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AERODYNAMIC FORCES ON MULTIPLE UNIT TRAINS IN CROSS WINDS

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1 INTRODUCTION

This paper reports the results of a series of wind tunnel tests that were carried out to determine the time average and the unsteady loads on a modern multiple unit train due to cross winds. These results were obtained as part of a project to investigate the relative movement of pantographs and overhead wires in high cross wind conditions. The overall project is reported in [1], and some of the unsteady results that were obtained are reported in [2] where a comparison is made with other model scale and full scale experimental results. In this paper the wind tunnel tests are described and the pressure distributions around the train and the aerodynamic forces and moments are presented and discussed.

2 THE WIND TUNNEL MEASUREMENTS

The experiments were carried out using a 1/30th scale model of a Class 365 electrical multiple unit, mounted statically in a simulation of the atmospheric boundary layer in the RWDI – Anemos environmental wind tunnel which has a working section of 15m x 2.4m x 1.8m. A photograph of the vehicle in the wind tunnel is shown in Fig. 1. Fig. 2 shows the simulated atmospheric boundary layer, which is a good representation of a 1/30 scale boundary layer with a full scale surface roughness length of 30mm. Fig. 3 shows the corresponding turbulence intensity simulation, which is again a good simulation of a 1/30 scale boundary layer with a similar roughness. Figure 4 shows a velocity power spectrum, measured at 3m (full scale equivalent) above the ground. It can be seen to be of the correct form (with a clear inertial sub-range), and the integral length scale can be calculated to be 14m (full scale equivalent) which is somewhat lower than would be ideal, but nonetheless acceptable. The wind tunnel forces and moments were measured on the first two vehicles of the train – car A is the leading vehicle and car B is the trailing vehicle with the pantograph. Measurements were made of the fluctuating surface pressure at approximately 100 pressure tappings on each vehicle, using a

256 channel pressure transducer system. Force time histories were then obtained by integration of the pressure field over the surface of the vehicle.

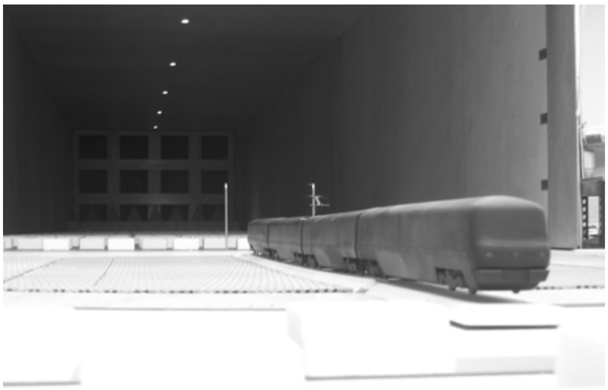

Fig. 1 The Class 365 EMU wind tunnel model.

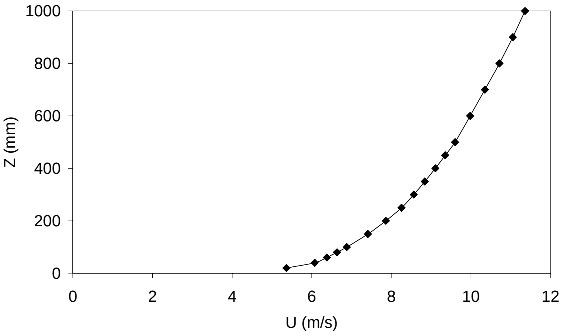

Fig. 2 The simulated velocity profile.

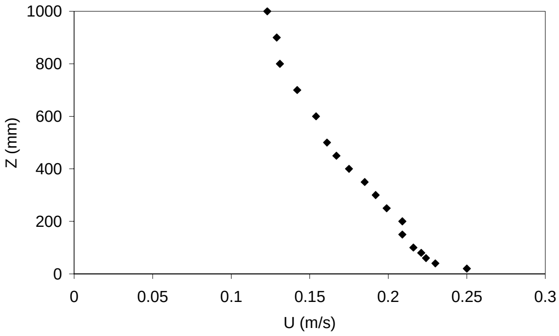

Fig.3 The simulated turbulence intensity profile.

