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DEVELOPMENT AND STRUCTURAL ANALYSIS OF TRANSLATION

CARRIAGE FOR REACH TRUCK

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Abstract – The objective of this paper is to develop and analyze Translation carriage for reach truck using CAD modeling and F.E.M. technique. This analysis has been carried out in terms of Strength and stiffness and by means of F.E.M. technique. There have been simulated different load cases and boundary conditions that the structure of carriage should bear. This load cases can be obtained from normal and extreme operation of the carriage and the results are validated.

Keywords – *Development, Reach truck, Translation carriager Linear Static structural , Finite element analysis.*

I. INTRODUCTION

Reach trucks are widely used throughout industry for moving materials and goods, they are the original narrow-aisle lift truck. These trucks are small enough to turn in narrow aisles because they don't need a large counterweight. Instead, outrigger arms extend in front of the trucks to provide stability. The outrigger arms, however, can prevent the trucks, depending on storage configuration. They are called reach trucks because the mast is moved forwards or reached out to pick up the load. For travelling, the load is reached back and carried within the wheelbase which allows greater maneuverability. They are specially used for storing material in rack type structure.

According to function Reach trucks are classified as:

a) *Pentographic type*

b) *Moving mast with sliding carriage*

In pantographic type the Forks are moving with the help of pantograph mechanism and in moving mast type the mast is fixed on to the Translation carriage and the carriage is slides between the reach legs with the help of bearings. This carriage has to be Stronger; because it takes total weight of mast assembly, pay load and it also slides between C-sectioned reach legs to go in the desired direction for unloading and loading purpose.

The main goal of this study is to develop a Translation carriage of a Reach truck for specified load lifting capacity and according to Indian standards. Modeling will be done with the help of Computer Aided Design (CAD) software i.e. Solidworks11. Next, the Strength, safety factor of the model will be evaluated using the Finite Element Analysis (FEA) technique, with the help of ANSYS workbench.

II. GENERAL LAYOUT OF REACH TRUCK

The typical layout of reach truck is shown in fig.1 in which all major parts are shown .The mast assembly; forks are attached to the Translation carriage.

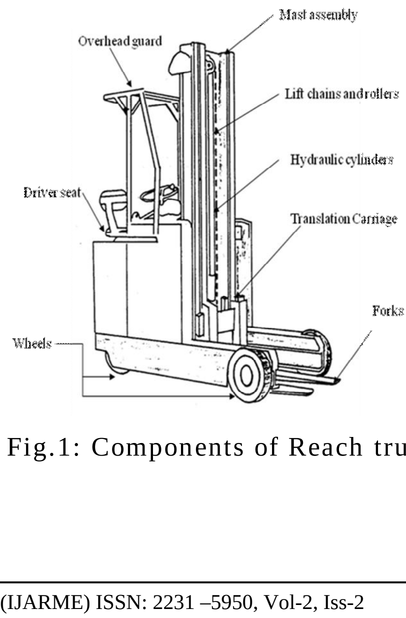

Fig.1: Components of Reach truck

III. TECHNICAL PARAMETERS

The reach trucks are of various categories, design and configurations according to its function .The reach truck which is area of interest of this study has following specifications:

TABLE I. TECHNICAL PARAMETERS

1	Power unit		Electric
2	Loading capacity	(ton)	1.6
3	Centre of gravity for a lifting load	(mm)	600
4	Wheel base	(mm)	1442
5	Weight without battery	kg	3530
6	Mast tilt	degree	1 to2
7	Load Lifting height	(mm)	8000
8	Fork dimensions	s/e/l (mm)	50 / 100 / 1150
9	Fork carriage type		FEM II B
10	Minimum turning radius	(mm)	1702
11	Travel speed (loaded/unloaded)	Km/h	12/12
12	Lifting speed (loaded/unloaded)	m/s	0.32/0.60
13	Lowering speed (loaded/unloaded)	m/s	0.54/0.46
14	Service brake Type		Hydro mechanical
15	Voltage / Rated capacity	V / Ah	48/700

IV. MATERIAL SELECTION

Translation Carriage has to be stiff enough so that it will withstand in the forces applied on them. If the carriage bends a little then it will lead to instability of truck (tipping phenomena).also it will affect on lifting performance of the truck. However, you cannot make it completely stiff. That would cause it to be brittle. There will start to appear weak points and it would end breaking throw the weakest. So you need to reach a point where it is neither too stiff nor too weak.

