NUMERICAL ANALYSIS OF HYPERLOOP TRANSPORTATION STRUCTURE

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Abstract - *The conventional mode of transportation of the present is by means of air, water and land and these methods of transportation are slow and some are even expensive. Hyperloop is a new method of transportation brought up by tesla group of companies and this can change the face of present transportation system. It is relatively fast and inexpensive. The passengers can travel long distances in very less time in Hyperloop pods which are capsule shaped vehicle model. This system uses electromagnetism and propulsion theory to travel at high speed inside a vacuum tube. In this paper the dynamics of Hyperloop supporting structures are explored. Since the hyperpod is said to travel at 600-900kmph it introduces dynamic responses that have not been observed in high speed trains. The stability of the structure with respect to the dynamic load movement is studied and the seismic analysis is also performed along with it. Therefore, in the preliminary design stage, the response of tube to the environmental load is the key point of the study. ANSYS software is used for vigorous dynamic analysis of the structure.*

Key Words: Hyperpod, Stability, Vacuum, Dynamics, Ultra high speed, Transportation, Pressure, Nonlinear, Tetrahedral mesh

1. INTRODUCTION

Transportation plays an important role in the economy. It cab increase the production efficiency and also it can link the logistics system. The land transportation comprises of rails and road network. Carrying of goods is easy via rail transport system and the traffic congestion is nil. The main disadvantage is that it uses fuel in greater rate and the material usage for construction is also high. The climatic condition doesn't affect this transportation system. Road networks are more complex but more flexible. It has the ability to move vehicles fast and different routes can be taken into account for reaching a destination and it can have door to door services. The construction cost is high and this system is greatly affected by climatic conditions. The productivity is very less. The air transportation system is more fast than any other present system but the initial cost is high and it completely depends on climatic conditions. The same is with waterway but the speed is very low.

People are still using the nonrenewable source i.e. petroleum for transportation system and the use of electricity for such systems are under development. This has caused in research into new transportation systems and use of alternative fuel sources for developing the system. Here the Hyperloop structures are working under electrical energy. Hyperloop is a new method of transportation system which is quick and inexpensive for travelling from one place to another for people and also for carrying goods.

Fig -1: Hyperloop concept

1.1 Objective

- To study and analyse the deformations of the Hyperloop structure
- To study and analyse the different vibration response of the structure and also resonance condition.
- To analyse the concept in real world scenarios

1.2 Scope of work

The scope of the study are listed below:

- Hyperloop structures are very important in case of structure with large spans or heavy loads
- To perform the numerical analysis of Hyperloop structure subjected to static and dynamic action

2. MODELLING

The Hyperloop tube is of steel and it has a concrete bed inside with aluminium rails attached to the concrete bed as shown in figure below. The tubes are of length 15m and they are connected by weld at inside and rivet joints throughout the exterior extruded portion. The tube has to be sealed completely because the environment of the interior of the tube is considered to be nearly vacuum i.e. of a low pressure about 100Pa. The tubes are supported at every 30m interval by fixed supports or pylons which are not designed because the main are of concern is the Hyperloop tube. In between the tube and the support on which it rests a PTFE bearing is considered for damping purpose and its assumed with damping ratio 5%. Some of the important properties of the materials used are listed below in the table.

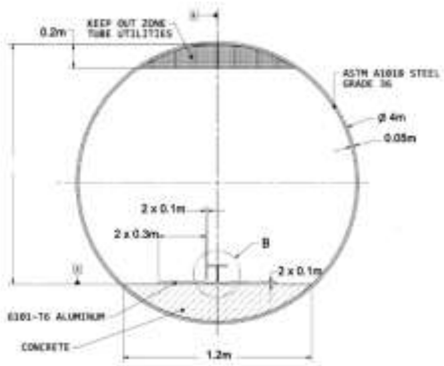

Fig -2: Cross section of the tube

Table -1: Properties of ASTM A1018

Property	Value
Density	7.88 g/cc
Tensile strength, Ultimate	≥ 365 MPa
Tensile strength, Yield	≥ 250 MPa
Elongation at break	≥ 22%
Modulus of elasticity	200 GPa
Electric resistivity	0.000142 ohm-cm
Thermal conductivity	89 W/m-K
Shear modulus	78 GPa
Poisons ratio	0.29
Carbon component	0.14 – 0.20 %
Iron component	98.91 – 99.26 %

ASTM A1018 is a standard specification for hot-rolled, heavy-thickness coils of carbon steel, commercial steel, drawing steel, structural steel, high-strength low-alloy steel and ultra-high strength steel. The specification covers steel coils in thicknesses of 0.230 in. to 1.000 in. A1018 Structural Steel (SS) Grade 36 has specified minimum yield strength of 250 MPa.

