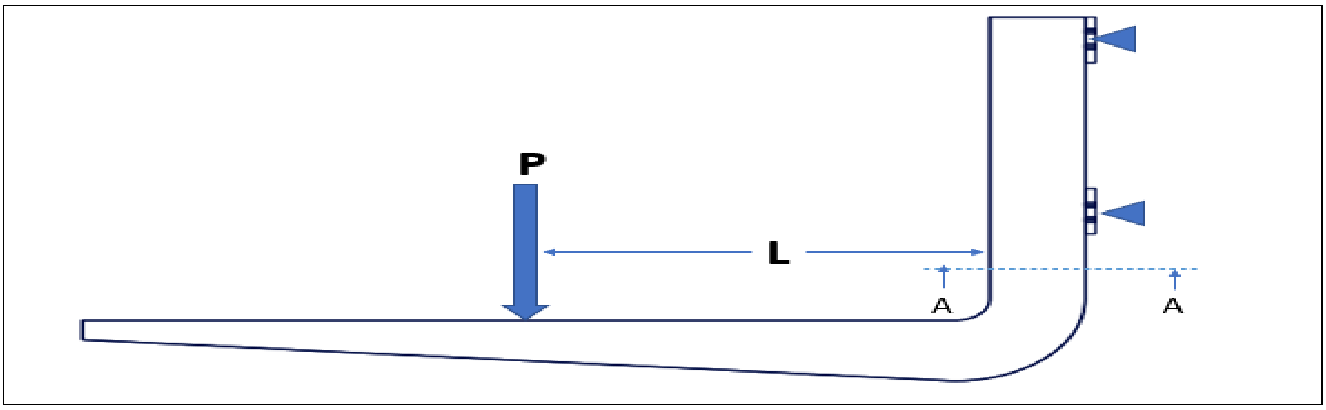

Fig 3: Load on Fork tine

The payload is depicted by "P" and divides on the two fork tines with an overload factor of 25%. The load imposed on each fork tine is depicted by "F".

P=Payload × 1.25(25% one load factor)

L= $\frac{1880}{2} + \bar{x}$

M= F× L

F= $\frac{P}{2}$

➢ *Section properties for Fork Tine:*

Section is obtained by welding 20mm thick plates welded together, using GMAW welding process to get a C section as shown in section AA.

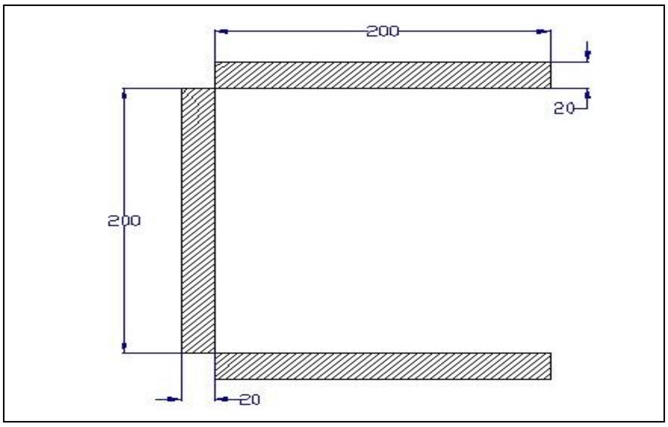

Figure 4: Cross section AA of tine

A= section area=200× 20 × 3= 1200mm^2

$\bar{x}$= CG location of section from surface

$$\bar{x} = \frac{\sum A_i \bar{x}_i}{A}$$

$$\sum A_i \bar{x}_i = 200 \times 20 \times 10 + 20 \times 200 \times 20(100 + 20)$$
$$= 1000000$$

Now,

$$\bar{x} = \frac{\sum A_i \bar{x}_i}{A} = \frac{1000000}{12000} = 83.33mm$$

$$Iyy = \frac{1}{12} \times 200(20)^3 + \frac{1}{12} \times 20(200)^3 \times 2 + 200 \times 20 \times (\bar{x} - 10)^2 2$$

$$\times 200 \times 20 \times (100 + 20 - \bar{x})^2$$

$$= 59066666.67mm^4$$

➢ *Stresses for Fork tine:*

Through hand calculations, stresses which depict the strength, are calculated for at the critical section a-a. fea is utilized for the fine stress values and determining the deflections (rigidity), for which correct estimation is not possible with manual calculations die to constraints of idealization.

