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Effects of high geotemperature and high altitude on the pressure wave of high-speed trains running in a long tunnel

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Research Summary

- High-speed railway tunnels in high-altitude areas are notably long and face unique conditions like low pressure and high temperatures. These factors affect air density, viscosity, and other properties, influencing the characteristics of pressure waves generated during train operation.
- Studying the effects of high temperature and high altitude on pressure waves in high-speed train tunnels is valuable, as it provides technical support for tunnel design.

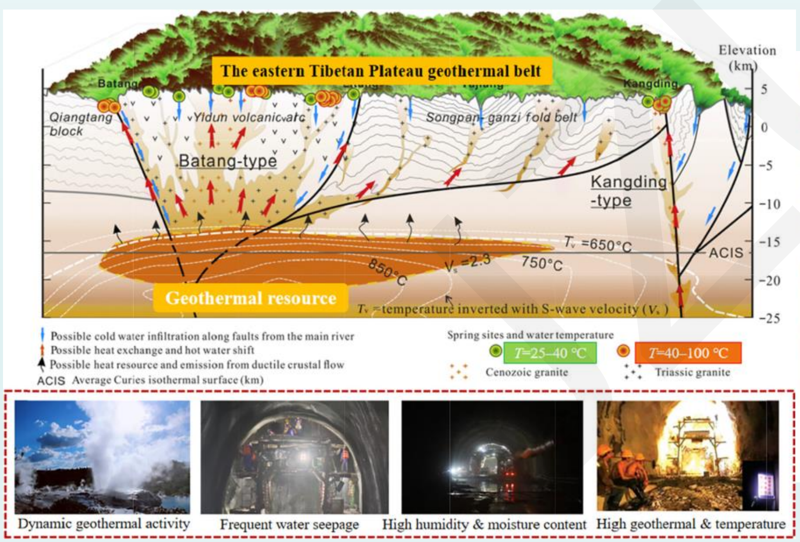


Fig. 1. Engineering geological background of a tunnel

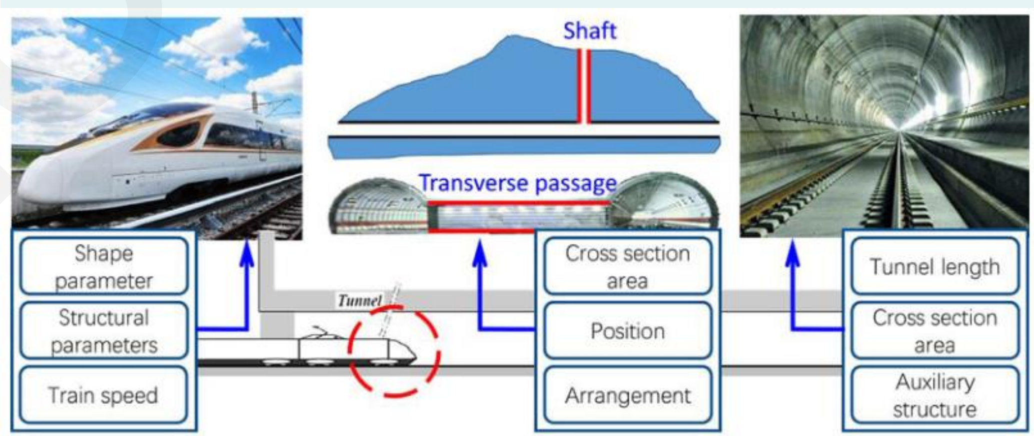
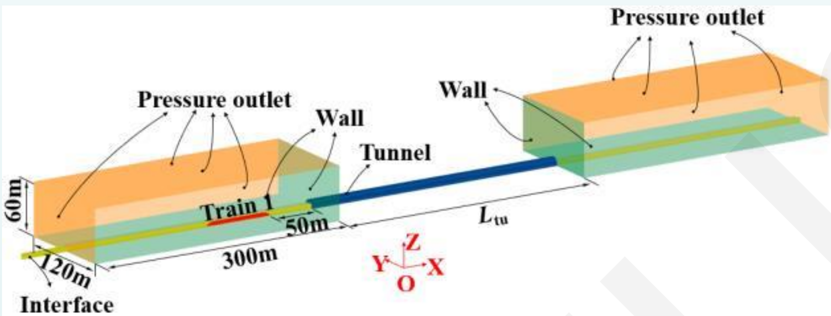


