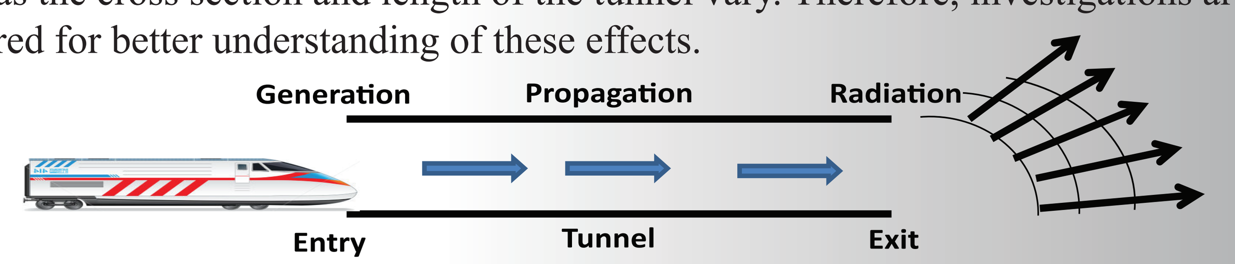
UNIVERSITY OF BIRMINGHAM

AERODYNAMIC OF TRAINS IN TUNNELS

1. Background

The continuous demand of increasing train operating speed raised more aerodynamic concerns both in open air and confined spaces such as tunnels. When a train moves in open-air, it generates regions of highly turbulent flow known as slipstream. The slipstream is generally associated with high air velocities and rapidly-changing pressure fields which can create significant problems for passengers on platforms and also for the trackside workers. However, when a train passes a confined space such as a tunnel, additional aerodynamic issues appear, which are different than those in the open air. This can be explained through the underlying phenomena such as the compressibility of the air around high-speed trains due to running in a confined space. This generates pressure transients propagating along the tunnel and radiated from the tunnel exit. The flow inside a tunnel can have different properties if the particular geometry parameters such as the cross section and length of the tunnel vary. Therefore, investigations are required for better understanding of these effects.



2. Aims and objectives

From the available literature it has been found that the effect of the tunnel length on both the flow and pressure fields around the train and inside the tunnel has not been properly investigated. Thus the aim of this research is to study a moving train model in a single-track tunnel using numerical simulations. In order to fulfill this aim the following objectives are set:

1. **carry out a critical literature review of the flow around trains in tunnels,**
2. **gain an appreciation of the different methods of investigating the flow around trains in tunnels with a specific emphasis on computational techniques,**
3. **create a generic train model for use in the numerical simulations and validate the numerical model with the results from the literature,**
4. **create a train model (ICE2 train model) similar to the one used in Gilbert et al., (2013) and perform a numerical simulation around the train in a short tunnel length to obtain the flow and pressure fields,**
5. **repeat the numerical simulations in Objective 3 with a double tunnel length,**
6. **compare the results (velocity and pressure fields) obtained from the simulation with short and long tunnels and thus investigate the effect of tunnel length.**

