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Static and Dynamic Analysis of Stretcher Elevator

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ABSTRACT

A stretcher elevator is a type of elevator that is used in hospitals for carrying a patient on a stretcher along with escorts from one floor to another. Considering this application, cabin of this elevator is larger in size as compared to conventional passenger elevators. The case under study deals with static and dynamic analysis of stretcher elevator. To analyse the operational/functional safety of newly designed frame (elevator tower structure), static and dynamic analysis is necessary.

Keywords – elevator, tower, frame, structure analysis, static, dynamic, safety.

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I. INTRODUCTION

In this project, the main objective is performing static and dynamic analysis of the stretcher elevator. The exterior tower frame structure of the model under study is newly designed and it is first of its kind (as per our knowledge).In this case a single framed structure (trusses in the form of cage) is extruded for housing both counter weight and car. As per the innovative technique, there is no duct required and elevator will be constructed outside the pre constructed building. Hence operational/functional safety of this structure has to be verified before the further stages of development. The analysis is to be done in two ways.

(1)**Static analysis** – In this case, the structure will be in static condition and its behaviour will be studied under the static loading e.g. self-weight of the structure, weight of various components and mountings, etc.

(2)**Dynamic analysis**- In this case, the behaviour of the structure under dynamic loading conditions (actions having high acceleration) will be studied and inertia forces of the structure will also come into picture.

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II. CONSTRUCTIONAL DETAILS OF AN ELEVATOR SYSTEM

The elevator is basically a floating platform used to lift and carry the load from one floor to another. The load may be passengers or commercial (material) load. It works on the simple principle of getting mechanical advantage from balancing of weights.It consists of a lift car or cabin which is suspended on steel ropes. The steel ropes are passed over a driving sheave (grooved pulley) or driving drum. The other ends of the ropes are attached to counter weight on the other side of the sheave. The weight of the counter weight is half of the lift car when the car is fully loaded to its rated capacity. The number of.ropes may vary from 1 to 5.The driving electric motor is of variable speed. The power transmission is done by Variable Friction Drive (V.F.D.). The vertical motion of the lift is guided by guide rails in the form of T-slots. The movement of elevator from one floor to another is governed by electronic controller placed near driving sheave. The compensation pulley is provided at bottom to provide balance between car and counterweights. Damping is provided at the base.

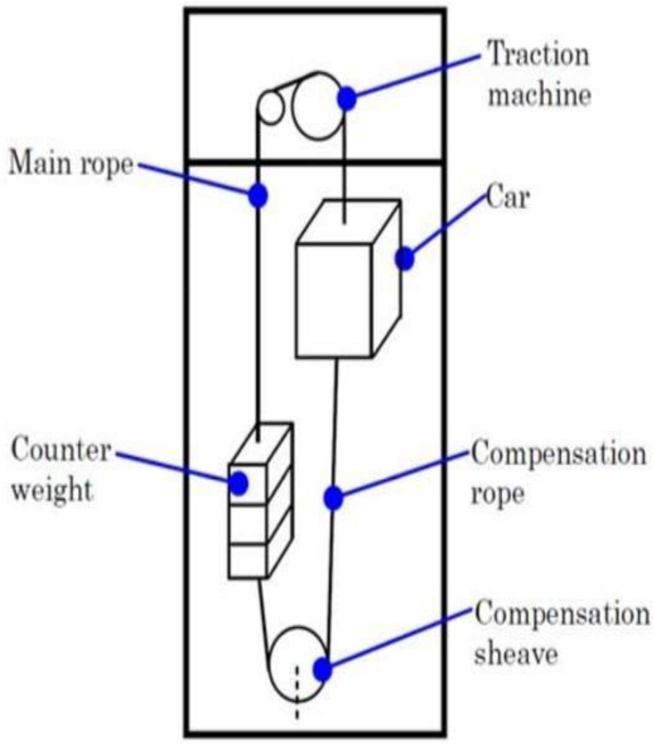


Fig.1 - schematic diagram of an elevator system

III. STRUCTURE OF THE ELEVATOR TOWER UNDER STUDY

- In normal elevator tower designs, the tower frame structure is surrounded by thick walls of concrete on all sides.
- The opening for door at each floor is made in the concrete wall.
- The typical concrete wall thickness ranges from 500mm at the base gradually reducing to 350 mm at upper floors.
- Hence this process of housing the elevator tower is costly considering the height of elevator towers.
- The design under study implies truss structure which houses the car and counterweights inside it and works as a cage for both.
- It uses the trusses of „Y" shape as shown in Fig. 2
- Trusses are having I cross section, ensuring good strength and rigidity of a structure.
- Hence this structure reduces the assembly cost to a great extent as compared to the conventional structure.
- It also reduces the construction time required to build up the system.
- As there is no duct requirement, the elevator can be constructed even on the external side of the pre-constructed building.
- Only the small part (up to 1500mm height) at the base is kept inside the concrete walls to ensure maximum support at the base.