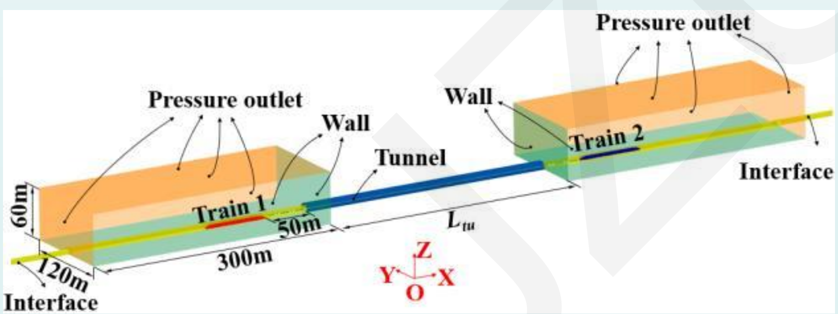
Fig. 2. Factors affecting the aerodynamics of railway train/tunnel systems

Methodology

- Using the three-dimensional, unsteady, compressible Reynolds time-mean equation and the RNG $k-\varepsilon$ turbulence model, the pressure wave behaviour of high-speed train tunnel passing and tunnel intersection is studied, focusing on the effects of high altitude and high altitude.

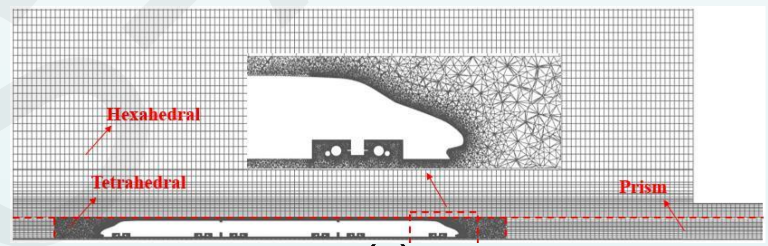


(a)

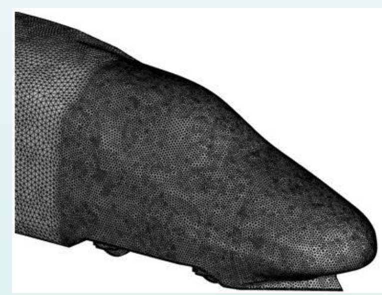


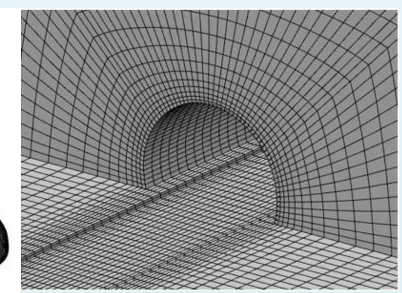
(b)

Fig. 3. Computational region and boundary conditions: (a) a train passing through the tunnel; (b) two trains passing by each other in the tunnel.



(a)