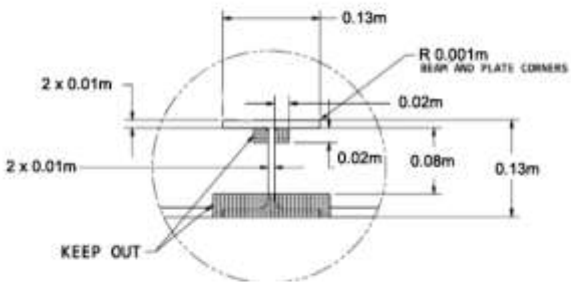

Fig -3: Aluminum rail cross section

Table -2: Properties of Aluminum 6061-T6

Property	Value
Density	2.70 g/cc
Tensile strength, Ultimate	310 MPa
Tensile strength, Yield	276 MPa
Modulus of elasticity	68.9GPa
Ultimate bearing strength	607 MPa
Bearing yield strength	386 MPa
Electric resistivity	0.000142 ohm-cm
Specific heat capacity	0.481 J/g
Thermal conductivity	89 W/m-K
Shear modulus	26 GPa
Poisons ratio	0.33
Carbon component	0.14 – 0.20 %
Iron component	98.91 – 99.26 %
Magnesium component	0.60 – 0.90 %
Phosphorous component	≤ 0.040 %

Wrought aluminum alloys, such as the 6061 alloy, are worked by extruding, rolling or forging them into specified shapes. The alpha-numeric suffixes attached to alloys, such as 6061-T6, represent the temper, or degree of hardness. They also represent the method by which the hardness was obtained. In the case of 6061-T6 aluminum alloy, the "T6" indicates that it was solution heat-treated and artificially aged.

The models are generated and ground to solid longitudinal connections is assigned. Since the model is symmetrical in shape a split is made and half of the symmetric section is considered for the further analysis procedures.

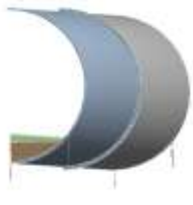

Fig -4: Exterior view of the symmetric section of model

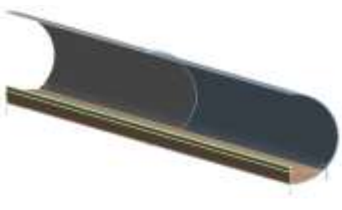

Fig -5: Interior view of the symmetric section of model

2.1 Meshing

In Hyperloop model a mesh size of 50mm is used throughout, with 42997 number of nodes. Tetrahedral shaped meshes were used. The more the finer the more the time it takes and more is the accuracy. Mesh convergence is advised to be done before fixing the size of the mesh to be used in solving out the problem. The concrete bed were used to have a rectangular shaped mesh.

Fig -6: Meshed structure

3. ANALYSIS

In this section the analysis like Static analysis, Dynamic analysis, Time History analysis and Modal analysis. Each analysis has a set of loading and boundary conditions that need to be applied for performing the analysis.

3.1 Static Analysis

In the static position or while hyper pod is resting on its guide way, the thickness of the air gap between vehicle and guide way is nil. Therefore, the total load of the vehicle weight will be transmitted to the guide way. The load that is considered for static position is 20 tonne which is the maximum condition. The static analysis is performed for the Hyperloop tube model and the analysis results like total deformation and directional deformation are listed below.

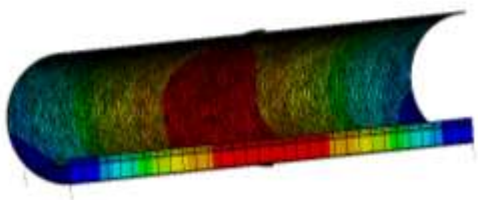

Fig -7: Static deformations of the structure

3.2 Transient Analysis

The dynamic load primarily considered is the train dynamic load. The response vibration of a stress wave induced by the track structure at the wheel rail interface was employed as the train dynamic load. The following figure 5.3 representing the variation of train dynamic load (wagon force) with time for velocity of 50kmph without considering the Fast Fourier Transformation (FFT).