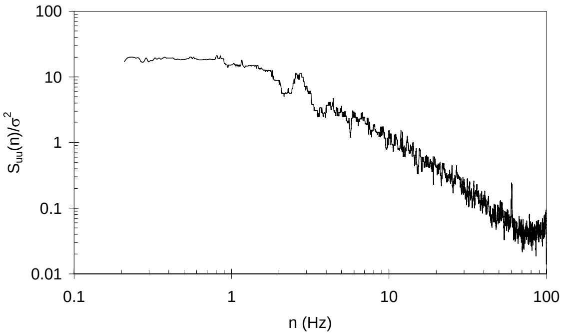

Fig. 4 The simulated velocity spectrum at z = 100mm.

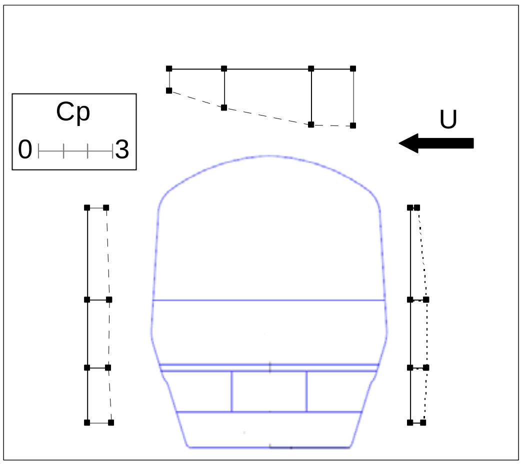

Fig. 5 Mean pressure coefficient distributions for a yaw angle of 45 degrees.

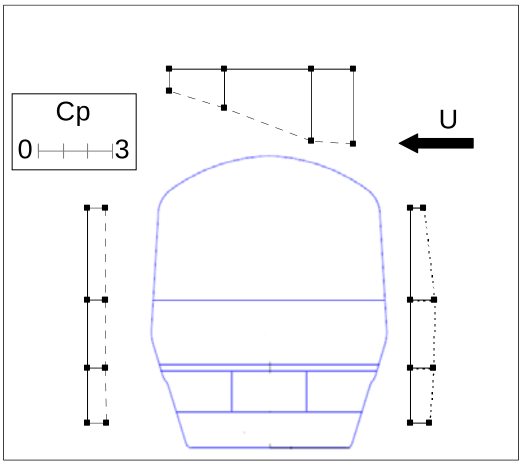

Fig. 6 Mean pressure coefficient distributions for a yaw angle of 90 degrees.

3 PRESSURE DISTRIBUTIONS

Figs. 5 and 6 show the variation of the mean pressure coefficient distribution along the centreline of the train at yaw angles of 45 degrees and 90 degrees. The reference velocity used in the formation of the coefficients was the wind tunnel velocity at 3m (full scale equivalent) height. In these figures the pressure coefficients are given by a dotted line from the solid line datum. A pressure coefficient closer to the indicated train surface indicates a suction. It can be seen that there are large suctions over the windward roof edge of the train at both yaw angles indicating flow separation at that point. A full description of the pressure coefficients for both vehicles will be given in the full paper.

4 FORCE AND MOMENT COEFFICIENTS

Figs. 7 and 8 show the variation of the time average force and moment coefficients obtained from an integration of the pressure distributions. In the formation of the coefficients the full-scale equivalent reference areas of 70m^2 and 67.7m^2 have been used for car A and car B respectively. The reference velocity is the same as used to derive the pressure coefficients. The coefficients for both cars A and B are shown. It can be seen that these are broadly similar. The side force coefficient magnitudes are similar to those obtained in wind tunnel tests on other trains (see [3] for example), but the lift force coefficients are significantly higher than previously observed. It is conjectured that this is because the under-train gap on the Class 365 is significantly smaller than for most of the vehicles previously studied, and thus much of the flow will go over the train, with a greater reduction in roof pressure and thus a greater lift. Figs. 9 and 10 show the ratio of the extreme force coefficients to the mean coefficients. The extreme force coefficients were based on the extreme 3 second value of force and the extreme 3 second value of the reference wind speed. It can be seen that the values of this ratio are below unity, as has been observed for other vehicles [3] and reflects the lack of correlation of extreme pressures over the surface of the train for short period, and thus relatively small, wind gusts.

