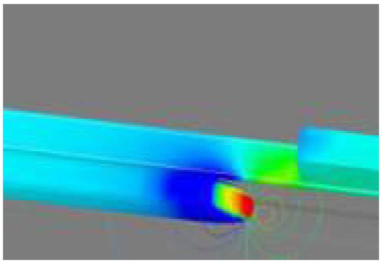
Vehicle Aerodynamics:
Calculation of Passing Train Aerodynamic Loads

Fast motor vehicles and trains are often moving in close proximity to each other or to fixed objects such as tunnels or buildings. These interactions can produce significant loads on the vehicle or the fixed object. The magnitude and duration of the load depends on the velocity and geometry of the vehicles and also on the ambient wind speed and direction. In several recent studies we examined the loads produced by passing trains and their potential for causing an accident. From experience, we know that the largest changes in load are generated near the ends of the passing trains and that these loads can have serious consequences. In recent studies for the US Department of Transportation, we used computational fluid dynamics (CFD) to simulate a high speed passenger train passing a moving freight train at closing speeds of up to 200 mph (333 km/hr). A series of calculations were used to explore the effects of train geometry and speed as well as the effects of ambient wind speed and direction. (See "High-Speed Passenger and Intercity Train Aerodynamic Computer Modeling" pdf) These simulations were later verified with experiments. (See "Measurement of the Aerodynamic Pressures Produced by Passing Trains" pdf)

Figure 1 shows predicted pressure contours on the surface of two passing trains and isobars on the ground at four times as the locomotive of the passenger train passes a single shipping container on a string of flat cars in the freight train. Visualizations such as this show that the strong pressure bubble ahead of the locomotive (red contours) and the low pressure area on the side of the cab (blue contours) create a push-pull effect on the container car.

Figure 1. Predicted Pressure of Two Passing Trains



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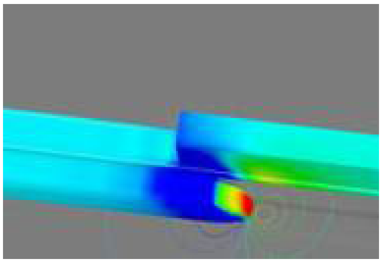

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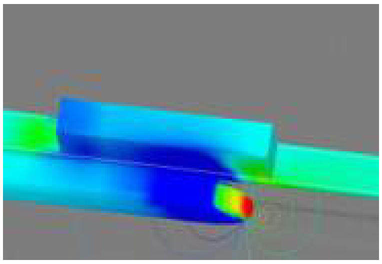

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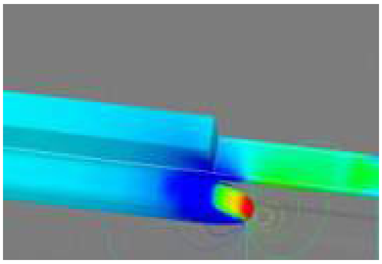
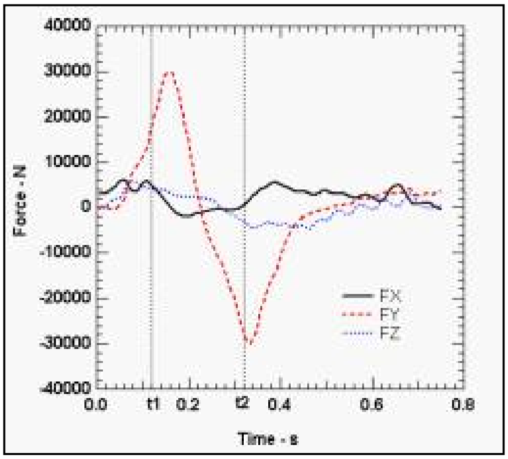


1d

The force resultants on the individual cars of the two trains were calculated by integrating the surface pressures at each time step. An example of the force resultant histories is shown in Figure 2. In this figure, Fx is the drag force on the container car, Fy is the lateral force and Fz is the vertical force. The positive X-axis is in the direction of the passenger train and the Y-axis is directed away from the passenger train. The large excursions in Fy are the side-to-side loads on the container car. The dashed lines in the figure pinpoint the times at which the passenger locomotive reaches the front and back ends of the container car.

Figure 2. Time History of Forces on the Container Car

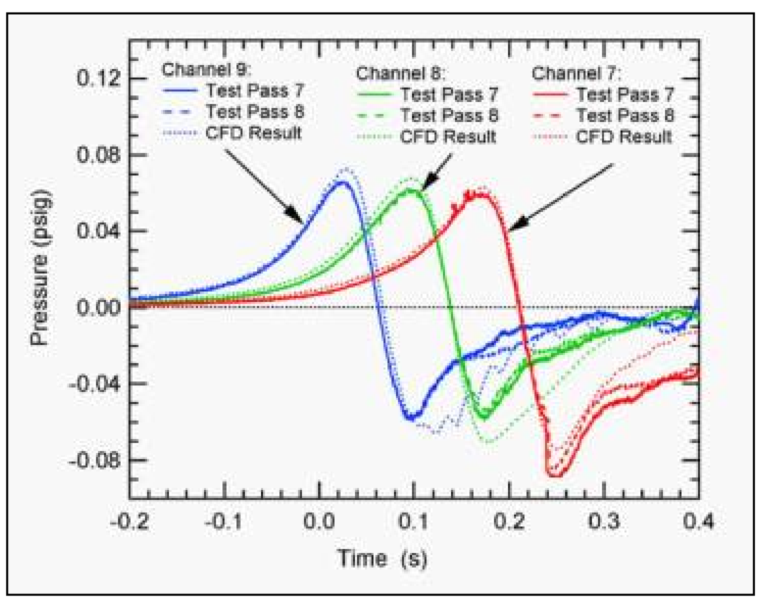


The accuracy of the simulations was tested in a separate program in which pressure measurements were made on a stationary container car passed by a high speed train. Figure 3 shows the high speed train and the stationary container car with instrumented container. A comparison of the predicted and measured pressure pulses at three of the 11 gage locations on the side of the container car is given in Figure 4.

Other vehicle aerodynamics experience includes study of the wind noise generated by automotive, aircraft and train structures, the noise and dynamics of a train entering a tunnel and related vehicle dynamics problems.

Figure 3. High Speed Train Passing Stationary Container Car

Figure 4. Comparison of Predicted and Measured Pressure Histories



Further information on these studies can be found in the references below:

- Holmes, S. , Schroeder M., and Toma E., "High-Speed Passenger and Intercity Train Aerodynamic Computer Modeling," Rail Transportation, 2000 ed. S. K. Punwani, ASME Publication 2000 168 pp. ISBN: 0-7918-1926-4 RTD-Vol. 19, 2000.

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