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CFD analysis of maglev train for high speed corridor project

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Abstract — It is always important to have knowledge of the fluid flow in case to find out the aerodynamics performances. Indian government has decided to implement High speed train project for the better transportation. In this article the proposed model of Maglev Train for this project is suggested. A scaled geometry model is proposed and Computational fluid dynamic (CFD) analysis is done by using Ansys Fluent software, the possible results from these CFD analysis such as Total Pressure is then used for structural analysis purpose. Through the structural analysis possible stresses are found. To interact the CFD analysis result and structural analysis fluid structure interaction. (FSI) is used, For CFD analysis the model is enclosed in enclosure as per boundary conditions, air is given to inlet and output as pressure and then air is passed over this model from inlet . The stresses found from structural analysis are suggested

Keywords— FSI; Maglev Train; CFD

1 INTRODUCTION

In the current scenario, evolution of technology is rapid and very fast so that it becomes need to adapt these new technology to compete the world as well for betterment of any country. This technology can be used in transportation also, for comforts as well to reduce the travel time in case of rail transport too much development has been carried out and new technology is the only reason to happen this .Now a days to many countries uses the Maglev technology for transportation purpose and it have many more advantages over existing rail system .Here in this paper the proposed model is presented.

1.1 Principle of Maglev Train

The principal of a Maglev train is depends on a magnetic field and is propelled by a linear induction motor. These trains follow guidance tracks with magnets. These trains are generally referred as Magnetically Levitated trains and abbreviated as Maglev trains. In fact Maglev trains do not use steel wheel on steel rail usually associated with trains. As the Magnetism in elementary science states that like poles repel to each other and opposites poles are attract to each other. When two magnets of the same poles are towards each other a repulsion force can be felt and likewise a pair of the opposite poles will attract to each other. Maglev trains use these basic principles to force the train in the upwards direction above the track surface

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So now it comes to us to establish the levitation part, in order to move train in the direction we want to go then Maglev trains use the principles of linear induction and magnetism to propel the train forward or backwards. Now if we imagine the train is levitated by using magnetism upwards in the direction as well as forwards then the combination of repulsive and attractive magnetic force causes the train to move towards a region to track. In the same way in order to slow down the train while it is moving in that case we must apply the repulsive and attractive force in such a way that just opposite to which the motion started.

1.2 Working of Maglev Train

A Maglev train floats 10 mm above the guide way on a magnetic field. It is propelled by the guide way itself. Once the train is pulled into next section the magnetism switches so that the train is pulled on again. In order to understand how Maglev trains work requires some knowledge then the advance topics such as calculus, physics, and chemistry must be known. It is also important to know how common variables are assigned to physics terms and a brief overview of chemistry laws which are related to magnets. Most of the equations used to determine how the Maglev trains move is derived from formulae used to calculate electric current, induced voltages loops, and many other formulae dealing with electromagnetism.

One of the first concepts that from the basis of how Maglev trains work understands magnetism and use of magnetic propulsion. If you were to have a bar magnet you should know that one end is designated a north pole while the other end is to be South Pole. Now suppose you are given a second bar magnet experimenting with if you will find that opposite poles attract while attractive poles repel. This simple form of attraction and repulsion is the same idea used to move those Maglev trains. Since the magnets needed required enough strength to move a train engineers have devised, the Maglev train using electromagnets and superconducting magnets. Electromagnets are metals with electric current running through them giving the metals a magnetic field similar to that of the bar magnets and superconducting magnets are able to induce charge, or give charge, to a material causing repulsive forces.

1.3 Basics of High Speed corridor Train

High speed train is a new way of transport and an integration of the latest high technologies in the field of transportation. Research on vehicle structure has been always a very active area over the last few decades. The high speed corridor train technology is the modern technology in Transport system. The high speed corridor train is the fastest commercial train currently in operation and has a top speed of 430 km/h (270 mph). This technology is more superior to the conventional train system. High speed trains shape design especially its head and coach shape has great impact on the aesthetic performance and aerodynamic performance. The shapes of high-speed train with optimal synthetic aerodynamic performance can efficiently reduce the influence of the aerodynamic phenomena on the train operation and the environment. And the whole train aerodynamic performance is influenced by streamlined shape. In order to reduce air drag and improve its aerodynamic performance, people usually pursue optimal shape of high speed train. The shape of train should be such that it should reduce the air drag and provide wind stability. Reducing the air drag will reduce the energy demand for trains and its cost. Limiting the air drag increases the stability. Liming drag and increasing stability increases the acceleration which will in turn reduces the travel time.