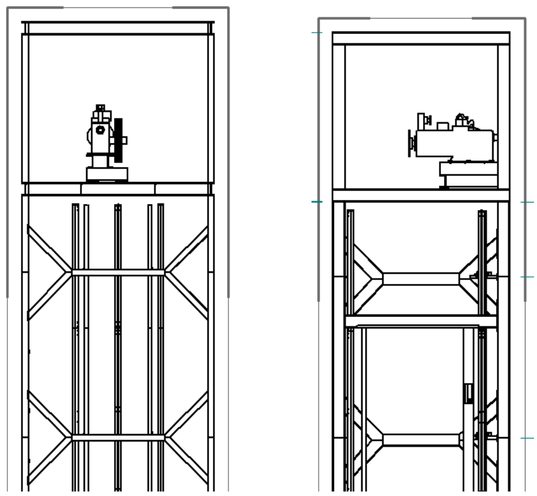


Fig.2 - structure of the elevator under study.

IV. STATIC ANALYSIS

Structural analysis is mainly concerned with finding out the behaviour of the physical structure under the action of force. This action can be in the form of load due to the weight of things such as people, furniture, wind, etc. In essence, all these loads are dynamic, including the self-weight of the structure because at some point in time, these forces were not there. The distinction between the dynamic and static analysis is made on the basis of whether the applied action has enough acceleration in comparison to the structure"s natural frequency. If the load is applied sufficiently slowly, the inertia forces (Newton"s second law of motion) and the analysis can be simplified as static analysis. The static analysis for this project will be done for two types of loads.

Dead load – It is also called as permanent load. It is the self-weight of the structural members. It is constant in magnitude and fixed in position throughout the lifetime of the structure.

Live load – Live load is assumed to be produced by the intended use or occupancy including distributed and concentrated loads. These loads vary in magnitude and are also known as imposed or transient loads.

Dead load analysis – The dead load is calculated as

Dead load = Total self-weight of the structure = sum of weights of all individual truss members. This load is divided by four and applied on four columns of the structure as point load in Ansys Software. The base is completely constrained. The resultant stresses and deflections are shown in the figures below.

