Reducing the Air Resistance of Vehicles

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Introduction

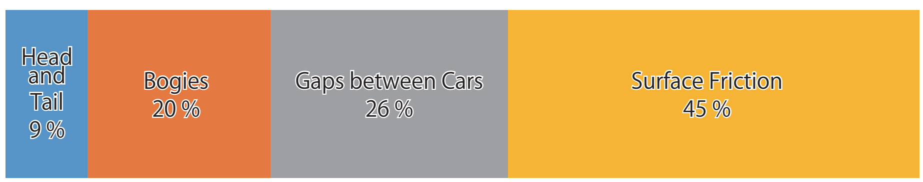
The running resistance of a train, which increases as it runs faster, consists of rolling resistance, which is proportional to the train speed, and air resistance, which is proportional to the square of the train speed. With high-speed trains like Shinkansen, most of the running resistance is accounted for by air resistance. Therefore, reduction of air resistance is vital to achieving faster speed with high energy efficiency.

A Shinkansen train set is extremely long and thin (e.g. a set of 16 vehicles is 400-meter long and 3.65-meter high). The air resistance of its front and rear ends accounts for an extremely small portion of the entire train set's air resistance. Therefore, any improvement in the shape of the front and rear ends would hardly help reduce the train set's air resistance. On the other hand, the air resistance of the intermediate vehicles accounts for nearly all the train set's air resistance. It can be reduced by smoothing the underfloor profile.

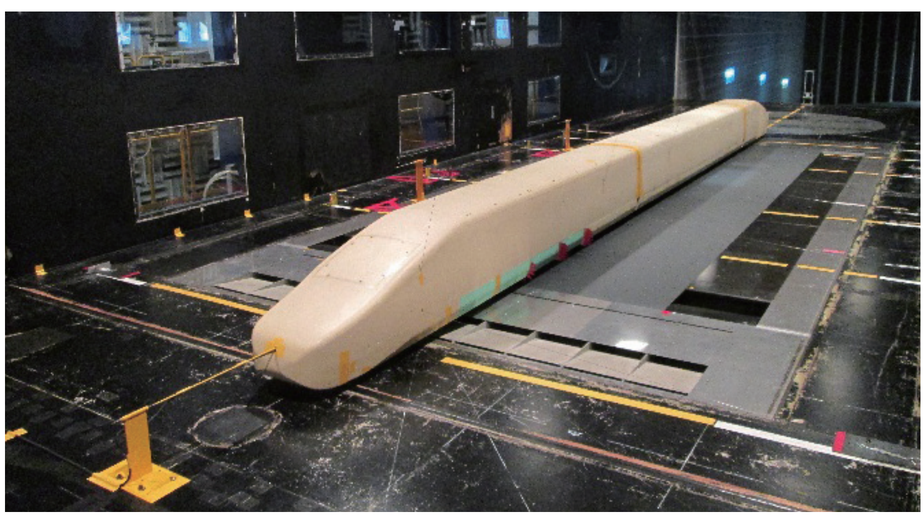
While smoothing the vehicles' underfloor profile reduces air resistance, it also increases the cost for producing and maintaining vehicles. Cost effectiveness (energy saving from lower air resistance versus increased production and maintenance costs) therefore needs to be examined. The above shows that reducing the air resistance of vehicles involves accurate examination of possible air resistance mitigation methods and, no less important, other expected effects of the mitigation.

Evaluation of an entire train set's air resistance

Air resistance is typically evaluated by means of wind tunnel tests, actual vehicle tests or numerical calculations. Among these, wind tunnel testing is the most practical in terms of accuracy and costs involved. Presented below is a wind tunnel test from which highly accurate evaluation can be made. Tests conducted in the past using actual vehicles revealed that a solid boundary layer develops on the third vehicle from the front and the following vehicles. This creates a nearly constant flow field below the floor of those intermediate vehicles. Therefore, the air resistance of those intermediate vehicles, or from the third vehicle down, can be regarded as almost constant. Based on the above, the air resistance of an entire train set can be estimated in wind tunnel test by evaluating the air resistance of an intermediate vehicle and then multiplying the evaluated value