Advantages of High speed Trains

1. A reduction in travel times;
2. A reduction in pollution of air, land, water - environmentally-friendly effects with lighter construction materials;
3. The need to reduce rising operating costs of traditional; transportation devices such as airplanes, autos, buses, and trains;
4. Enhanced travelling experience with aesthetic qualities of greater comfort, provision of online services, and spacious seating; and
5. Promoting economic integration.

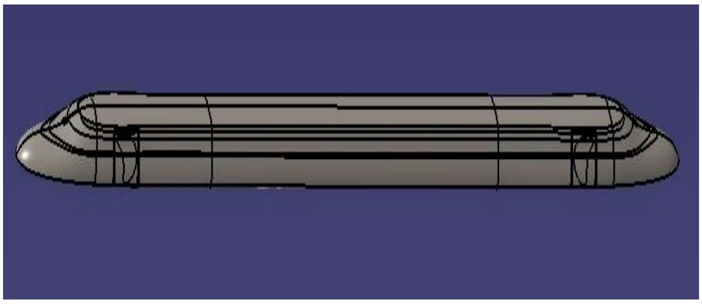

Fig1. Outer CAD model of Proposed Maglev train for high speed corridor

2 Simulation Work

The main objective of this article is to determine the pressure variation and velocity variation along the geometry as well as the possible stresses for Indian Conditions. Determining the pressure variation along the geometry will help in determining the maximum pressure and pressure variation along the geometry. This will help in implementation of high speed train project in India.

In this article we will focus on the basics of aerodynamic analysis, the simulation. Before going to simulate actual geometry of the train model the fluent set up is prepared for this problem and applying it over the train model and the result obtained from the fluent is used to find out effect of it over the train and for that purpose the Fluid Structural Interaction will be carried out and final CFD analysis will carried out.

Before going to direct CFD analysis few aspects must be discuss here and those are as follows

2.1 Basics of Aerodynamics

Aerodynamics is a branch of fluid dynamics concerned with studying the motion of air, particularly when it interacts with a solid object. Aerodynamics can be studied by using Computational Fluid Dynamics (CFD), wind tunnel. Aerodynamics, the effects of air flow over surfaces, is an indispensable element for modern vehicle efficiencies, both economics and performance related, because aerodynamics helps to decrease the drag force, makes cars more stabilized and gives a chance of reducing fuel consumption. One of the significant benefits of aerodynamics is increasing performance by reducing the drag force and making the car more stabilized. To begin with the basics of aerodynamics, the effect of air flow stands out. Basically the formula is,

$$Fd = Cd * (\rho AV^2 / 2)$$

Where Fd is the drag force,

'ρ' is the density of the fluid,

'V' is the speed of the object relative to the fluid.
'Cd' is the drag coefficient which varies with the geometry of the surface and
'A' is the projection area over the plane normal to flow direction.

As seen from the formula, the bigger the frontal area is the more unwanted drag force occurs. Passing through the air by less separating the gas molecules from each other in the atmosphere as much as possible is the approach to mold an aerodynamic car. This makes it clear that reducing drag means lower energy is needed to accelerate or to increase top speed.

In this paper the pressure distribution, velocity distribution along the coach is studied. The pressure distribution helps in knowing the maximum pressure acting on geometry, its location which will help future researchers' to design optimum shape of high speed train for Indian conditions. The velocity distribution helps in determining the velocity profile along the given model.

2.2 Basics of passenger coach

A passenger car (known as a coach or carriage, and also known as a bogie is a piece of railway rolling stock that is designed to carry passengers. The term passenger car can also be associated with a sleeping car, baggage, dining, railway post office and prisoner transport cars. The passenger coach of the train should be Lightweight, airtight, pressurized for tunnels and crossings, Very low weight per seat. It should be provide with the Articulated with anti-overturning and anti-vertical hunting mechanisms, improving stability on travel. The coaches should be made up of light weight material and it must be resistant to corrosion. The passenger car should provide high degree of comfort, low energy consumption, and should provide high safety. It should provide optimum aerodynamics performance.

