Effect of ballast shoulder height on a passenger trains slipstreams and wake

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1. Project background

The research being conducted is part of the EPSRC funded project "The measurement of train aerodynamic phenomena in operational conditions". This project aims to measure aerodynamic phenomena observed in real train operation and compare the results to model-scale measurements and Computational Fluid Dynamics (CFD) calculations.

2. Research introduction

The velocities and pressures within a trains slipstream are important flow characteristics that have an effect on the safety of both passengers and nearby personal such as railway workers. Within the Technical Specifications for Interoperability (TSI) requirements are specified for the maximum train slipstream velocities and pressures. The range of ballast shoulder heights allowed may lead to variations in both the measured pressures and velocities. This research investigates the effect ballast shoulder height has on velocities and pressures within the slipstream of a passenger train.

3. Experimental data

Within this research CFD results are compared to experimental results.

The experimental data was collected by another PhD student at the Moving Model Rig (MMR). The MMR is a facility owned by the University of Birmingham, it comprises of a 150m long track that the train is model is catapulted along. The MMR experiments used an adjusted class 43 High Speed Train (HST) model to account for the firing chassis, 25 runs were completed at a train speed of 40 m/s in order to provide an ensemble average of the data.

4. CFD setup

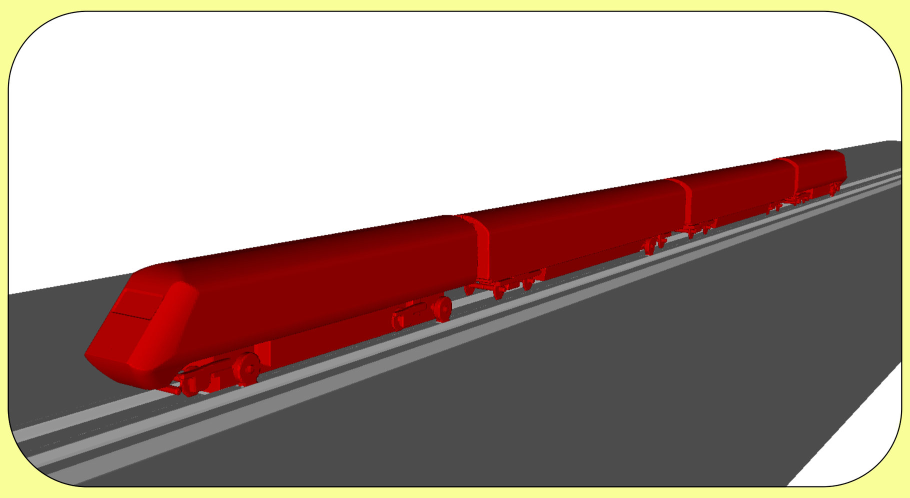


Figure 1: close up of the train mounted upon a rails and a scale equivalent 30cm ballast shoulder. Replicating one of three MMR tests conditions

The CFD approach chosen for this research is Delayed Detached Eddy Simulation (DDES). . The geometry used in the CFD experiments closely represents that of the MMR model with only a few simplifications around the launch mechanism, both geometries were 1/25th scale. Three simulations were run following a mesh sensitivity study, these three simulations were conducted with a single sided ballast shoulder at different heights. The heights investigated were 0m (flat), 0.3m and 0.75m at full scale. these heights were chosen as they provided a range of the more common UK heights.

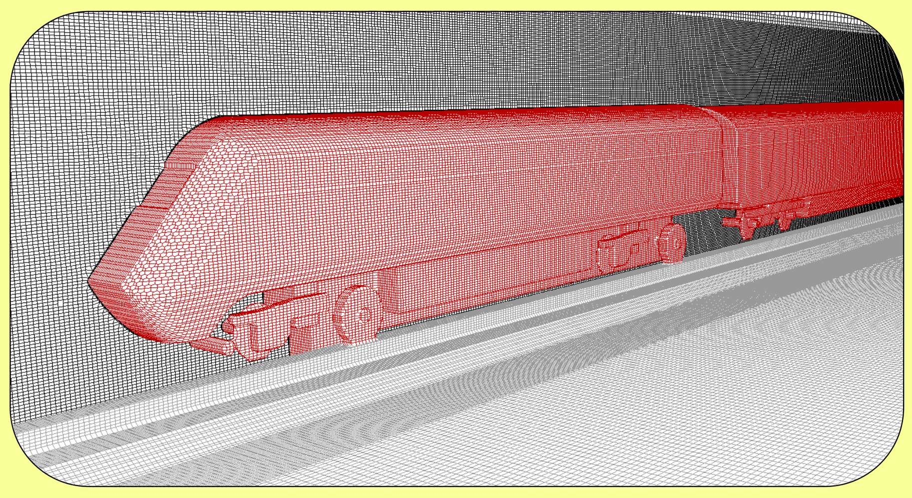


Figure 2: close up of the computational mesh for the 30cm ballast shoulder. The mesh comprises of 48 million cells that grow in size with distance from the train.

