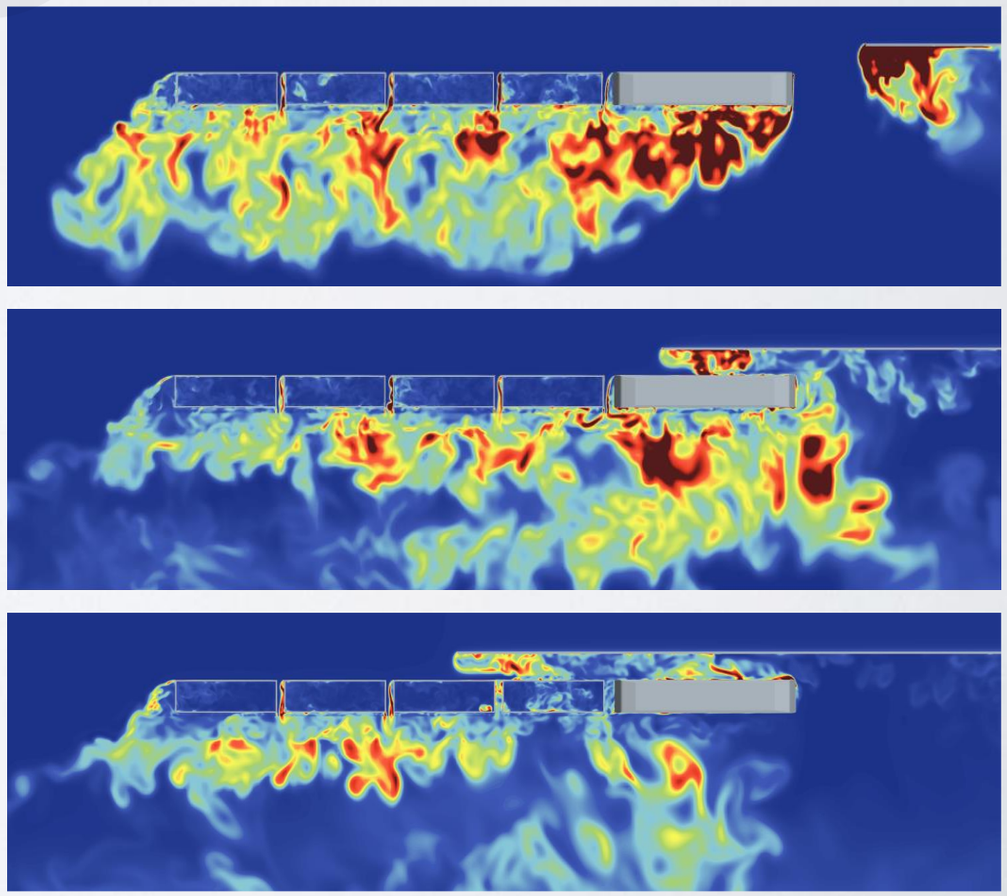
Journal of Zhejiang University-SCIENCE A

Cite this as: Jiayuan SONG, Wentao HE, Yanlin HU, Kaiyun WANG, 2026. Comparative analysis of windbreak configurations for unloaded gondola train cars under crosswinds based on computational fluid dynamics and multi-body dynamics. *Journal of Zhejiang University-SCIENCE A*, 27(1):26-42.
https://doi.org/10.1631/jzus.A2500044