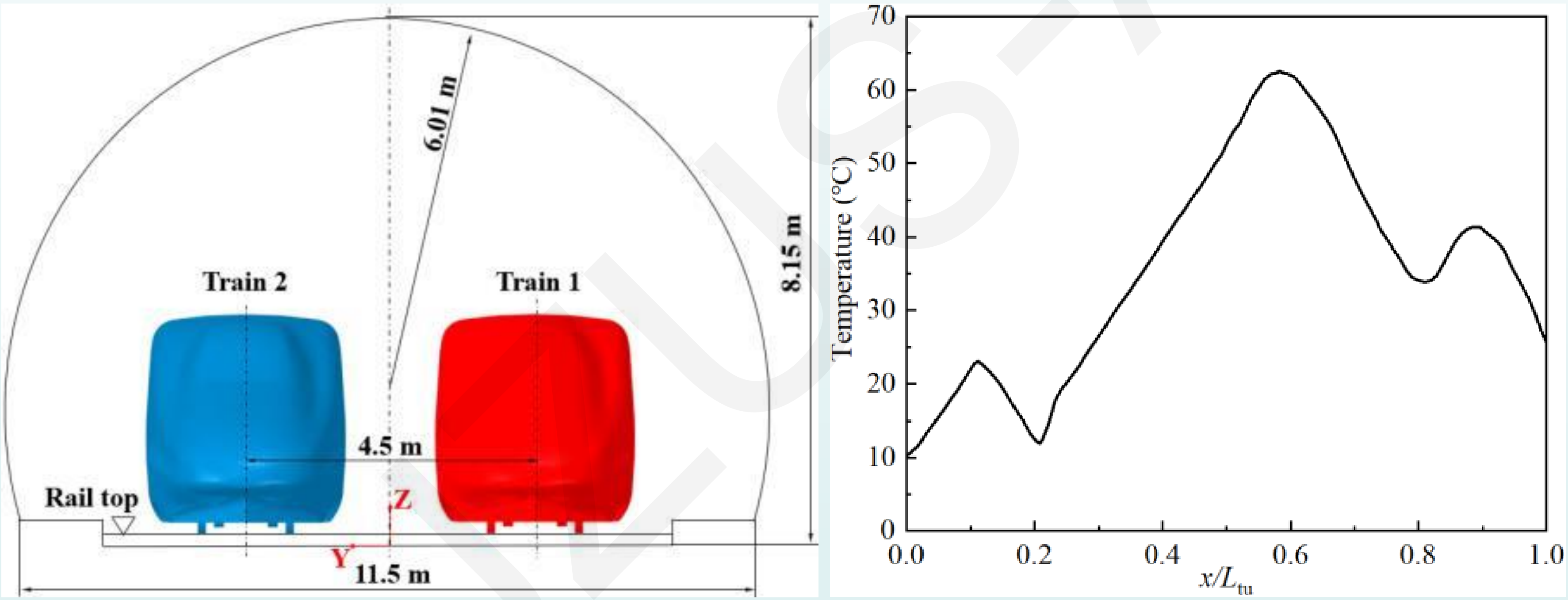


(b) (c)

Fig. 4. Grid diagram: (a) longitudinal section of the computational region; (b) surface mesh of the head car; (c) surface mesh at the tunnel portal

Innovation points

- The distribution of high temperature along the entire tunnel is considered in the established computational aerodynamic simulation model to simulate a more realistic high ground temperature environment.



(a) (b)

Fig. 5. Tunnel model and temperature distribution curve: (a) tunnel cross-section; (b) predicted temperature distribution along the Layue tunnel (Zhang, 2021)Engineering geological background of a tunnel

Innovation points

- By analyzing the influence of tunnel length on the pressure wave of high-speed train operating in tunnels, a representative tunnel length is determined for simulation, so as to save the calculation cost and effectively reflect the characteristics of pressure wave of high-speed train operating in long tunnels.