5. Results

Results obtained using the MMR and CFD are compared along multiple measurement lines, these measurement lines fall within the slipstream of the train, both pressure coefficient (Cp) and normalised velocity profiles are compared. Results for the Cp match well between experimental and CFD, small differences can be seen along the sides of the two passenger carriages. The Cp results show little variation due to ballast height, an example of this can be seen in Figure 3 where CFD and experimental data are compared. The results for the normalised velocity (Figure 4) show a much larger effect of ballast height, the results show that as ballast height is increased the velocity decreases. This reduction in velocity is due to the increased area for shed vortices to expand into. This effect can be seen by looking at the instantaneous results for shed vortices. Figure 5 shows Iso-surfaces of the Q-criterion, the Iso-surfaces show that a large proportion of the vortices produced are released from the under carriage. Due to its close location to the ballast edge these vortices can be seen to quickly roll down the ballast side.

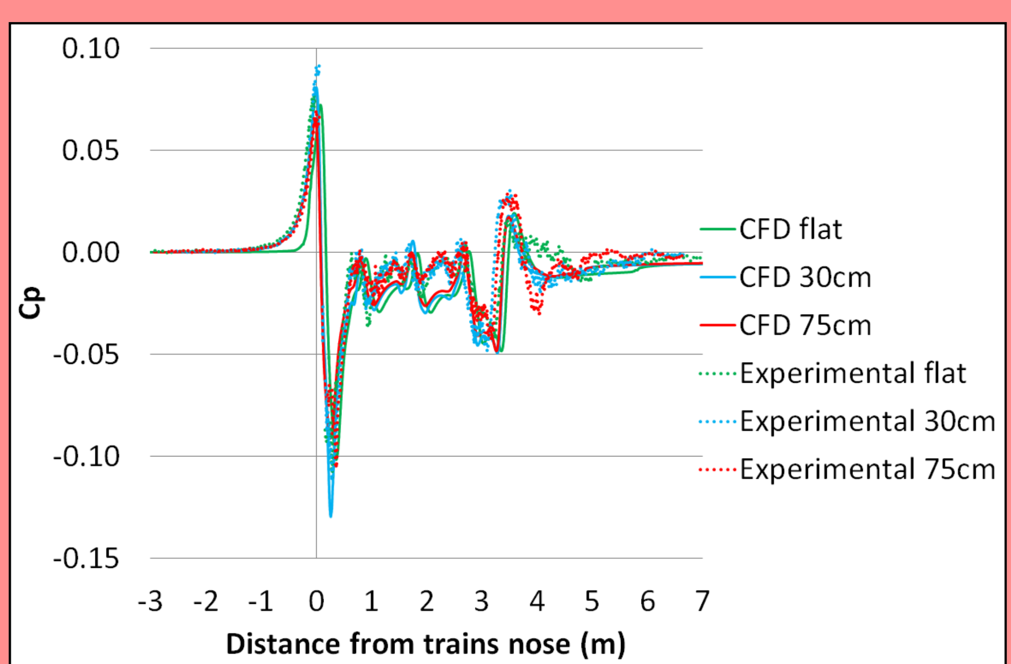


Figure 3: Comparison of CFD and Experimental predictions for the pressure coefficient along a measurement location within the trains slipstream at three ballast heights.

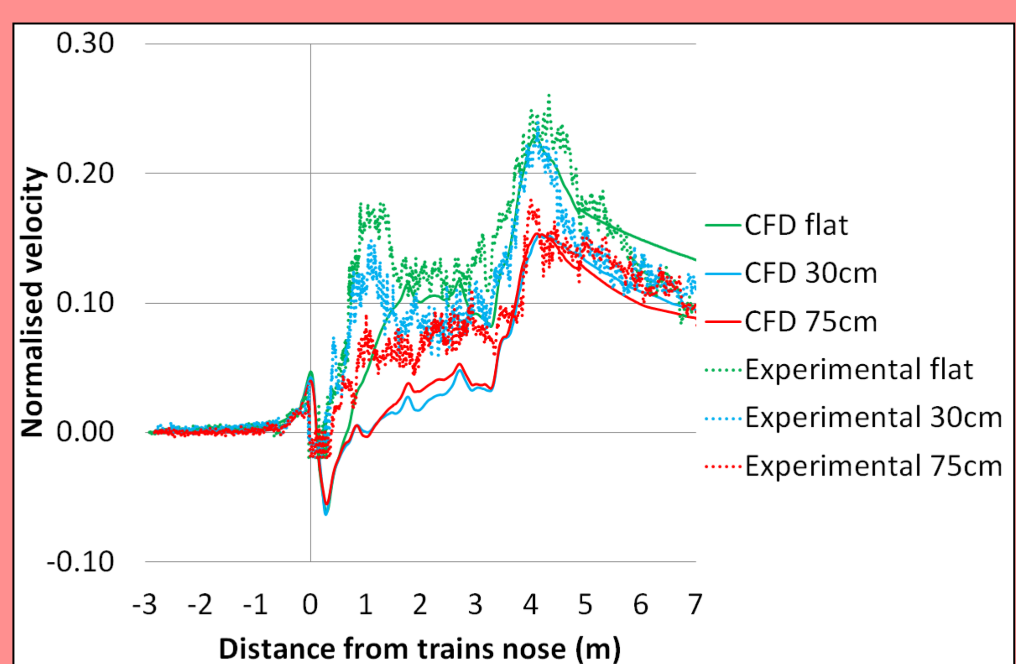


Figure 4: Comparison of CFD and Experimental predictions for the normalized velocity along a measurement location within the trains slipstream at three ballast heights.