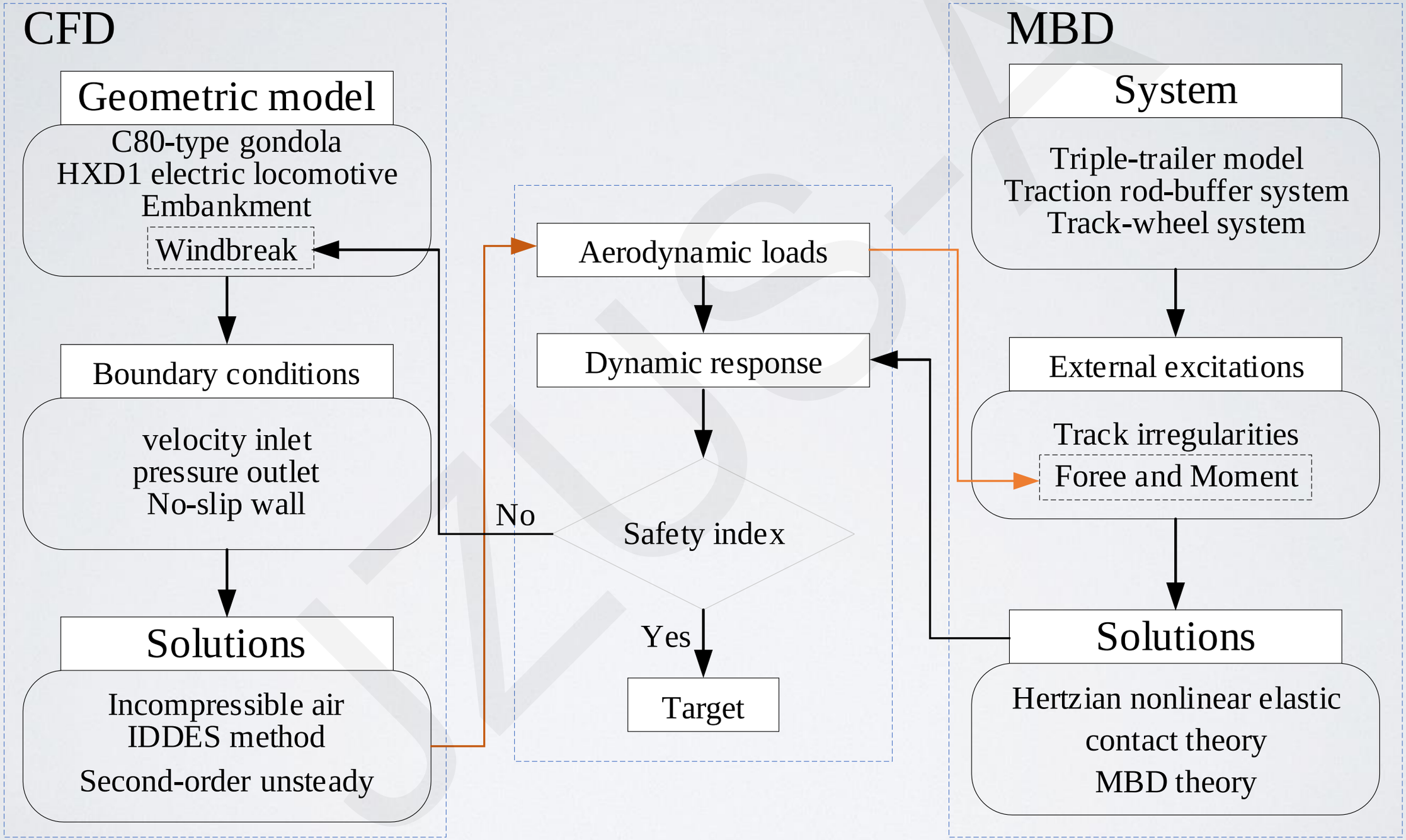
Comparative analysis of windbreak configurations for unloaded gondola train cars under crosswinds based on computational fluid dynamics and multi-body dynamics

Key words:

Crosswind; Train gondola; Unsteady aerodynamics; Dynamic response; Train safety; Windbreaks