The main material used to build carriage is High tensile steel. The mechanical properties of the steel are very much suitable as they have high impact energy absorption before fail and also they have high strength. Also it is easily available in Indian market and in various thicknesses, which are required for fabrication of carriage. Weld ability is also a criteria for selecting this material, So considering all these factors the material selected for carriage is "**FE 540**" according to "**IS 2062**".

Its mechanical properties and chemical composition of are listed below:

TABLE II. CHEMICAL COMPOSITION OF Fe 540: IS 2062

C %	**Mn %**	**S %**	**P %**	**Si %**	**Carbon Equivalent (CE) Max %**
0.2	1.6	0.045	0.045	0.045	0.44

TABLE III. MECHANICAL PROPERTIES OF Fe 540: IS 2062

Quality Structural Type	**Tensile Strength**		**Yield**	**Elongation**
	Thickness (mm)	**Minimum (N/mm2)**	**Stress (N/mm2)**	**Range %**
Fe 540-HT	Up to 16	540	350	20-25
	16 to 32	540	340	20-25
	32 to 63	510	330	20-25
	Above 63	490	280	20-25

V. MODELING OF TRANSLATION CARRIAGE

The carriage is developed and modeled using Solid works 11.The sheet metal features are mainly used for modeling bend plates. The final model of carriage contains various sub assemblies that are:

1) *Fabrication assembly:*

This assembly contains main structure of the carriage.for modeling this, plates having various thicknesses ranging from 6mm to 50 mm thick are used.these thicknesses are chosen according to indian standards and availability in the market.These are welded together to form a main structure .

2) *Battery lock plate assembly:*

The reach truck is Electrically Powered. For this a 48V battery is required. The tray containing this battery is placed below dashboard and above the translation carriage and is supported on two reach legs. In this truck if battery is required for charging or some other purpose then carriage comes out with battery tray containing battery and in normal working carriage comes out without battery. To achieve this function a latching mechanism is used in which battery tray get engages to carriage whenever required and which is operated by driver. For this, lock plate assembly is bolted on the main structure as shown in fig.2

3) Hose assembly:

This assembly gives direction to the hoses that are connected to the mast assembly and contains hydraulic fluid. This assembly also bolted to the main structure.

4) Block assembly:

These blocks are bolted on the top of the carriage through which mast assembly is mounted on the carriage. Bushes are provided in the hole to minimize wear.

5) Support Plate assembly:

This provides support between two side plates to make it rigid.

6) Carriage with roller bearings:

The carriage slides between reach legs as shown in fig. 3 for these purpose roller bearings are attached.

The justified mates are provided between all these sub-assemblies in solid works to form the main assembly as shown in fig.2

Also whole frame of reach truck including top and bottom chassis, driver seat, etc. are modeled. The translation carriage assembly is imported in that assembly and mates provided to it as shown in fig.3, which also shows location of translation carriage which slides between two reach legs.