Fig. 2. Train Passenger Coach

2.3 CFD analysis of geometry model

Problem set up

Solver : ANSYS FLUENT, Pressure based
Time : Transient
Models Viscous Model : K-epsilon (2-eqn), Realizable model with Realizable wall functions
Material: Air IDEAL
Boundary Conditions: Velocity Z component -30m/s, Enclosure having zero shear, Surface Train Wall is with NO SLIP Condition.
Solution Methods: SIMPLE Scheme solver, standard discretization methods
Time based problem we considered least time steps like 1secends to evaluate the flow patterns and gradients.

2.4 CFD Result

As our aim is to find out the pressure variation and the velocity variation so the result are just taken of the pressure and velocity only which are as follows

Total Pressure at Mid Plane

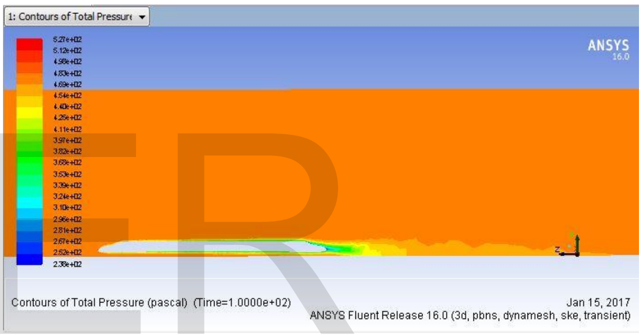

Fig.3 Contours of Total pressure

From the above Fig. it can be seen that how the flow pattern is developed at the end of the train here the maximum pressure id obtained as 527 N/m2 and minimum total pressure is 233 N/m2
The result are shown over the mid plane because to identified the effect over the surface of the train

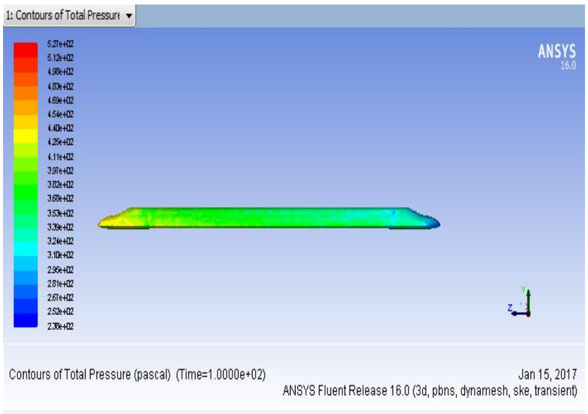

Fig.4 Contours of Total pressure – side view

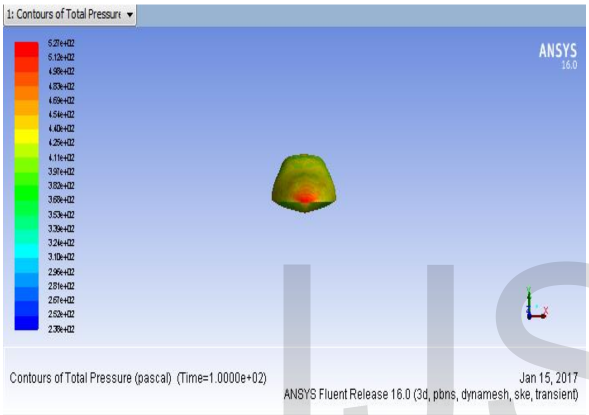

Fig.5 Contours of Total pressure – Front View

Velocity Vectors

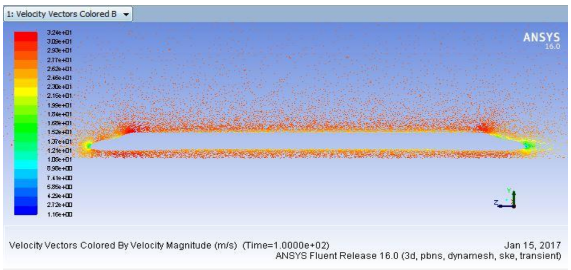

Fig.6 Velocity vectors

As we can see from the above fig. the maximum velocity vectors at both head and it is recognizing by red color where as minimum is blue color. Velocity vectors are denoted by an arrow.