5 FURTHER WORK

In the full paper the results outlined above will be expanded and considered in more detail. In addition the fluctuating pressure coefficient distributions will be considered in terms of the standard deviation and extreme value pressure coefficient distributions. A proper orthogonal decomposition analysis will also be described that uses the measured pressure time histories and the pressure coefficient modes revealed by these distributions will reveal fundamental information about the nature of the fluctuating flow field around the train.

REFERENCES

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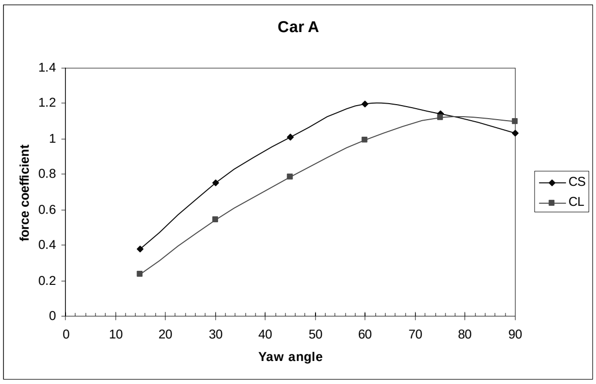


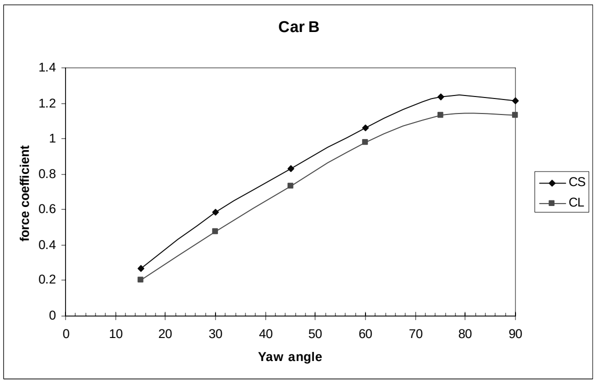
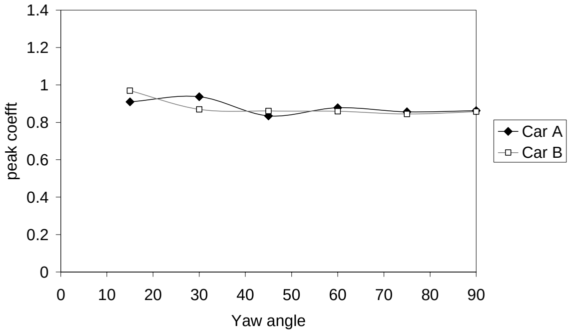


Fig. 7 Mean force coefficients for Car A

Fig.8 Mean force coefficients for Car B



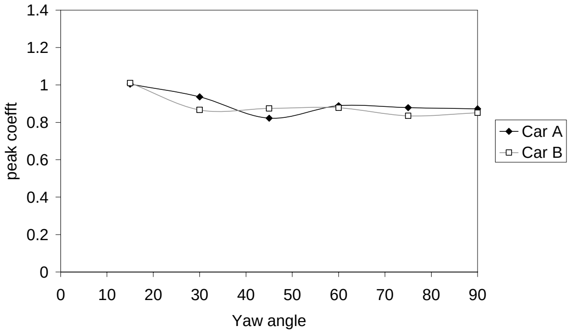


Fig.9 Ratio of extreme to mean side force coefficients

Fig.10 Ratio of extreme to mean lift force coefficients