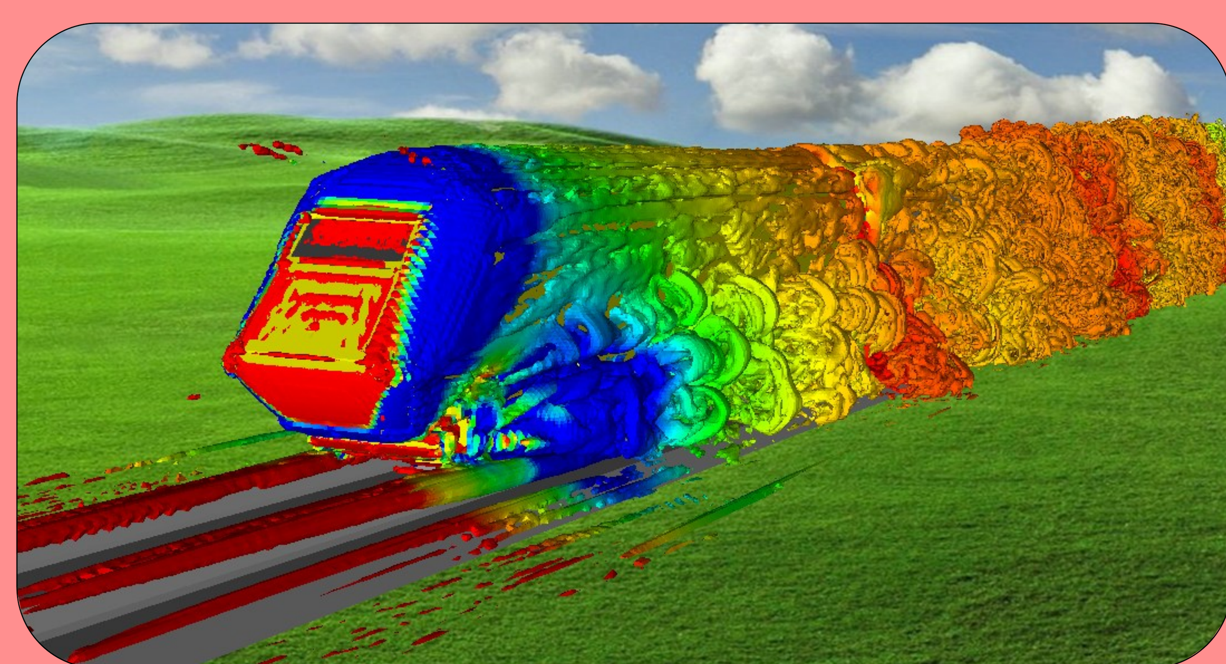
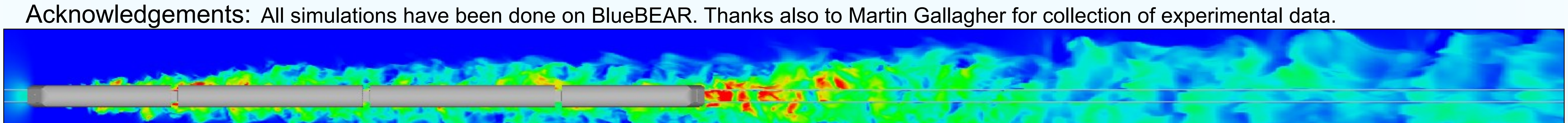


Figure 5: Instantaneous DDES results for a 30cm ballast shoulder. Iso-surfaces of Q-criterion showing the turbulence released from the train. Coloured by instantaneous pressures.

6. Conclusion

- Good agreement can be seen between both experimental and CFD results for the pressure profiles, whilst velocity agreement is not as good.
- Ballast height can be seen to have a large effect on the velocities within the slipstream and a smaller effect on pressures within the slipstream, with a height increase resulting in a reduction of both variable measurements.
- A large effect that occurs from single sided ballast shoulders is the wake is pulled towards the ballast shoulder side, this is due to the stronger and more frequent shedding of vortices on the ballast shoulder side.

Acknowledgements: All simulations have been done on BlueBEAR. Thanks also to Martin Gallagher for collection of experimental data.



Velocity contours at top of rail height. Blue = low velocity, Red = high velocity