3. Numerical models

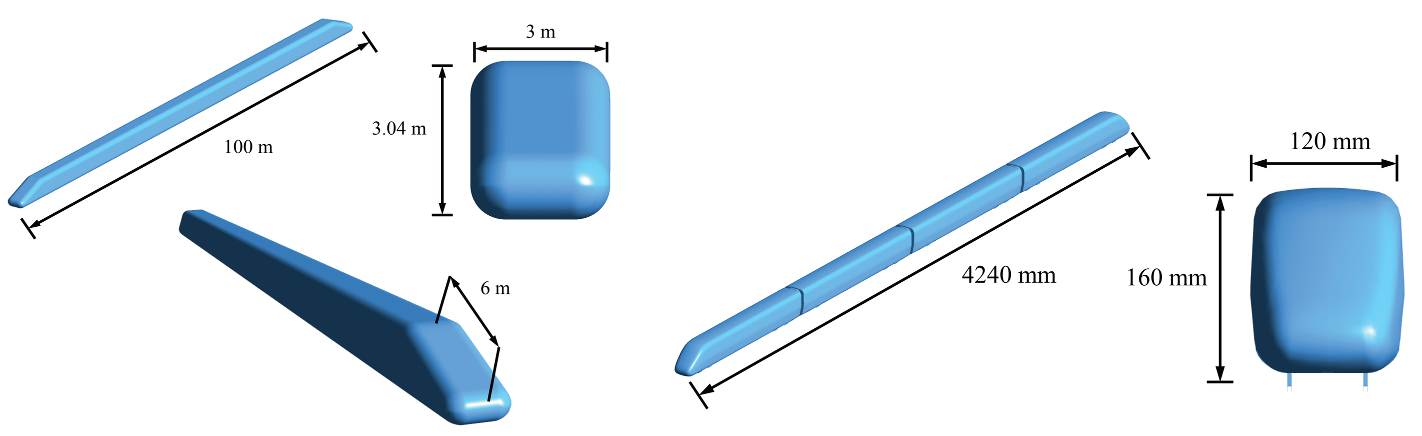


Figure 1: Dimensions of two different train models used in the simulations; generic train (left) and the ICE2 train (right)

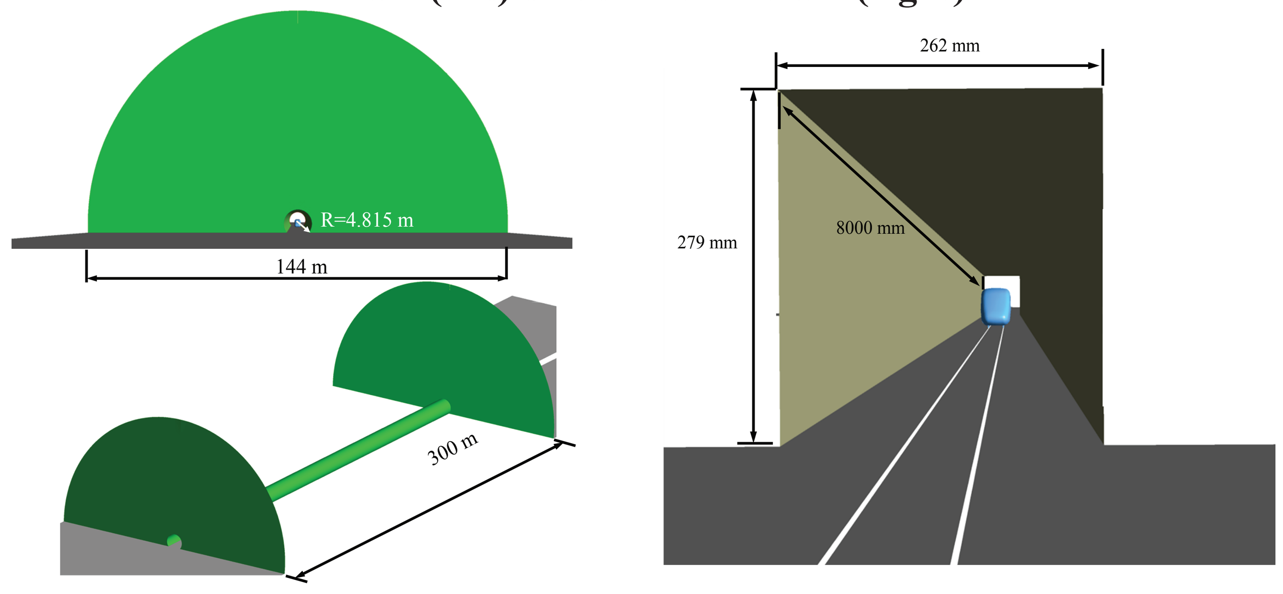


Figure 2: Dimensions of two different tunnel models used in the simulations; generic tunnel (left) and ICE2 tunnel (right)

ANSYS software package has been used to create both the generic and the ICE2 models. The dimensions of the generic model are in full scale while, the ICE2 modelling has been carried out in a 1/25 scale. The running speeds of the generic train and ICE2 train were set as 70 m/s and 32 m/s respectively. Generic train simulation has been carried out in order to validate the computational model. However, the ICE2 model has been created initially with a tunnel length of 8 m (known as short tunnel in this study) and then of 16 m (known as long tunnel) in order to investigate the effect of tunnel length on the results.

