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Analysis of Aerodynamic Load Characteristics at the Connection of Windshield-less High-Speed Train Carriages

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Introduction

In recent years, the speed of high-speed trains in China has gradually increased, and aerodynamic drag during train operation has become an issue that cannot be ignored. The connection between carriages links the train cars, playing a critical role in ensuring operational stability. However, the hollow structure of the interior of the train car connections results in relatively weak strength and stiffness, and there is a risk of strength problems.

This study establishes a 1:1 model of the CRH3 train as shown in figure 1. To ensure computational accuracy while improving efficiency, carriages with identical features are omitted. The model has a length of L = 76.4 m, a height of H = 3.4 m, and a width of W = 3.256 m. The connection between the head and middle carriages is designated as Connection 1, while the connection between the middle and tail carriages is designatedas Connection 2.

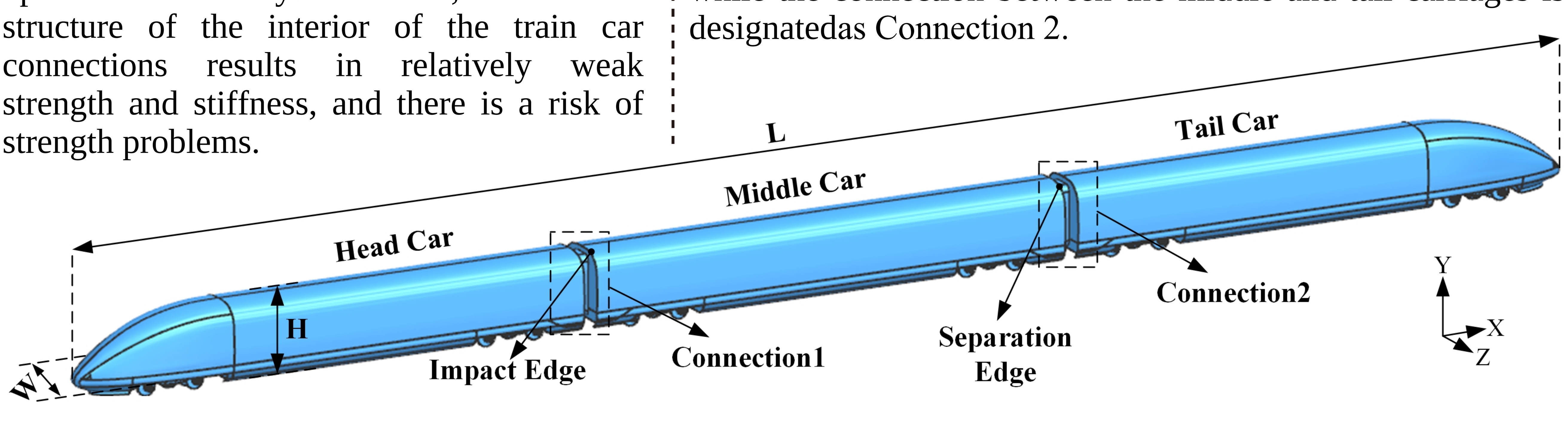

Figure 1. Train Model.

Research objectives

- Demonstration and analysis of vortex structures at the connection of carriages of a high-speed train without windshield.
- Analyzing the aerodynamic loading characteristics at the connection of carriages of a high-speed train without windshield.

Numerical simulation

Computational Domain and Mesh Strategy

This study uses the high-speed train as the reference frame, simulating its actual motion on a straight track by having external air flow at a fixed speed toward the rear of the train.

