Bullet Train Aerodynamics using Zonal Methods

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Recent technology innovations have increased train speeds tremendously. Now, some of the trains run at the speed higher than 250 km/h, that corresponds to the Mach number more than 0.2. Future trains will even increase their speeds substantially. MAGLEV(magnetic levitation) trains under planning in Japan, for instance, will have 500 km/h (M=0.42). With increased speeds, a lot of aerodynamic problems emerge. Trains have large aerodynamic loads especially in two cases. One occurs when trains move into a tunnel. The other occurs when two trains pass by each other. Complicated aerodynamic loads may work on train bodies and it is not easy to predict them because relative position of the train bodies changes in time and therefore the flow field is very unsteady.

Recent progress of the computer capability and numerical methods allows us to simulate such flow fields even in three dimensions. Using domain decomposition method with moving grid system, such flow configurations can be easily realized virtually in computers. In this presentation, an overset zonal method called FSA is briefly described first. FSA stands for the interface scheme called Fortified Solution Algorithm (FSA). This zonal method can be considered as one version of the Chimera method but has more flexibility. Using the FSA zonal method, many problems have been solved, but here two examples for high speed trains are taken as application examples.

First example is a train moving into a tunnel. The flow field is important not only because of the strong aerodynamic loads on the train but also because strong compression waves created in front of the train eventually become so called "booming noise" at the exit. One-dimensional, Axisymmetric two-dimensional and fully three dimensional flow simulations using Euler and Navier-Stokes equations were carried out. The result shows the detailed flow field and the applicability limit of the one-dimensional theory for practical problems.

Second example is the three-dimensional flow field that occurs when two trains pass by each other inside a tunnel. The time sequence of the flow field and the history of the aerodynamic forces acting on the trains are investigated. The result shows the behavior of the aerodynamic forces that occur when two trains pass by each other at high speed in a tunnel.

Although large-scale simulations and their visualized results help our understanding aerodynamics of high speed trains, it is very necessary to develop the design methodology to reduce the strength of the compression waves and the aerodynamic loads on the train. The presentation refers to the theory we have developed. The theory accurately predicts the behavior of the compression waves in the tunnel without such high-cost computations. Using this theory, we may design the nose region of the future trains that would create less compression waves.