4. Results

The suitability of the numerical method and the effect of the tunnel length on the velocity and pressure around train passing through a tunnel have been investigated by performing the following simulations; 1.a generic train passing through a single tunnel, 2. a simplified ICE2 train passing through a short tunnel and 3. a simplified ICE2 train passing through a long tunnel. The CFD (Computational Fluid Dynamics) results for the generic train showed a good agreement to the AeroTRAIN project. This validates the computational model for further investigations.

Moreover, the results from the short tunnel shows that When the train enters the tunnel, a large vortex occurs at the front of the tunnel as the train drags air from the outside, into the tunnel. Some of this air comes from the environment above the tunnel to form a large circulation region as shown by the second invariant of the velocity gradient tensor in Figure 3 and the streamlines in Figure 4.

On the other hand, the results from the long tunnel in terms of the velocity profiles can be observed in figures 5 and 6. Figure 5 shows the symmetry plane coloured by the velocity magnitude and Figure 6 shows the same plane coloured by the longitudinal velocity component. The slipstream is observed as a small belt of air around the train which moves in the direction of train travel. The thickness of the slipstream is shown to increase along train length. Due to existence of measuring point located very close to the train, some reversed flow along the first car can be observed. After the first car, the slipstream is thicker and thus measuring point is immersed in it and the surface of the train and thus the velocity component is positive. Further simulation results of the flow for the short and long tunnels (velocity and pressure parameters) have been obtained and illustrated in the study.

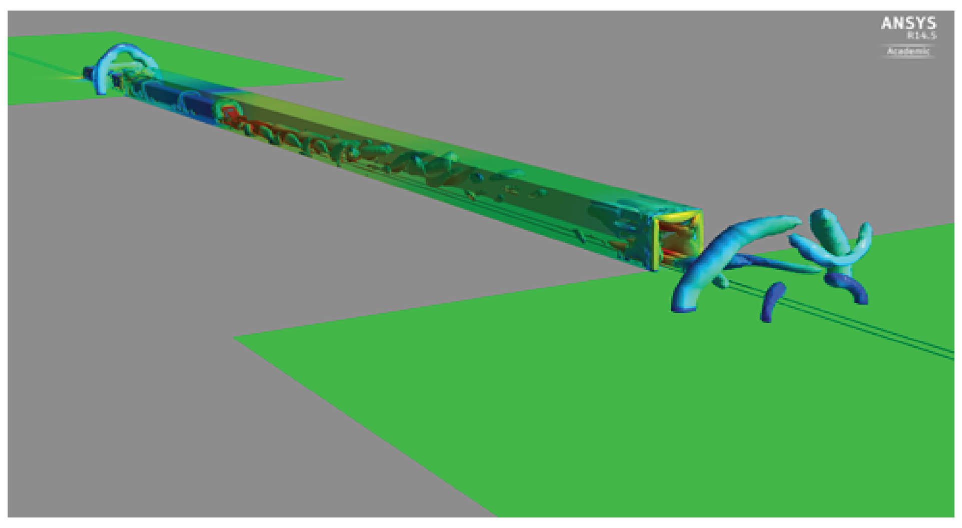


Figure 3: Short tunnel; Second invariant of the velocity gradient tensor in the short tunnel showing the large vortex at the tunnel entrance.