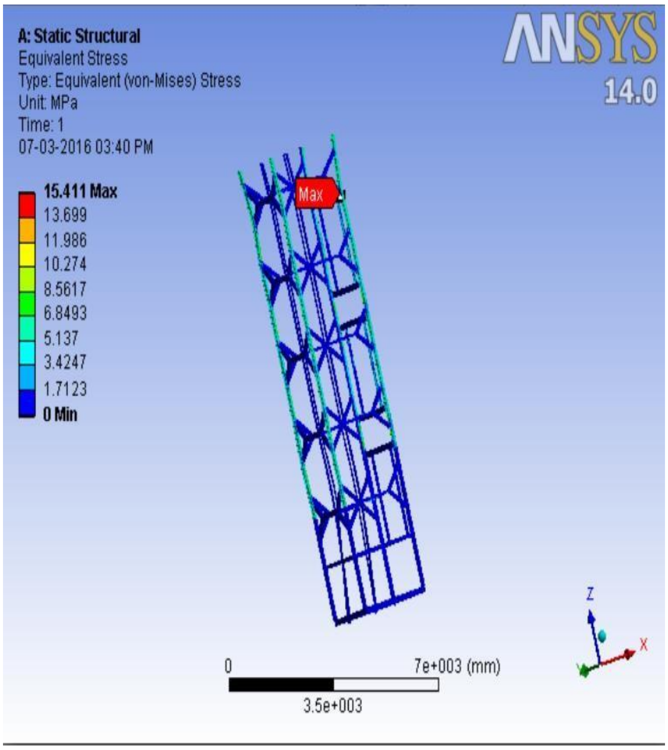


Fig.3 – simulation results showing stresses in the structure

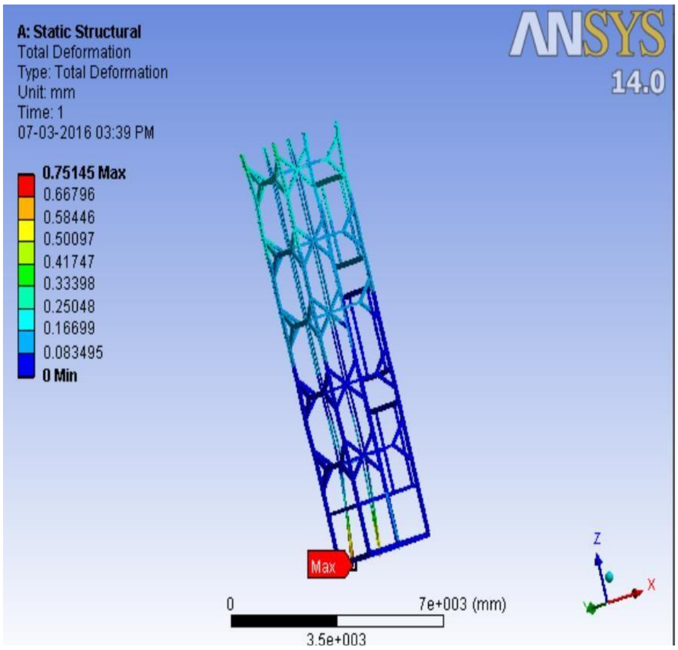


Fig 4 – simulation results showing deformation in the structure.

V. DYNAMIC ANALYSIS

It is the type of the structural analysis which covers the behaviour of the structure subjected to dynamic (actions having high acceleration) loading. Dynamic loads include wind, waves, blasts, etc. Dynamic analysis can be used to find out dynamic displacements, time history and modal analysis. The dynamic loading is also related to the inertia forces generated in the structure when it is excited by the means of dynamic loads applied suddenly (e.g. wind blast, explosion, etc.).

In the case under observation, the elevator system is converted into the suitable "spring, mass and damper" system. The ropes are treated as springs. The model of the system and model of the corresponding spring, mass and damper system are as shown in the figures respectively.

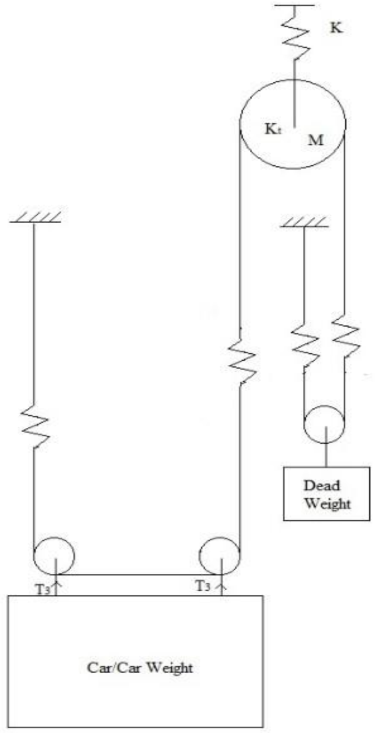


Fig.5 (a) – schematic spring mass diagram of system under consideration

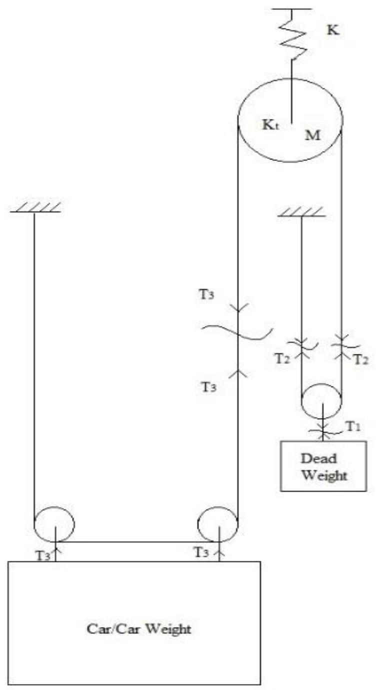


Fig.5 (b) – forces in the system

Where,

M denotes respective masses.

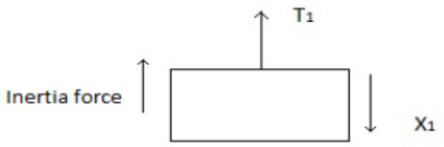
X denotes respective displacements.

K denotes the stiffness for corresponding ropes.