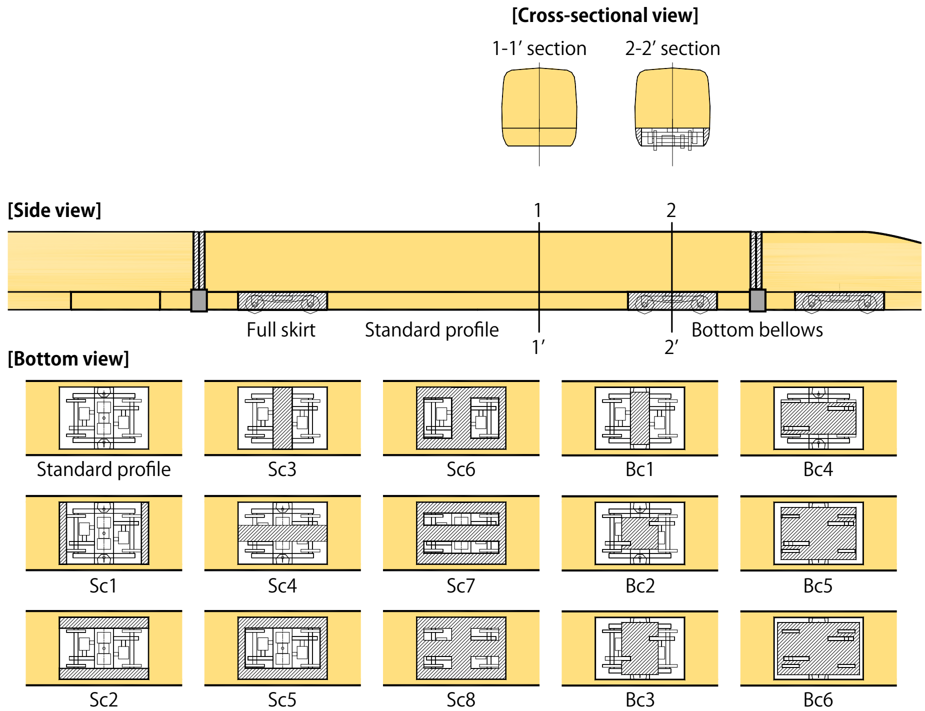
Contribution to aerodynamic drug of compornents in a high speed train of 16 cars



The track surface flow is simulated using a moving belt and a boundary layer suction device. A spire installed on the front vehicle controls the boundary layer formed under the vehicle floors to reproduce the underfloor flow field on the intermediate vehicle.

by the number of vehicles in the train set.

In our test, noncontact LDV (Laser Doppler Velocimetry) flowmeters were used to measure air current fields under the floors of actual vehicles including areas off the vehicles that had not been measurable. The data on the distribution of flows under the floors of intermediate vehicles was then reproduced in wind tunnel tests. In the wind tunnel test, a 1/7 scale model train set of three (front, intermediate and rear) vehicles was used. The underfloor flow velocity of an intermediate vehicle in wind tunnel test is faster than that of actual vehicles. To compensate for this, a spire is installed under the floor of the front vehicle in wind tunnel tests to reduce the underfloor flow velocity. Then the distribution of flow velocity under the floor of the intermediate vehicle can be made to agree with that of actual vehicles, making it possible to highly accurately estimate the air resistance of the entire train set.

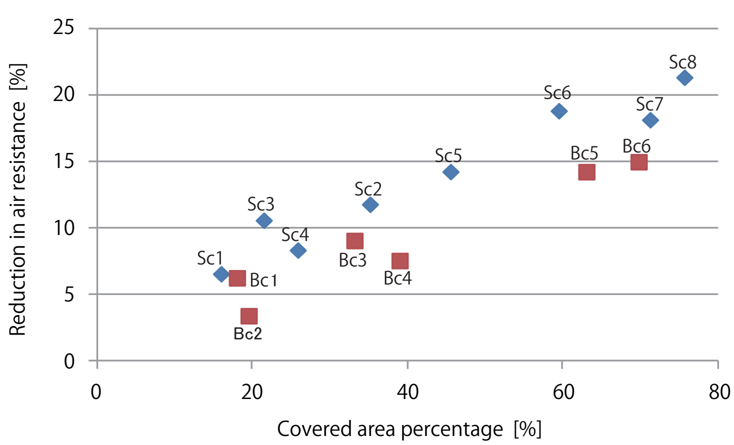


Different Types of Bogie Bottom Covering

Air resistance is reduced by smoothing the underfloor profile of vehicles using bogie bottom coverings and gangway bottom bellows. There are two types of bogie bottom coverings. Sc types are attached to a car body. Bc types attached to a bogie itself.

Air resistance reduction method and its effect

Practical ways to smoothing the surface of actual Shinkansen vehicles include bogie bottom coverings and gangway bottom bellows. Shown below is the effect of bogie bottom coverings on reducing air resistance. The air resistance reduction effect is shown to increase in proportion to the area of the covering under the bogies. It has also been confirmed that installing gangway bottom bellows can reduce air resistance. By combining these and other underfloor smoothing methods, air resistance can possibly be reduced by several dozen percent on older and the latest Shinkansen vehicles.



Air resistance is reduced in proportion to the area of bogie bottom covering.

Future plans

Smoothing the underfloor profile of Shinkansen vehicles increases vehicle production and maintenance costs, but also can be expected to reduce snow accretion to bogies as well as underfloor aerodynamic sound. The smoothing methods will need to be examined further for these and other effects in addition to the reduction in air resistance before they can be introduced on actual vehicles.