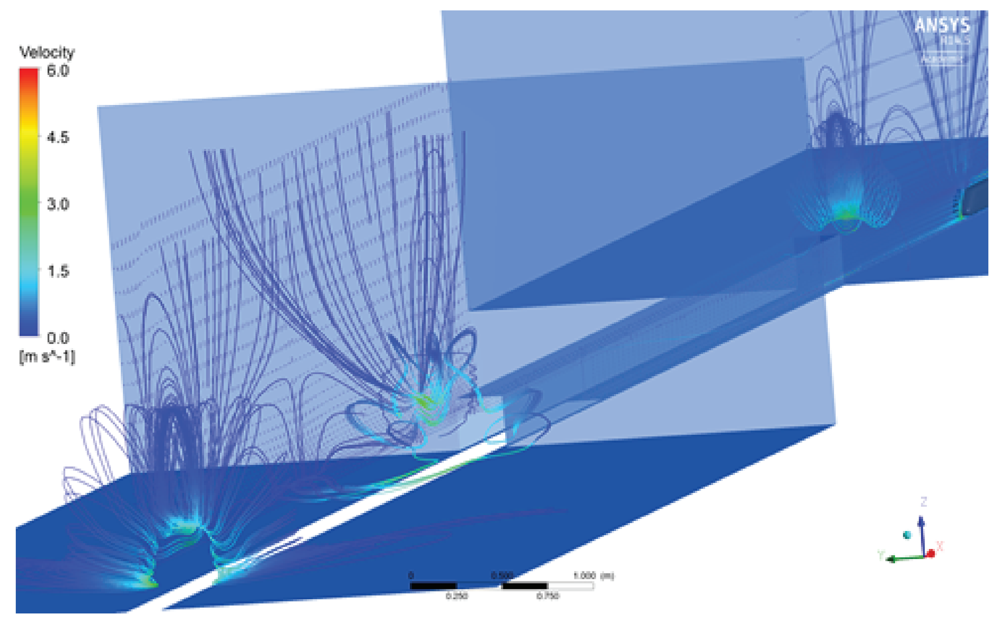


Figure 4: Short tunnel; Three-dimensional streamlines showing the large vortices at the entrance and exit of the short tunnel.

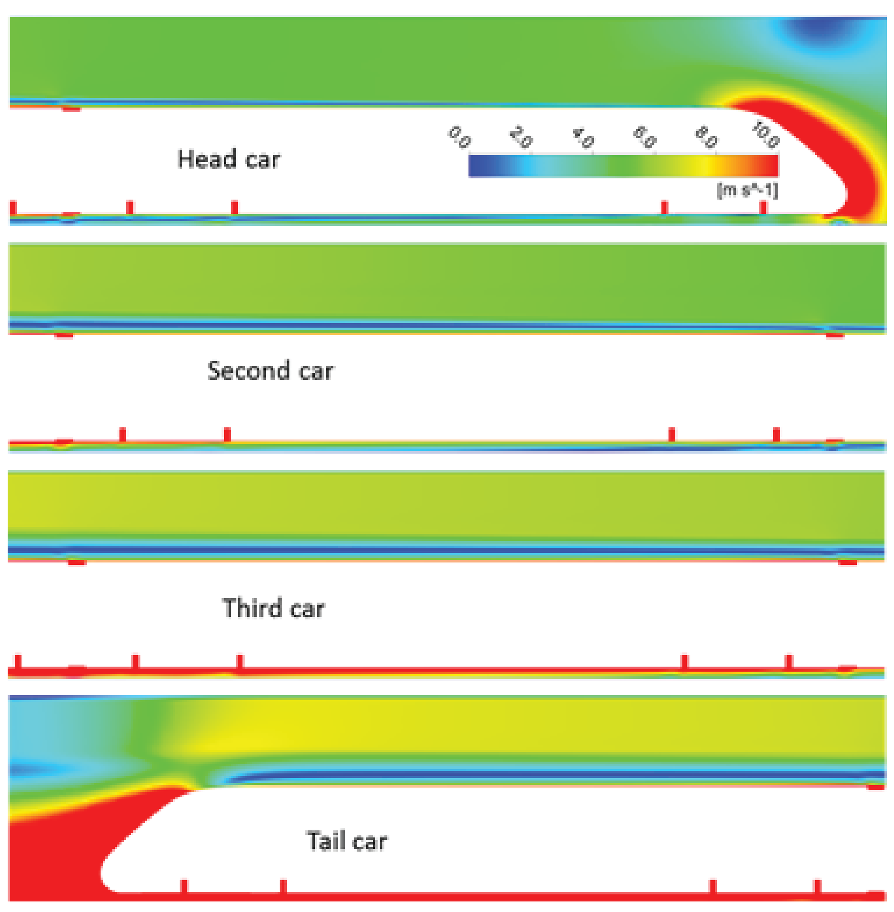


Figure 5: Long tunnel; Symmetry plane coloured by the velocity magnitude, showing the flow around the train in the tunnel