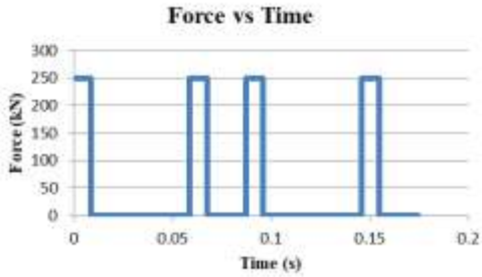

Fig -8: Dynamic loads without FFT (50 kmph)

The proposed speed of Hyperloop system is about 800-900kmph. The velocity which is considered for this study is about 900kmph. The hyper pod dynamic load (train dynamic load) with time for velocity of 900kmph was calibrated with respect to the Fourier series coefficient and the corresponding principal frequencies from 0 to ∞. The dynamic load after performing the Fast Fourier Transformation is shown in figure below.

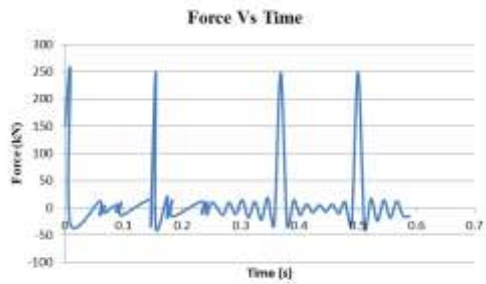

Fig -9: Dynamic loads with FFT (900 kmph)

Based on the above calibrated graph the dynamic load is applied throughout the length of the rail (considering the same hyper pod length as 30m) as shown in the figure below.

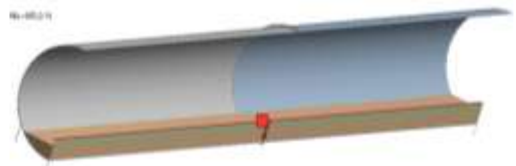

Fig -10: Load acting downwards throughout the rail

Fig -11: Total deformation in transient analysis

4. CONCLUSIONS

Based on the numerical analysis the following conclusions are drawn;
The deformation is maximum at the middle portion of the structure in dynamic analysis. the static analysis results are satisfactory but the dynamic results shows a large deflection value which are not permissible. The natural frequency of the model doesn't match with any operating frequency at any time and thus no resonant condition occurs. Since there is no proper codal provisions to check the limiting values of these results it is hard to find a proper conclusion for the analysis results. Some euro code transportation based clauses can be related to this model and the shell structures design and analysis can also be related to the tube model. Since the maximum value was observed in the center of the structure either it can be redesigned or can be checked by giving a support at every 15m span, but this increases the number of pylons and the construction cost also increses with respect to that.

4.1 Future Scope

- Since speed of this transportation system is very high the dynamics play a vital role in this design. The amplification factor study can be considered.
- The use of dampers and stiffener in this design is also a vast area for study because since a heavy load passes over this structure via levitation damping and stiffener components has to be designed accurately to ensure more stability of the structure during and ground motions.
- Since the tube is cylindrical in shape and the environment inside is having a very low pressure, buckling analysis can be done.
- Seismic response check of the structure has to be done vigorously

REFERENCES

[1] Van Goeverden CD, Van Arem B, Van Nes R (2016) Volume and GHG emissions of long-distance travelling by western Europeans. Transp Res D 45:28–47.

[2] Lee DS, Fahey DW, Forster PM, Newton PJ, Wit RCN, Lim LL, Owen B, Sausen R (2009) Aviation and global climate change in the 21st century. Atmos Environ 43:3520–3537.

[3] European Commission (2014) EU Energy, Transport and GHG Emissions, Trends to 2050, Reference Scenario 2013. Publications Office of the European Union, Luxembourg

[4] Musk E (2013) Hyperloop Alpha. SpaceX, Texas http://www.spacex.com/sites/spacex/files/hyperloop_alpha-20130812.pdf

[5] Abdelrahman AS, Sayeed J, Youssef MZ (2018) Hyperloop transportation system: analysis, design, control, and implementation. IEEE Trans Ind Electron 65(9):7427–7436.

[6] 6. Braun, J, Sousa, J, Pekardan, C (2017) Aerodynamic design and analysis of the hyperloop. AIAA Journal 55(12):4053-60

[7] Chin, JC, Gray, JS, Jones, SM, Berton, JJ (2015) Open-source conceptual sizing models for the hyperloop passenger pod. 56th AIAA/ASCE/AHS/ASC Structures, Structural dynamics, and materials Conference, Kissimmee, Florida.

[8] Janzen R (2017) TransPod ultra-high-speed tube transportation: dynamics of vehicles and infrastructure. Procedia Engineering 199:8–17