$$\Delta t_1 = \frac{L_{tr}}{v}$$

$$\Delta t_2 = \frac{cL_{tr}}{v(c+v)}$$

$$\Delta t_3 = \frac{L_{tu}}{c} - \frac{L_{tr}}{v}$$

$$\Delta t_4 = \frac{2L_{tu}}{c+v} - \frac{cL_{tr}}{v(c-v)}$$

$$x_1 / L_{tu} \approx 1 - \frac{cL_{tr}}{2vL_{tu}}$$

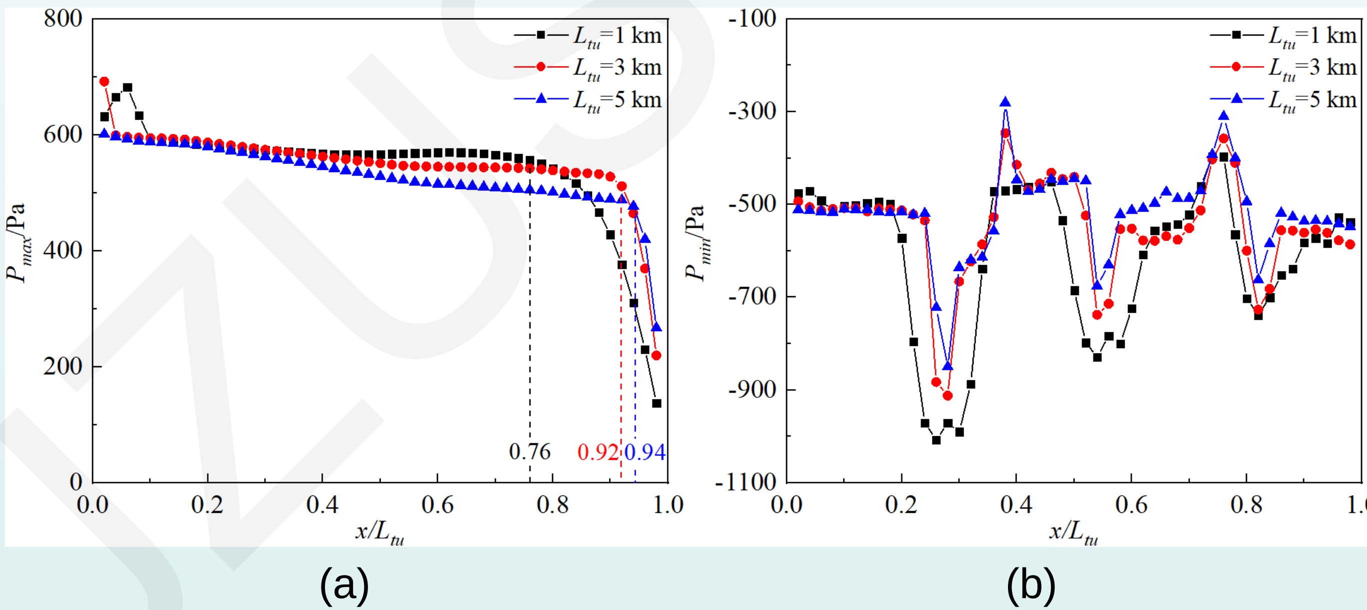


Fig. 6. Distribution of P_{max} and P_{min} on tunnel walls when trains pass through tunnels of different lengths: (a) P_{max} ; (b) P_{min}

Simulation results

- Effect of high geotemperature on the pressure wave

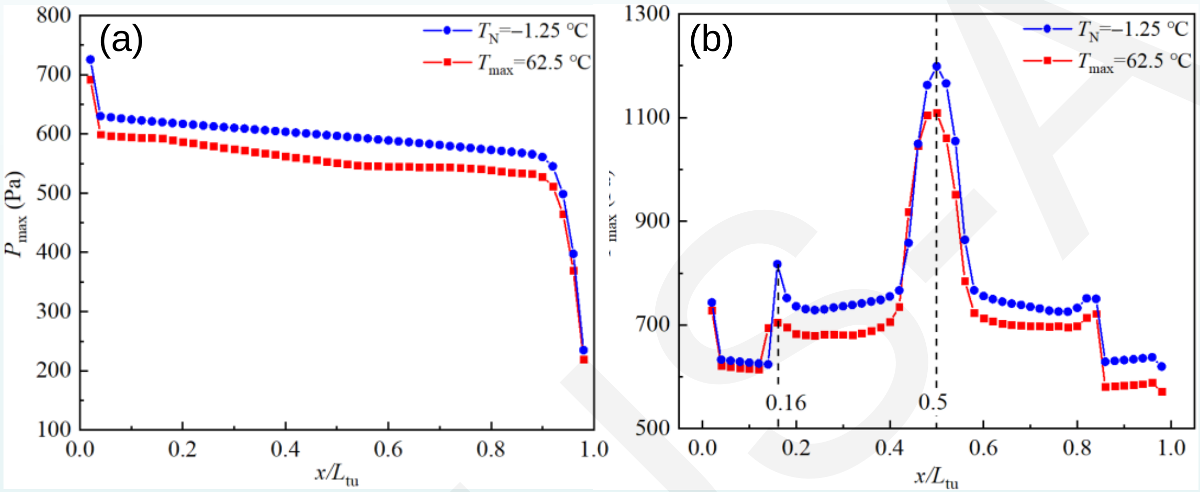


Fig. 7. Distributions of P_{max} and P_{min} along the tunnel when trains pass through an ambient-temperature tunnel and high-temperature tunnel: (a) P_{max}; (b) P_{min}.