Technological route



Innovation

Flow field structure

- Pressure coefficient distribution
- Vortices
- Aerodynamic load

Dynamic response

- Frequency-domain analysis
- Vibration mode
- Index of safety





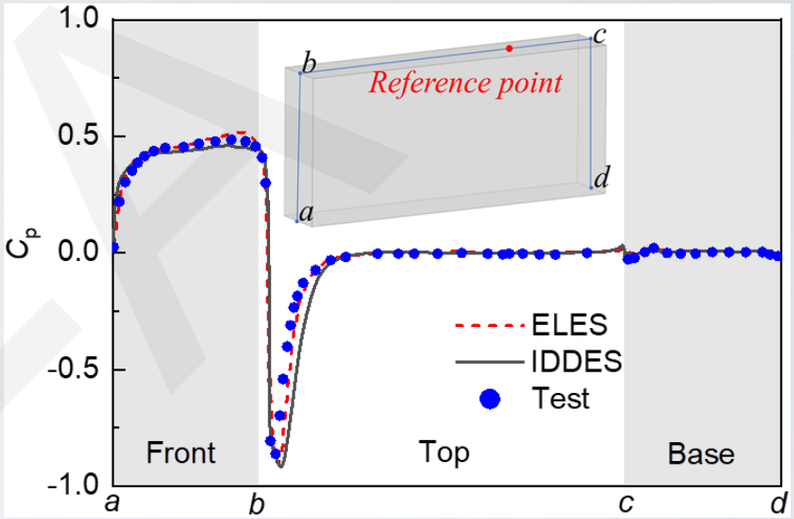
Method and Validation

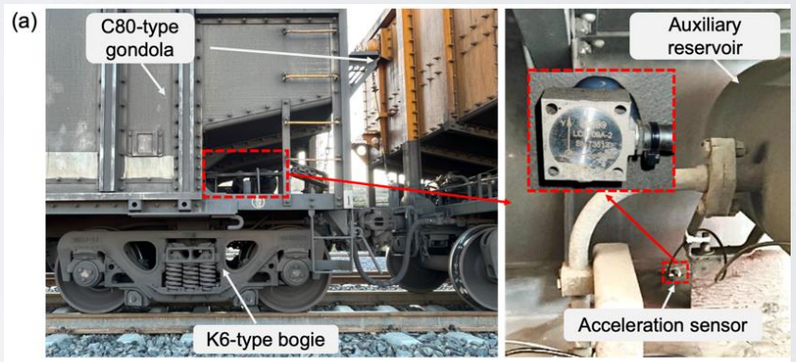
Aerodynamic model:

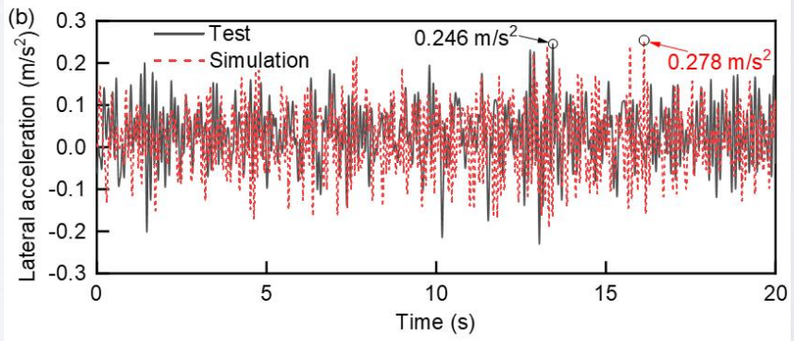
- Improved delayed detached eddy simulation (IDDES) method
- Overset numerical mesh

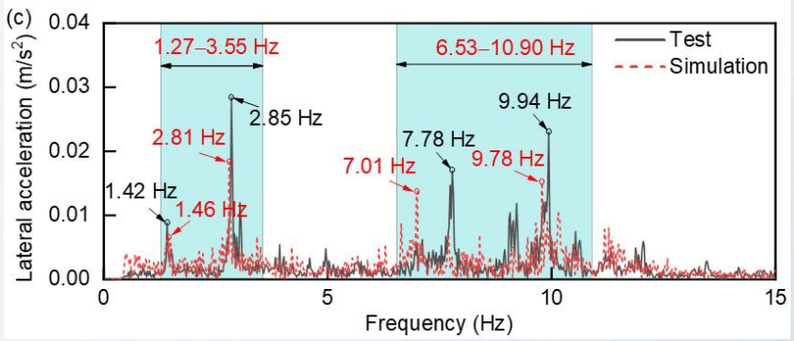
Multi-body dynamics model:

- C80-type gondola model
- drawbar-buffer model

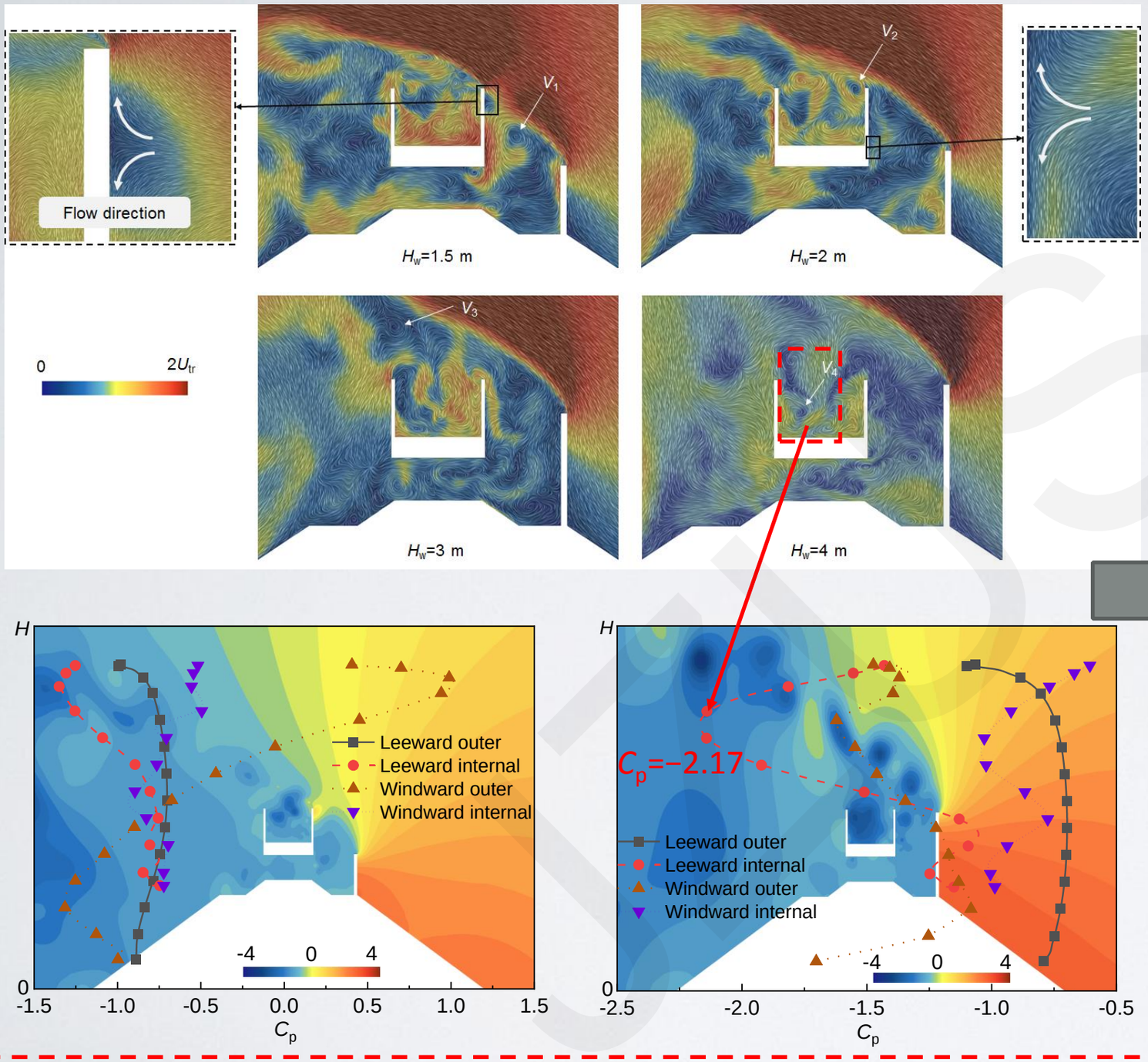




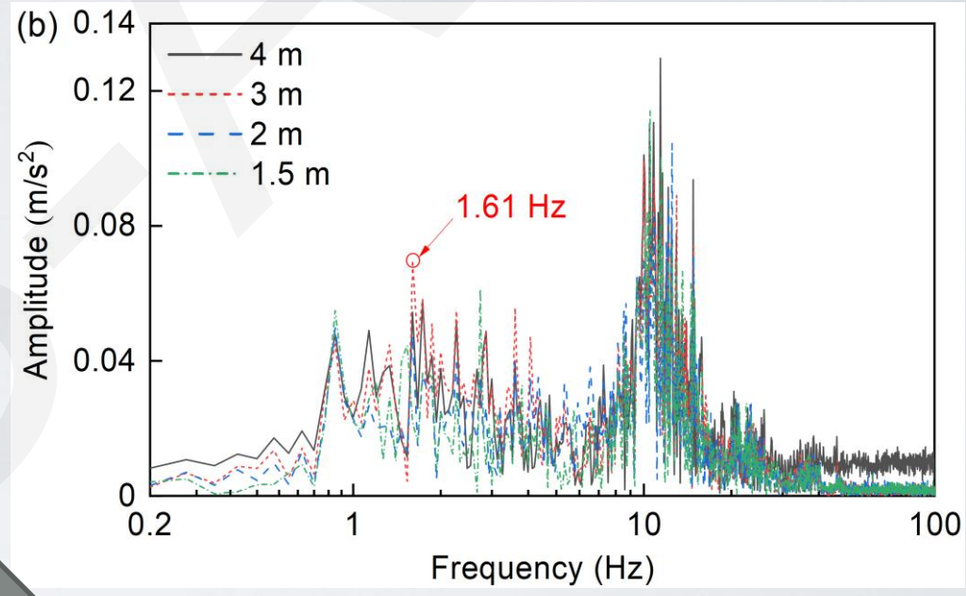




Mechanism



Frequency-domain analysis



Vibration mode type of car body	Numerical frequency (Hz)	Dynamic response (Hz)
Lateral sway and overturning	1.33	1.61 (lateral acceleration)
Lateral sway and overturning	1.46	1.61 (lateral acceleration)
Overturning	2.10	1.61 (lateral acceleration)
Bounce	20.73	23.66 (vertical acceleration)
Pitch	26.35	23.66 (vertical acceleration)

Conclusions

1. A windbreak of 2 m height was found to effectively shield the impact of crosswind flow on the sidewalls of the gondolas, significantly reducing the aerodynamic lateral force, yaw moment, and over-turning moment.

2. When the windbreak height exceeded 2 m, the flow field was primarily affected by the vortices within the gondola. Moreover, the lateral force and overturning moment resulted in a decrease in wheel–rail forces on the windward side, and an increase on the leeward side.

3. When the height of the windbreak exceeded 2 m, vortices within the gondola induced an adverse pressure coefficient distribution (Cp=−2.17) on the leeward internal wall, amplifying both the lateral force and overturning moment of the car body.

4. Frequency-domain analysis indicated that the vertical vibration of the car body is related to the bounce (20.73 Hz) and pitch (26.35 Hz), while the low-frequency overturning (2.10 Hz) vibration modes that correspond to the lateral vibrations are also excited un-der crosswind loads.