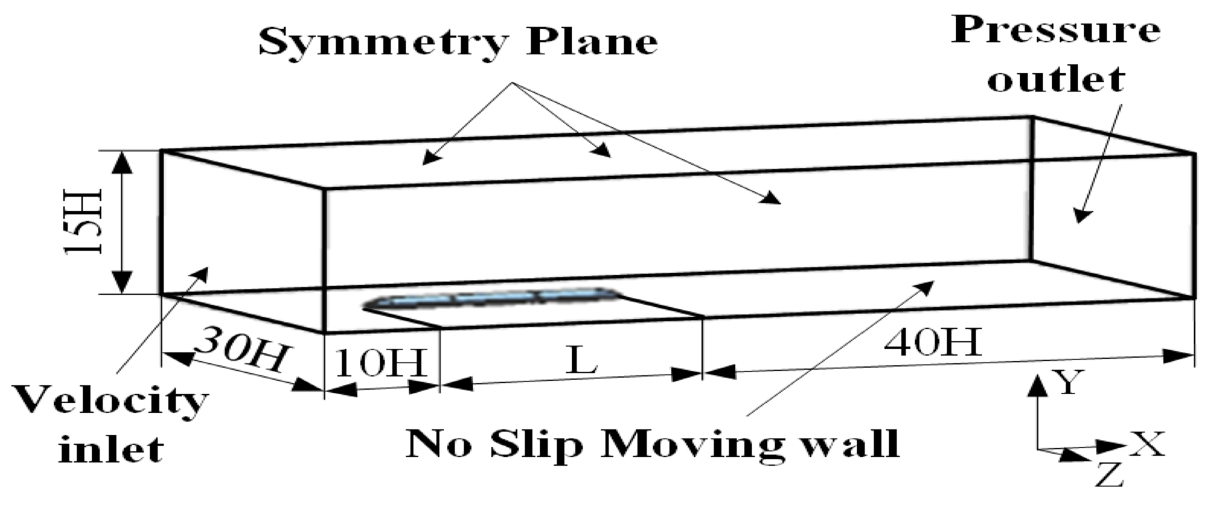

Figure 2. Computational Domain

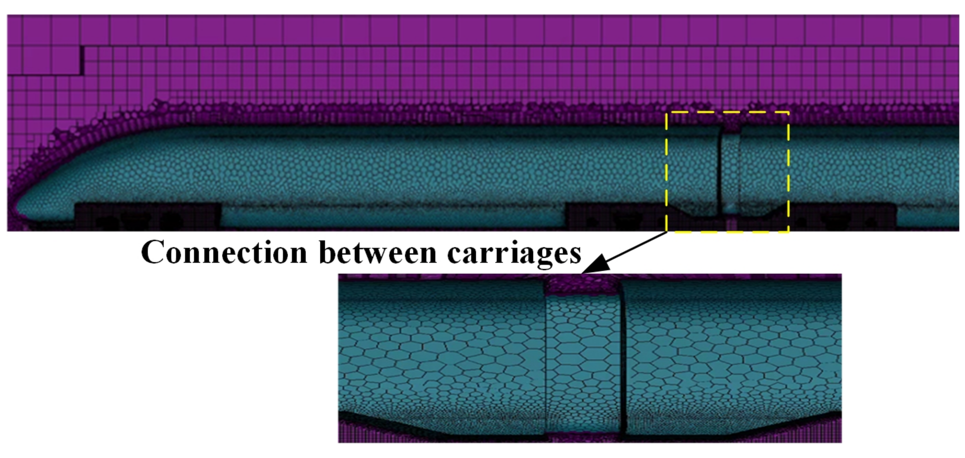

Figure 3. Mesh Strategy

Using train height H as the characteristic length, the computational domain and boundary conditions for the flow field are adopted as shown in figure 2 to ensure sufficient space. This study employs an unstructured approach to generate computational meshes, controlling their quantity. Multiple refined regions are established within the external flow field of the high-speed train, as shown in figure 3.

