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THE MEASUREMENT OF TRAIN SLIPSTREAM CHARACTERISTICS USING A ROTATING RAIL RIG

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1 INTRODUCTION

The movement of high speed trains through the atmosphere can result in significant air flow velocities at the side and in the wake of such vehicles. These velocities can in turn pose a safety risk for passengers and trackside workers, and can cause problems for pushchairs and luggage trolleys. These safety concerns have led to significant work in this field over recent years and a number of full scale and model scale tests have been carried out to measure these slipstream velocities. It will be shown in the next section that such measurements are by their nature difficult and time consuming, and involve measurements of repeated passings of model scale or full scale vehicles. This paper will present the results of a different type of techniques that uses an experimental set up known as a rotating rail rig that in principle allows such tests to be carried out much more rapidly. There are significant problems with the proposed methodology however, which will be detailed below. This investigation sets out to quantify these issues and to determine the level of experimental accuracy that might be obtained, using both experimental measurements and CFD calculations to bridge the gap between the proposed methodology and current measurement methods. This abstract presents the concept and some preliminary experimental work. Fuller details of the experimental results will be set out in the full paper.

2 CURRENT METHODS FOR MEASURING TRAIN SLIPSTREAM VELOCITIES

There are two current approaches to the measurement of train slipstreams – either at full scale through the use of trackside anemometry at different distances from the train which can measure the three components of wind velocity, or at model scale through the use of a moving model rig that fires model trains along a tests track, with the slipstream and wake velocities being measured by stationary hot film anemometry close to the track. In principle such tests can give all the required information for the assessment of passenger safety etc. However it is found that in both of these test techniques there is very considerable run to run variability in the data that is measured (as would be expected, since each run will provide one realisation of a very turbulent flow field) and that to obtain adequate results a number of identical tests need to be carried out (at least 10 and ideally 20) with the results being ensemble averaged to obtain mean and standard deviations of time histories [1]. Typical results obtained with 1/25th scale models on the TRAIR rig owned by DeltaRail in Derby, UK, are shown in Fig. (1) below. The wide variability between individual train passings is apparent, but the ensemble mean can be seen to be well defined. Reference [2] used such experiments to define the different flow regions around high speed trains – a nose region, a boundary-layer region, a near-wake region and a far-wake region. However neither full scale nor model scale tests are straightforward to carry out. Clearly at full scale to arrange 10 to 20 passes of identical train formations is logistically extremely difficult, but even at model scale it is only possible to carry out 8 to 10 runs of the moving model rig each day. In both cases obtaining the same train or model velocity over a number of runs, so that the ensemble average can be calculated is also far from straightforward.

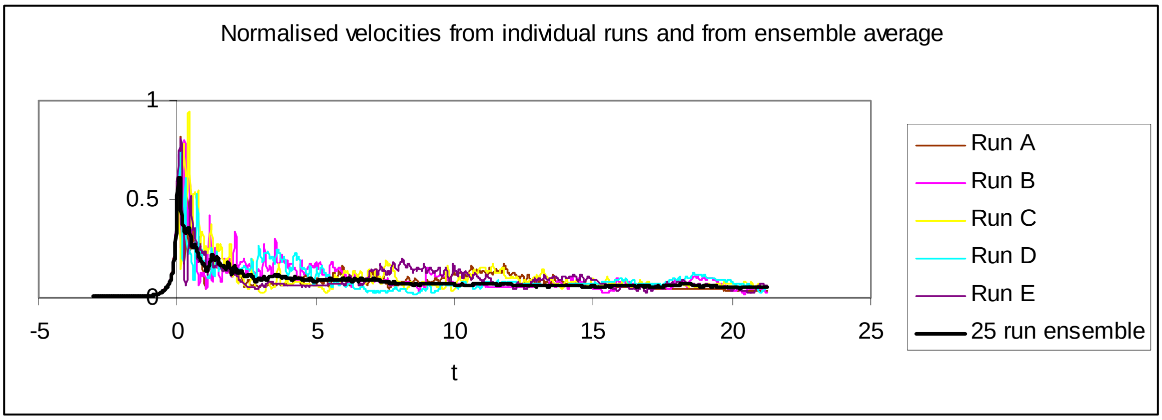

Figure 1. Model scale results for four car ICE train from the TRAIR rig (x axis shows time t normalised by vehicle velocity and train length, and y axis shows slipstream velocity normalised by vehicle velocity. Nose of train passes at t=0 and tail of train

3 THE ROTATING RAIL RIG

The rotating rail rig consists of a 3.61m diameter railway track on a frame that can be rotated at up to 118 r.p.m., which corresponds to a rail speed of 22 m/s, see Fig. (2). It was originally designed so that standard rail sections could be mounted on the frame to enable investigations into the removal of accreted organic matter using novel laser based techniques [4], and has since been used to investigate conductor shoe icing with a stationary conductor shoe held above the rotating rail whilst the temperature was lowered to below freezing conditions. In the current investigation a four car train model is fixed to the rotating rail via a clamp and a bolt (two sets in each carriage), so that they both move as a whole. In order to reduce the turbulence arising from the rotation of the wheel, as well as to provide a ground plane over which the train moves, a wooden platform with a circular slot slightly bigger than the rail is positioned above the rig. The gap between the train and the platform is closed with brushes. The way the train is attached to the rail, allows the carriages to be assembled and disassembled as required. Thus, measurements of the flow can be performed using any combination of the cars of the train. A schematic view is shown in Fig. (3).