L= 940+83.33= 1023.33mm

F= $\frac{\text{Load}}{\text{Tine}} = \frac{5000}{2} = 2500\text{kg}$

M= F × L= 2500 × 1023.33= 2500kg

σ = Tensile stress = $\frac{F}{A} = \frac{2500}{12000}$=0.21 kg/mm^2

σ_b = Bending stress = $\frac{M}{I} \times (220 - \bar{x})$= 5.92 kg/mm^2

$\sigma_r = (\sigma + \sigma_b)$= 0.21+5.92= 6.13 kg/mm^2

$\sigma_{y=}$yield stress = 240MPa = 24.47 kg/mm^2

FOS = $\frac{\sigma_y}{\sigma_r} = \frac{24.47}{6.13} = 3.99 = 4$

V. FEA ANALYSIS

The FEM also known as finite element analysis (FEA) is a numerical mathematical method used to obtain approximate solutions of boundary value problems in engineering. In a boundary value problem one or more dependent variables must satisfy a differential equation everywhere within a known domain of independent

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variables and satisfy specific conditions on the boundary of the domain.

A. Geometry

The first step in FEA analysts is to create a 3D model of the carriage subassembly. This model is made on SolidWorks software. Each part is made separately and an assembly is formed. Bonded connections are used for welded joints and rolling contact are given where roller is in contact with the carriage. The file is saved in IGES format which is later imported in the FEA package (i.e., ANSYS).

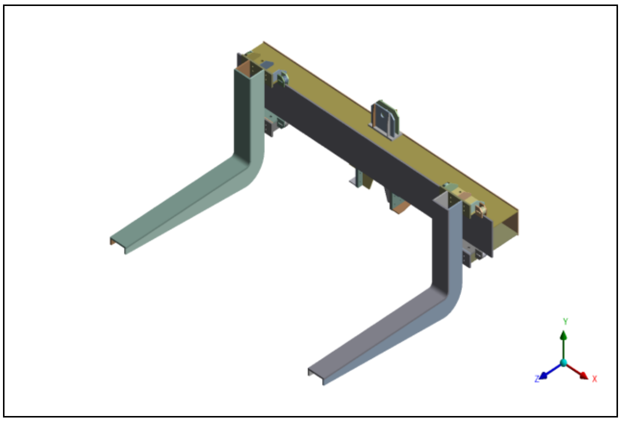

Fig 5: 3D Model of the Carriage Subassembly

B. FE Model and Constraints

Once the model is imported in ANSYS, the material is selected for each part as decided during the design phase. The material properties are matched with the actual material used. Predefined materials can be used by editing the material card as per the actual material.

C. Meshing

Meshing is the process of discretization of the solid part. It divides the solid into numerous elements. Following settings are used for meshing.

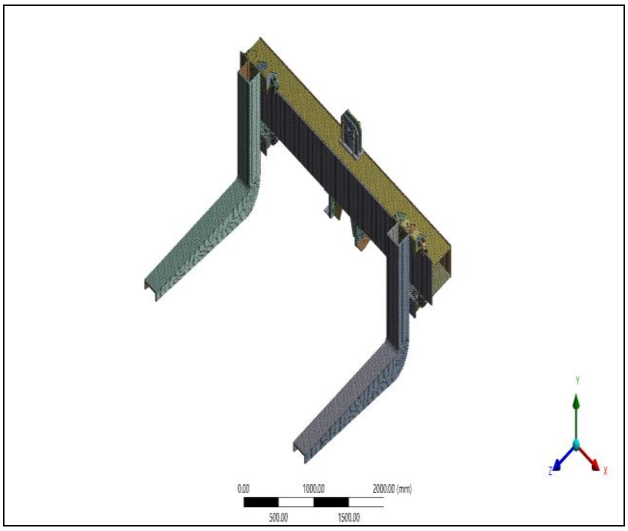

Fig 6: Meshing on the Assembly

D. Element Size

Selecting element size an important decision-making process. If we select bigger elements the computational time is reduced also the drawback is that the accuracy in result may reduce. Whereas if we select smaller element size the time and computational power required increases significantly. Hence, we need to check the element quality and ensure that majority of the elements how element quality better than 0.3. are the elements quality it is better. the element quality is determined by taking into consideration various factors like skewness of the element and aspect ratio.