2.5 Fluid structure intraction

Here in this paper the Transient structural analysis is used because the results obtained from the CFD are used to do the find out the stresses which will act over the surface of the train as well as different components such as I section, C section. In order to find out these stresses we must to do Fluid Structure Interaction (FSI).

FSI RESULTS

1) Equivalent stress

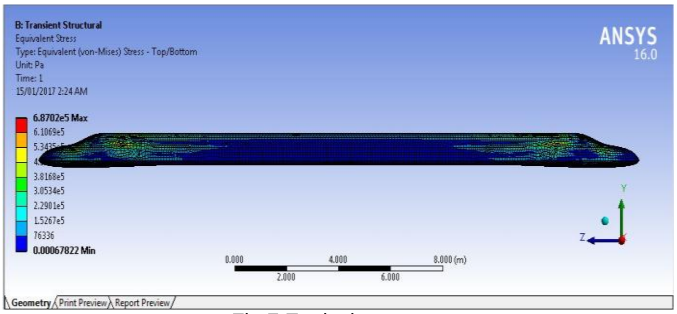

Fig.7 Equivalent stress

From FSI the equivalent stress are induces as clearly seen from above fig and is max with the value 6.8702e5 this stress will consider while in design the I section

2) Total deformation

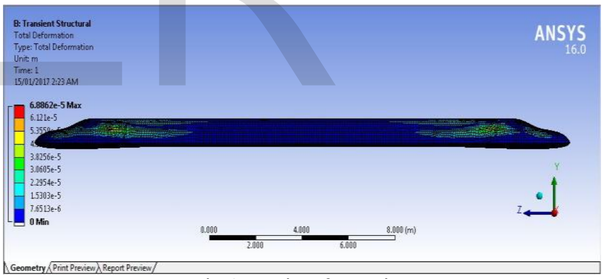

Fig.8 Total Deformation

From FSI result the total deformation of the train can clearly seen from above fig and is max with the value 6.8862e-5 meter This much deformation will obtained when the train runs at the velocity of 30 m/s inside the tunnel region.

3) Normal Stress

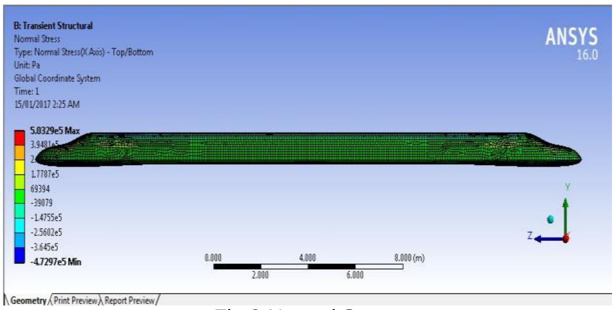

Fig.9 Normal Stress

From FSI results normal stress are induces as clearly seen from above fig and is max with the value 5.03298e5 Pa. This will help in final conclusion of the Problem

4) Shear Stress

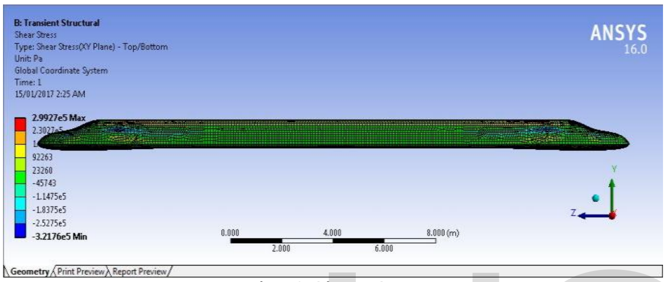

Fig.10 Shear Stress

The shear stress along XY plane can easily see from the above fig the max. Shear stress along the XY plane is 2.9927e5 pa. This much Shear stress will induces while train running through tunnel section

3 Conclusion

In this paper proposed model of Maglev train model is presented and simulation is done through Ansys fluent software as a result total pressure is obtained and is 583 Pa. It show how the fluid pattern develops while air passing over the train through enclosure fluid structure interaction is carried out so that it possible to find out maximum stresses which acts over the train surface and obtained results are quite good with given input Pressure.

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