The slipstream and wake velocities are measured using stationary Cobra probes (Turbulent Flow Instrumentation P/L) which are 4-hole pressure probes that can measure three components of velocity at speeds of up to 100 m/s.

The most important aspect of this rig is of course that multiple train passes can be achieved very quickly (one per revolution of the rig) and thus, in principle, experiments can be carried out much more rapidly than with the current full scale and model scale techniques.

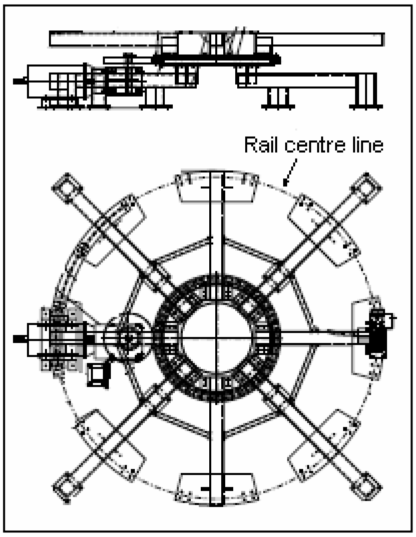

Figure 2: Rotating rail.

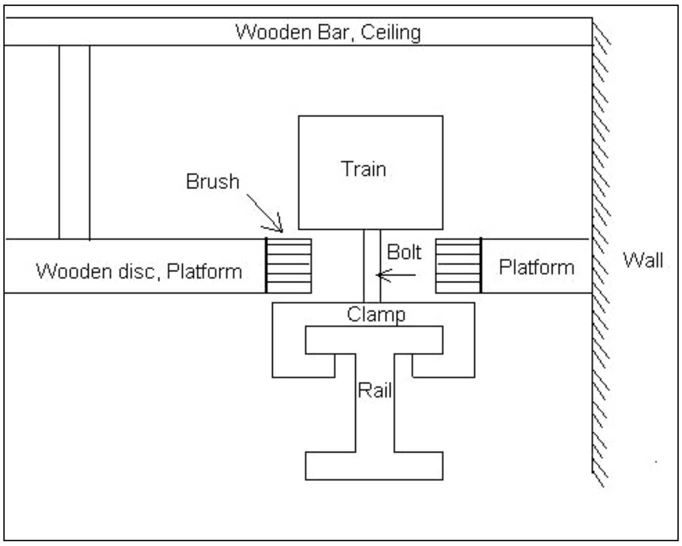

Figure 3: Rig components.

4 PRELIMINARY EXPERIMENTAL RESULTS

At the time of writing some preliminary experiments have been carried out using an existing 1/40th scale four-car train model. The problem that has emerged is that the length of these models (about 50 cm) is relatively large in comparison to the radius of curvature of the rig, and thus there are sharp discontinuities in train orientation at the end of each carriage. Also, the cross section is not constant along the train, so there is a significant variation in the probe measurement position from both the train top and side. In the next stage of the experiments a “curved” train will be constructed so that measurements are provided along “curved lines” next to the vehicle. However, the nose pulse is in broad agreement with the model results of [2] and [3]. Figure (4) shows the ensemble average of nose pulses measured at a distance of 10 mm over the top surface of the train, reaching a peak value of 0.346, which fits the range of values shown in Table (1).

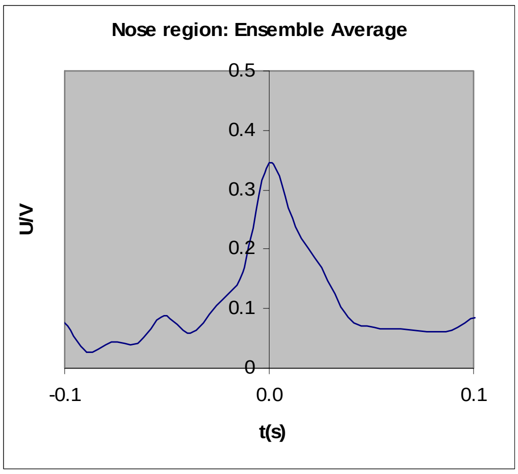

Figure 4: Ensemble mean of slipstream velocities for the nose region.

	Distance from train surface (mm)					
	5	15	20	30	40	80
Train Roof	0.364	0.2244	0.204	0.184	0.146	0.089
Train Side	0.278	0.209	0.178	0.166	0.134	0.081

Table 1: Maximum normalized nose velocities, ICE train from the TRAIR rig.

Taking into account that in the rotating rail rig a 1/50th scale ICE train model will be used, it is expected that the maximum normalised slipstream velocities, which take place in the nose region, obtained using the rotating rig will be similar to those achieved in the TRAIR rig (where a 1/25th scale ICE train model was employed), as shown in Table (1). Obviously, these results will be affected by the curvature of the train (the more carriages used in the test the higher the effect), taking a higher value in the concave side of the train than in the convex side [5, 6].

5 CFD CONSIDERATIONS

Clearly the large curvature of the rig places a severe limitation on its use, and makes interpretation of the results difficult. To understand this effect further, a series of CFD calculations will be carried out which will be validated using the experimental results using the curved train described above. Further CFD calculations will then be carried out for larger track and model radii, and will include the modelling of the straight track. The results for the different curvatures will then be compared, which should enable a judgement to be made concerning the minimum radius of such a rig that will enable the slipstream results obtained to be representative of the full scale situation and thus to make recommendations for the design of a larger more representative rig that retains the utility of being able to simulate many train passes rapidly whilst being more representative of reality.

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