It can be seen from the table below that majority of the elements are satisfying the element quality requirements. Hence, element size of 20 mm selected.

E. Boundary Condition Specification

The step following creation of geometry and meshing is applied on the boundary conditions. While applying the boundary conditions it is ensured that that real life conditions are replicated for the simulation purposes.

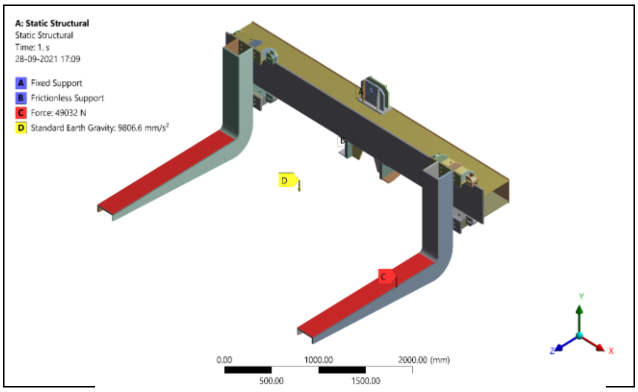

Fig 7: Boundary Conditions of Carriage Subassembly

VI. RESULT

The final step in a FEA is to obtain the results to analyze the design. In this case the Von Mises stress and the deformation are of prime importance to critically analyze the design.

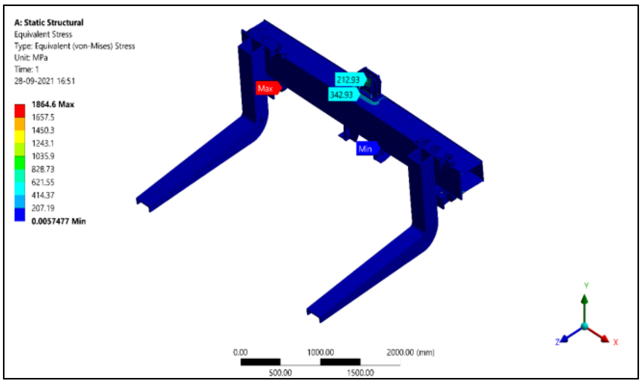

Fig 8: Equivalent Stress on the Assembly

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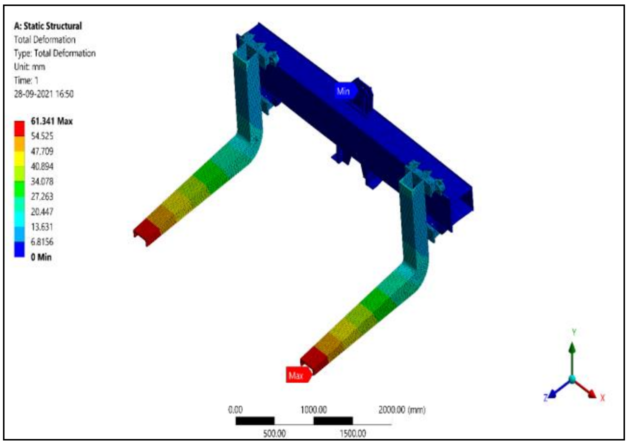

Fig 9: Total Deformation of the Body

VII. CONCLUSION

To implement the innovation in design of overhead stacker crane adjustable times can be introduced. In this dissertation the design was taken from conceptual level and analyzed critically with the help of traditional analytical methods as well as advanced FEA methods. The areas with high stress what identified and design recommendations were suggested. furthermore, the design is analyzed again with the help of FEA program and it is observed that the modified design is safe.

For static load analysis, the stresses are below the allowable strength of material. It can be concluded that the lifting carriage assembly have sufficient strength to meet the design requirement.

Through this analysis it can be concluded that despite analytical calculations it is difficult to decide the cross section of critical areas. On the other hand, advanced computational power allows to make quick changes in the design and instantly analyze the modified design. Thus, resulting in lower cycle time for an idea to reach the market as a product.

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