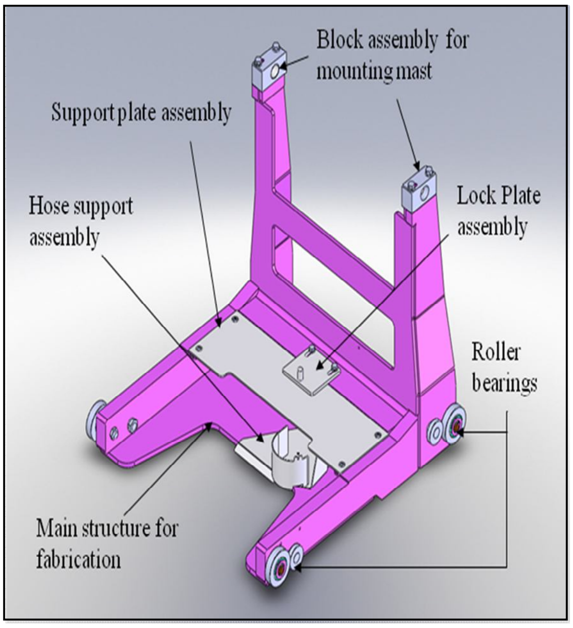

Fig. 2 : Cad model of Translation carriage

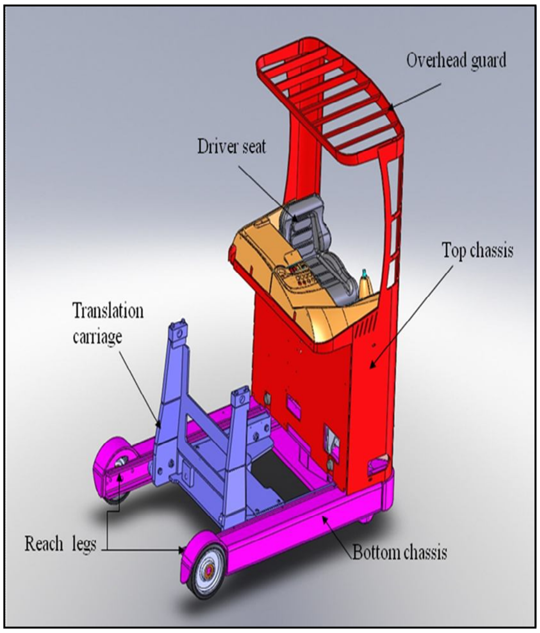

Fig. 3 : Reach truck frame showing Translation carriage.

VI. LOADING CASES

The calculations of theoretical loads on a carriage have not beer standardized, so the stress analysis of the structure is carried out by taking account the static external forces acting on it. The carriage Slides along Reach legs with the help of roller bearings and carry whole mast assembly including pay load and fork carrier assembly. Thus the lifting performance of truck is also depends on reliability of carriage. Practical experience suggest that a structure designed to be sufficiently strong for the maximum loads The carriage has to withstand in all the weights of these assemblies, moments produced by the forces in order to perform its function properly and will also have sufficient bending resistance.

The various loads acts on the carriage are calculated as below:

A. Self Weight of the carriage:

The self weight of carriage is calculated in solid works after modeling and assigning the material properties which comes out:

= 279.67 kg

=2800N.

B. Pay load (w):

The Reach truck which is going to developed is for lifting 1.6 ton load lifting Capacity.

Thus the weight of pay load acting on fork through C.G. of load.

= 1.6 ton

=16000 N

C. Weight of the mast assembly:

This Reach truck has the lifting height about 8m, so the triplex type mast assembly is used, which has the weight
=1.5 ton
=15000N.

D. Fork assembly weight:

Fork assembly contains Forks, fork carrier and load back rest. Forks used in this truck are of type FEM 2B (European Federation of Materials) as mentioned in technical parameters. Each fork is weighted 64 kg. Thus two forks have 64×2=128 kg weight. Also carrier and load back rest have 60 kg and 11 kg weights respectively.

Thus total weight of fork assembly is

=128+60+12

=200 kg

=2000N

This load acts from distance ‘E’ as shown in fig.4 and this distance is given as 300mm.

E. Moments acts on the carriage:

The bending moment’s acts on the carriage in normal condition and in mast tilting conditions are as follows:

1) Moments due to Pay load and Fork assembly weight in normal condition:

The pay load and fork assembly creates moment as shown in fig.4 and 5

The standard load centre distance (D) i.e. distance between C.G. of pay load and inner side of fork (as shown in fig.4) is mentioned in technical parameters and also according to “IS 7631:1993” for high lifting platform truck

= 600mm

The moment creates because of pay load and fork assembly weight acts on pin axis where mast is attached is

= (16000×0.9) + (2000×0.3)

=14400 + 600

=15000 Nm (clockwise)

This moment is equally distributed between both of the pins, so moment act on single pin

= (15000/2)

=7500 Nm (clockwise)

For equilibrium condition this moment resolved in forces F1 and F2 as shown in fig. 5.where F1 acts through points P1, P2 and F2 acts through points P3,P4 as shown in fig.5

Reaction forces: F1=F2

= (7500/0.795)

=9434 N

Therefore F1=9434 N (→)

And F2=9434 N (←)