Results

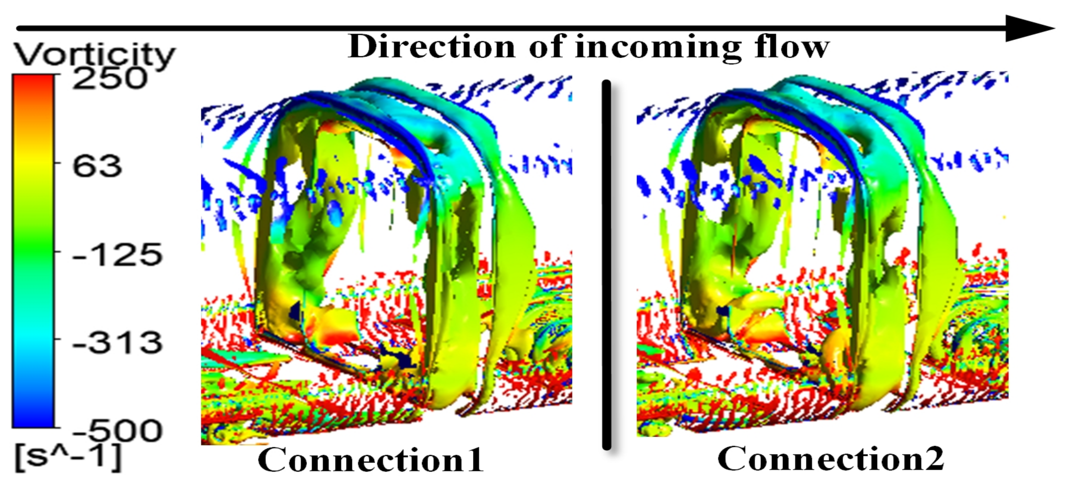

Figure 4.Q-Criterion

The Q-criterion is a method for characterizing turbulent structures and vortex regions, revealing the position and intensity of vortex structures within the flow. Figure 4 shows the Q-criterion vortex distribution at the carriage connection.

The pressure distribution patterns at both connections are generally similar, with high-pressure regions near the separation edge and low-pressure regions near the impact edge. Local high-pressure regions with similar distribution patterns exist on the surfaces of both connections. The phenomenon of flow separation at the connection results in the formation of local high-pressure regions.

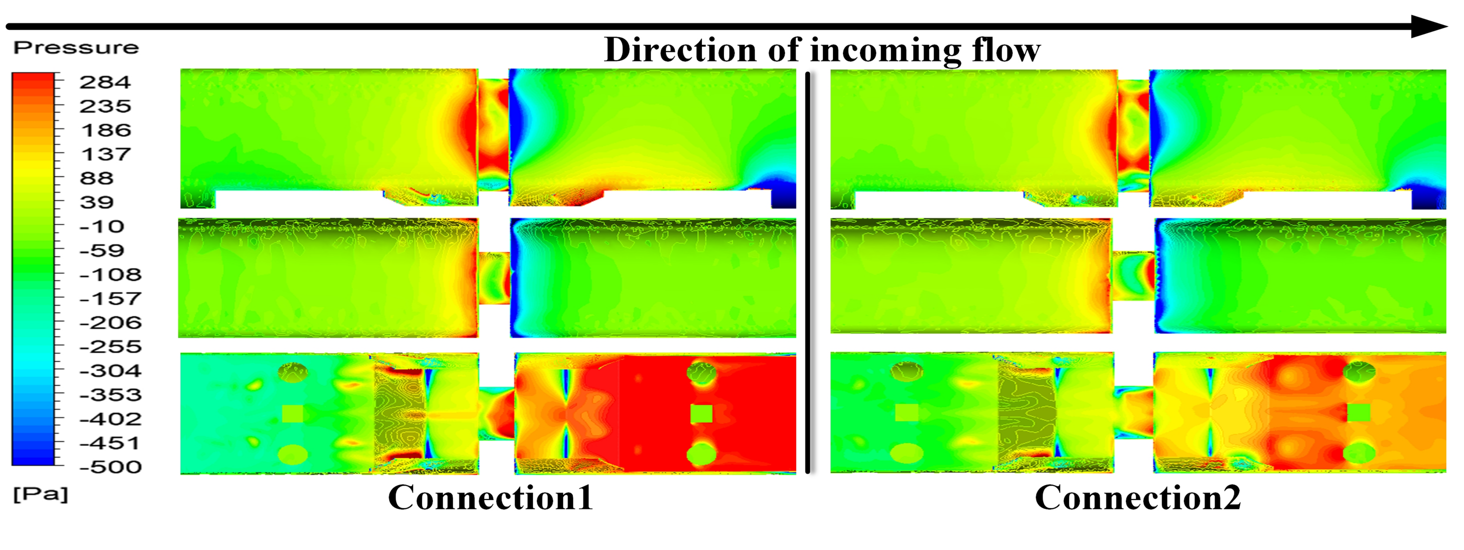

Figure 5. Surface Pressure Distribution Diagram.