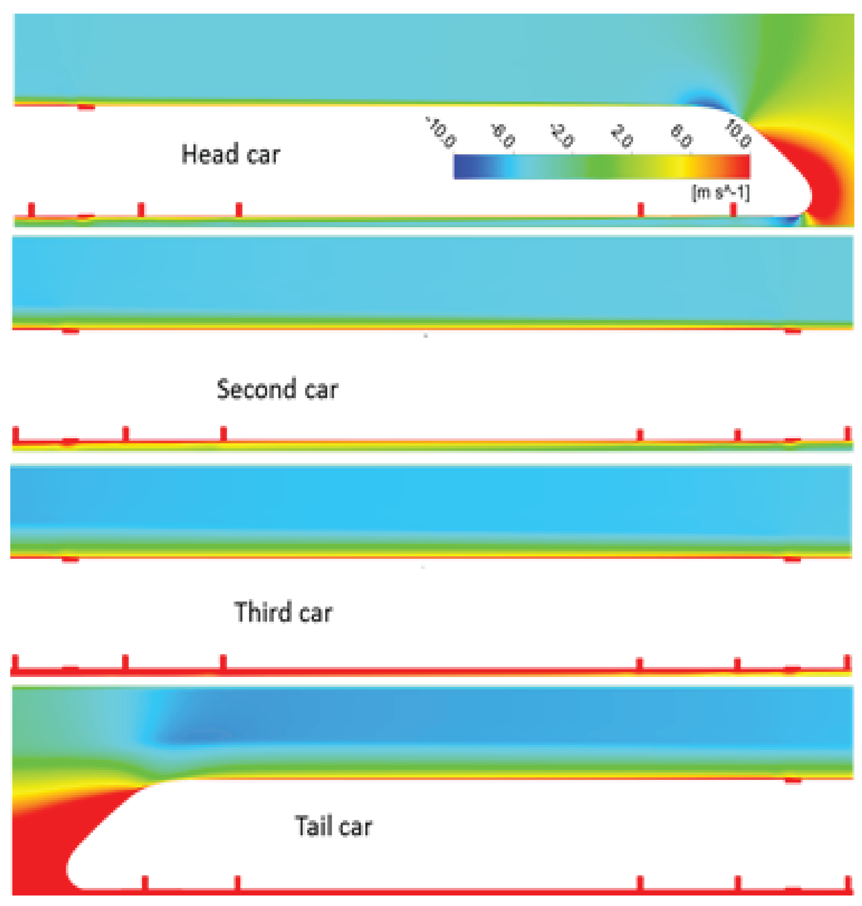


Figure 6: Long tunnel; Symmetry plane coloured by the velocity component in the direction of train travel, showing the flow around the train in the tunnel

5. Conclusions

Computational Fluid Dynamics was used to investigate the effect of tunnel length on the specific flow parameters. Based on the comparison between the simulations of the short and long tunnels, the following conclusions can be made:

- The pressure is the same for the same cross-sectional position in the tunnel.
- The maximum velocity and pressure in the tunnel occur when the nose of the train passes.
- Once the train passes a specific point in the tunnel there is a sudden reduction in the pressure and the air moves opposite to the direction of the train.
- Higher pressures are observed ahead of the train in the longer tunnel
- A sudden decrease in the tunnel pressure occurs when the tail of the train enters the tunnel and when the train nose passes.
- Although there is a large effect of the tunnel length on the static pressure in the tunnel, the pressure gradient is not affected significantly.

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