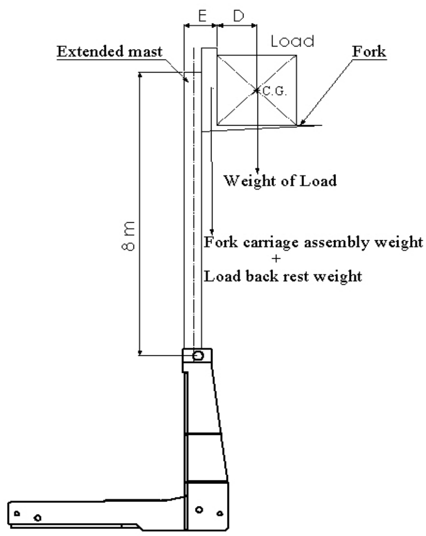

Fig. 4: Carriage showing extended mast, fork and payload

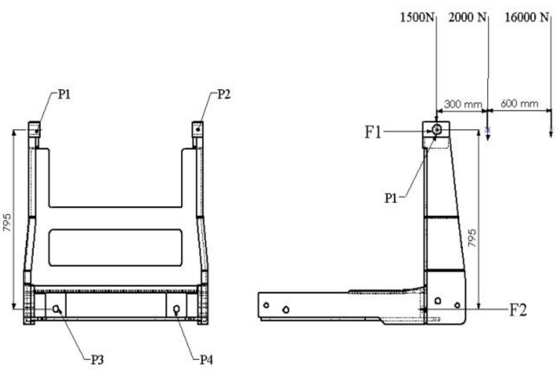

Fig. 5: Front and back view of carriage showing various forces acting on it.

2) Moments due to Pay load in mast tilting condition:

The mast tilting position is shown in fig.6.The tilting angle is given as 1° to 2°.

The component of load act on carriage in this condition is

$= w \times \sin\theta$

$=16000 \times \sin 2$

$=558.39$ N

$=560$ N

Thus moment act on pin

$=560 \times 8$

$=4480$Nm

Therefore moment act on each pin (P1 and P2)

$=4480/2$

$=2240$ Nm (clockwise)

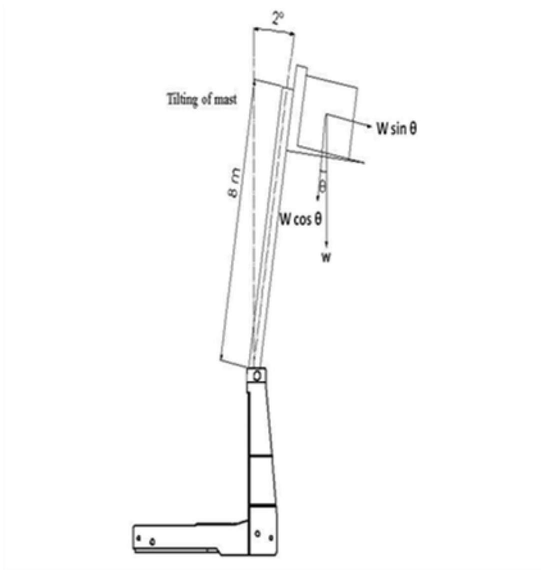

Fig. 6 : Forces acting on carriage in tilting mast condition

VII. FEM ANALYSIS OF TRANSLATION CARRIAGE

The finite element method (FEM) is a computational technique used to obtain approximate solutions of boundary value problems in engineering.

The analysis is done to calculate various stresses induced in the carriage, in order to check its reliability

The analysis type used for this purpose is a "*linear static structural analysis"* which is performed to obtain the response of a system in static loading condition. The tool used for the analysis is Ansys workbench 13.For a linear static structural analysis, the displacements {x} are solved for in the matrix equation below:

$$[K]\{x\}= \{F\}$$

Where stiffness matrix [K] is essentially constant and {F} is statically applied

The following assumptions are applied for the carriage:

- Linear elastic material behavior is assumed.
- Small deflection theory is used.
- No time-varying forces are considered.
- No inertial effects (mass, damping) are included.
- Total battery is rest on reach legs; only small amount of battery load is induced during engagement of battery through lock plate, so that effect is neglected.

Steps in the analysis:

A. Pre-processing (building the model) and Geometry creation:

The initial geometry was constructed using Solidworks 11. The geometry was then converted to IGES format and transferred to Ansys workbench to create a finite element model. Before transferring to ansys all unnecessary features e.g. fillets, chamfers, unnecessary holes are either suppressed or deleted, also the parts or assemblies which are not affecting analysis or loading cases i.e. non-load carrying members are suppressed e.g. hose assembly, rollers ,lock plate assembly etc.

B. Material property assignment:

The properties of Fe 540 listed above are defined and assigned in material under the "Engineering Data" branch.

C. Meshing of the model:

Cad geometry is idealization of physical model and mesh is a mathematical representation of cad model. Mesh generation is the process of discretizing the body into finite elements and assembling the discrete elements into an integral structure that approximates the original body.

The model was meshed with medium type elements for linear static analysis. The meshed model is shown in fig.7

Almost all bodies are meshed with element size20mm, but the bodies which are small in size are meshed with element size 5mm.

The no. of elements and nodes found out as:

Total No. of Elements: 38448

Total No. of Nodes: 96450

D. Boundary Condition specification:

The carriage is slides through roller bearing, so the boundary conditions are applied at the bearings location. It is constrained at the holes where bearings are attached.