Kt denotes the torsional resistance coefficient for driving pulley.

rd denotes the radius of driving pulley.
Θ denotes angle of wrap for driving pulley
et be the acceleration and hence denotes the inertia force for corresponding masses.
Neglecting the friction at car and counter weight pulleys and neglecting the mass of ropes, the governing equations can be written as

For counter weight-

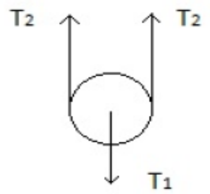


$$m_1\ddot{x}_1 + T_1 = 0$$

Therefore

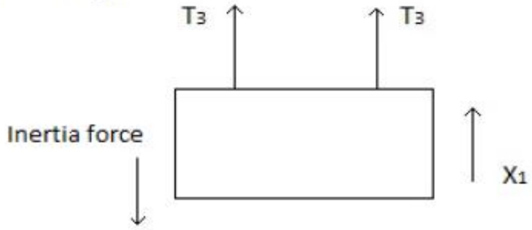
$$T_1 = -m_1\ddot{x}_1 \qquad (1)$$

For pulley attached to counter weight -



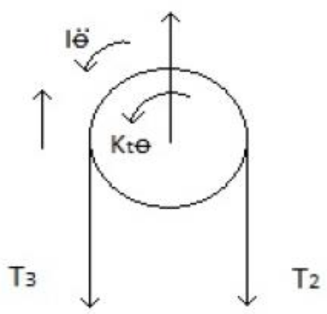
$$T_2 = 0.5 * T_1 = 0.5 * m_1\ddot{x}_1 \qquad (2)$$

For car weight -



$$T_3 = 0.5 * m_2\ddot{x}_1$$

For driving pulley,



After simplifying, the final equation is

$$T_3 = (M + m_1)R\ddot{\theta} + kR\theta \qquad (3)$$

Summation of (Inertia torque + External torque) = 0

$$\left(\frac{3}{2}M + 2m_1\right)R^2\ddot{\theta} + (kR^2\theta + k_t)\theta = 0 \qquad (4)$$

Equating (iii) and (iv)

$$(M + m_1 - m_2)R\ddot{\theta} + kR\theta = 0$$

VI. WIND LOAD

Definition - Load experienced by a member or a structure due to wind pressure acting on the surface is called wind load.The wind loads are the transient loads. The wind usually blows horizontal to the ground surface. The wind speeds are assessed with the aid of anemometers or anemographs which are installed at meteorological observatories at height generally varying from 10m to 30m above ground. The liability of the building or a structure to high wind pressures depends not only on geographical location but also upon the characteristics of the structure itself.The variation of wind with height depends primarily on the terrain conditions. The wind load depends upon terrain, height of structure, shape and size of the structure.For calculating the wind load, the wind speed at given terrain is noted from map and standard predetermined average values. The site location for this case is Pune. The standard value of basic wind speed for Pune is 39m/s (V_b).The design wind speed (V_z) is the wind speed for which the structure is designed which is calculated as

$$V_z = (K_1 * K_2 * K_3) * V_b$$

Where,
K_1 = Risk coefficient (Probability Factor) K_2 = Terrain, height and structure size factor K_3 = Topography factor
V_b = Basic wind speed V_z = Design wind speed

The values of K_1, K_2 and K_3 are taken from the standard tables and figures made by considering various conditions.

The wind load acting in a direction normal to a surface is determined by

$$W_L = \left(C_{pe} - C_{pi}\right) * A * p_d$$

Where,

W_L= Wind load acting on the structure C_{pe}= External pressure coefficient
C_{pi}= Internal pressure coefficient
A= Surface area of structure
p_d= Design wind pressure = $0.6(V_z)^2$
The values of Cpe and Cpi are taken from the standard tables
and figures made by considering various conditions.

VII. EXPERIMENTAL VALIDATION

Experimental validation will be done by comparing the results obtained theoretically (analytically) with the results obtained from the simulation software.
e.g.
The self-weight of one Y shaped truss will be applied on its C.G. point and results for stress and displacements will be obtained by treating the problem theoretically (F.E.A. theoretical calculations) and the results will be verified by simulation of the same component for the same load in simulation software (Ansys in this case.). If the results are approximately same for selected component, they will be similar for whole structure by the rule of finite element study.

VIII. CONCLUSION

For assuring operational safety of the newly build tower structure, it must be statically and dynamically analysed. As the structure is complex and having multiple members, the finite element method is best suited for analysis. The results can be confirmed after validation. The factor of safety against dead load is seen to be around 22 suggesting that the structure is safe.
The dynamic analysis must be performed to observe the behaviour of the structure under vibrations and dynamic actions.

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