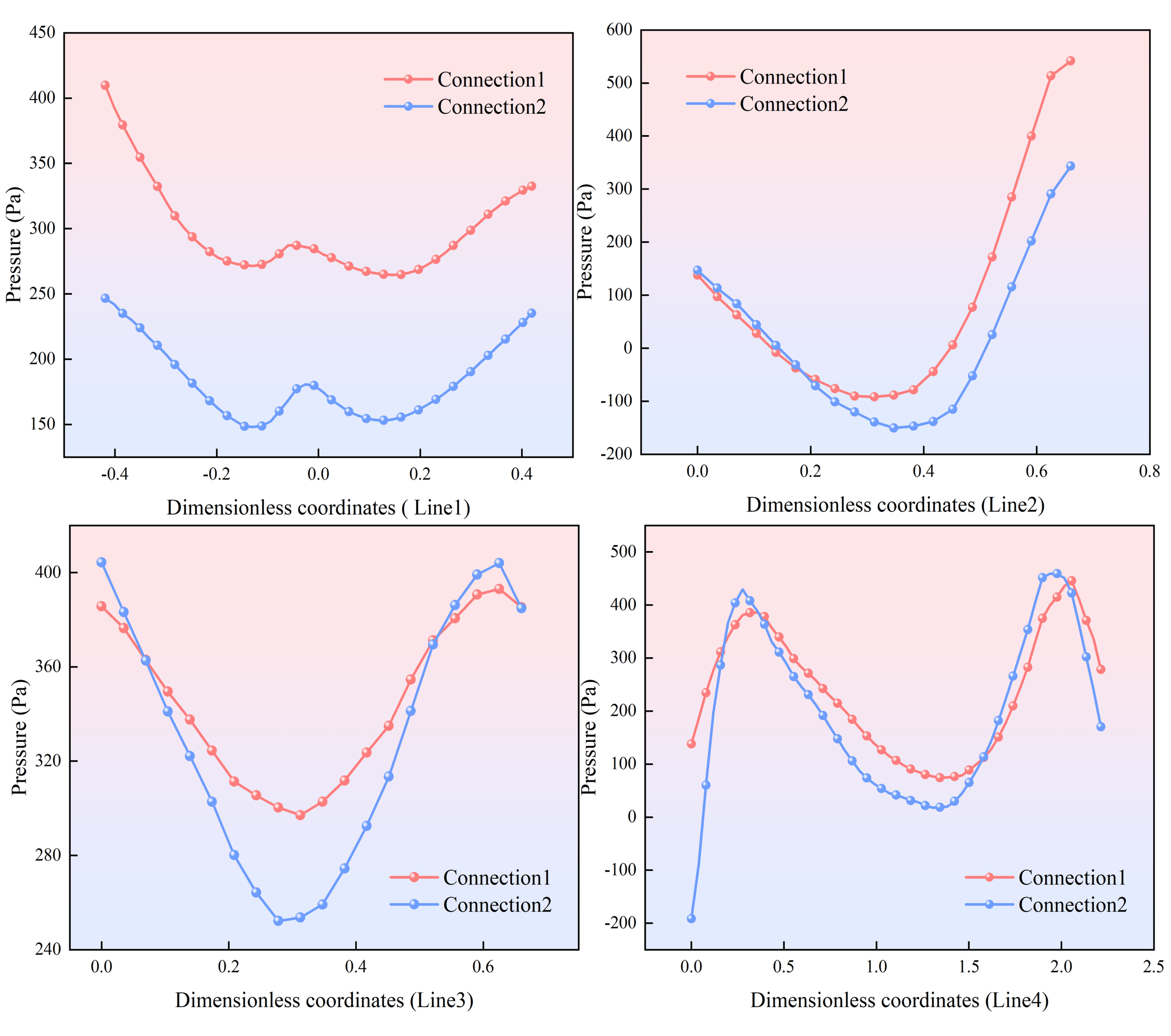

Figure 6. Pressure Variation Curve.

Figure 6 shows the pressure variation along the monitoring lines at connection 1 and connection 2. After dimensionless processing, the data for connection 1 and connection 2 are unified into the same coordinate system. It can be observed that the pressure variation patterns at connection 1 and connection 2 are generally similar, exhibiting a U-shaped distribution. The high-pressure regions on the surface of the carriage connection are concentrated near the eight vertices of the connection, while the surface pressure in the middle area of the connection is lower.The connection closer to the front of the train experiences greater pressure fluctuation, with more pronounced flow separation and disturbances, resulting in a larger impact from aerodynamic loads.

Conclusions

- Vortices created by flow separation phenomena at Carriage connections can cause pressure fluctuations that affect train safety.
- Carriage connections are prone to stress concentration problems near the apexes.
- Connections closer to the front of the train are more affected by aerodynamic loads.

Acknowledgement

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References

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