E. Apply loads:

The loads calculated in loading cases are applied to the model i.e. self weight (2800 N), mast assembly weight (1500N) and various moments and forces calculated in loading cases.

F. Solving the model:

The model is solved and equivalent stresses (von-misses) and total deformation are found out. The displacement and stress contours shown in fig.8 and fig.9.

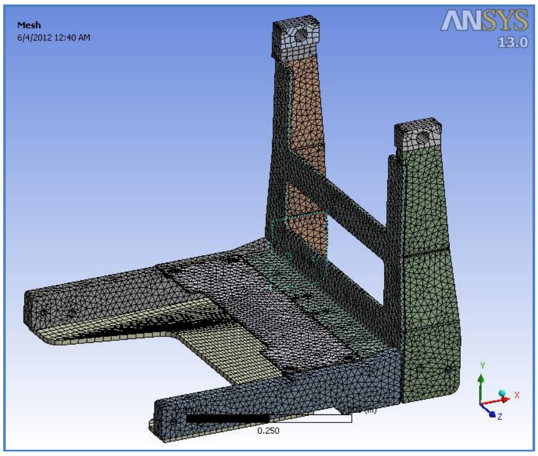

Fig. 7 : Meshed model of translation carriage

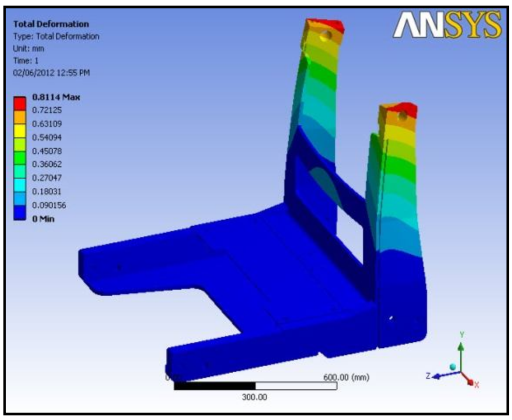

Fig. 8 : Total deformation in carriage

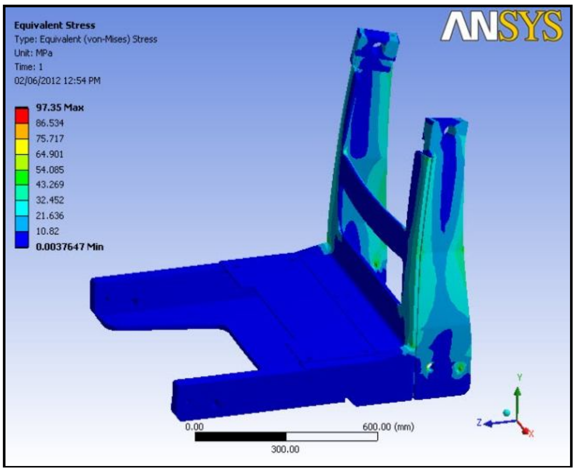

Fig. 9 : Equivalent (von-Mises) Stress

VIII. CONCLUSIONS

- For the linear static analysis, the stress distribution and deformation profile of the carriage subjected given loading conditions had been determined.
- Maximum equivalent stress occurred at the junction where side bend plate and bottom plates are welded, which has the value 97.35 N/mm^2.comparing this value with yield strength for 33 mm thick plate i.e. 330 N/mm^2 ,so it is safer.
- Factor of safety is a term describing the structural capacity of a system beyond the expected loads or actual loads. The safety factor of the design (i.e. the ratio of limiting to the actual loads) is a measure of the reliability of a particular design and the factor of safety comes out for carriage is

  330/97.35 =3.3.

  Automobiles use 3.0 F.O.S. Thus this much F.O.S. is required for the Translation carriage; because the lifting performance is depends on the reliability of carriage.
- Total deformation contour shows the maximum deformation occurs at top of the carriage, where mast is attached which is expected and the value of maximum deformation is 0.82mm which is acceptable. Thus the structure will withstand in bending.
- The support plate between two side plates is avoiding bending in inward direction and provides rigidity to structure.
- The bottom plate and two side carrier plates where bearings are mounted do not take any stress. (Non-load carrying members) but we can’t minimize theirs thickness as theirs rigidity is required in other function also whole carriage acts as a counterweight

for reach truck to provide stability. Thus it must be sufficiently rigid.

- Translation carriage design is philosophically the safe and economical design

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