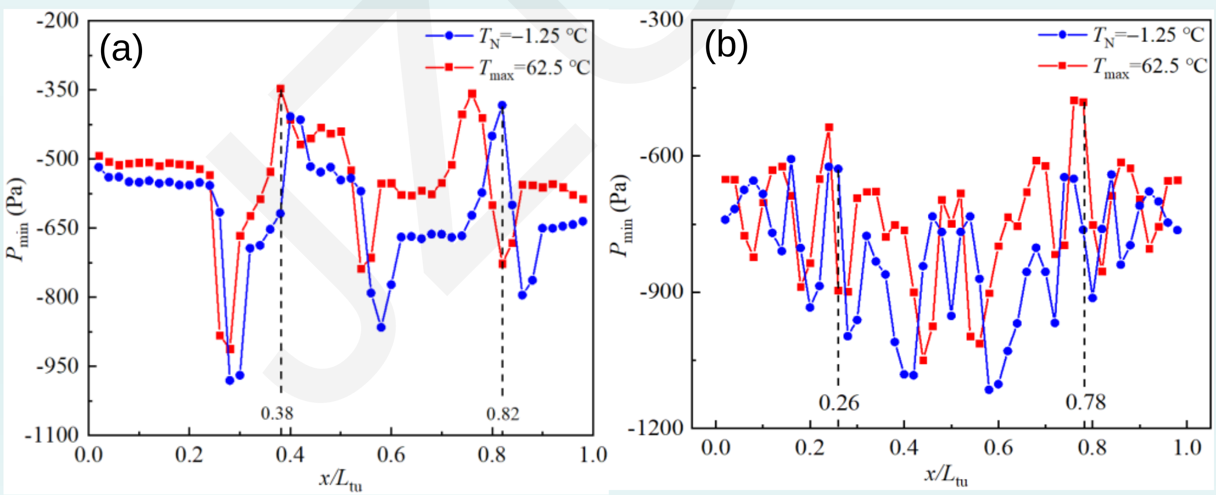


Fig. 8. Distributions of P_{max} and P_{min} along the tunnel when two trains pass each other in the ambient-temperature tunnel and high-temperature tunnel: (a) Pmax; (b) Pmin

Simulation results

- Effect of high altitude on pressure wave

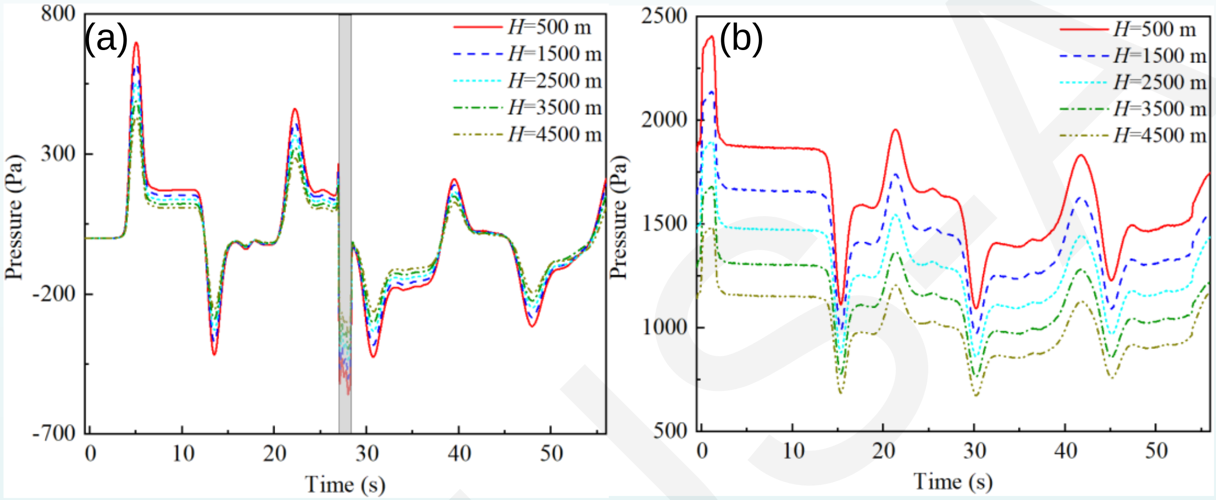


Fig. 9. Curves of pressure variation at observation points on the tunnel and train when trains pass through high-temperature tunnels at different altitudes: (a) TU_25; (b) TR_1

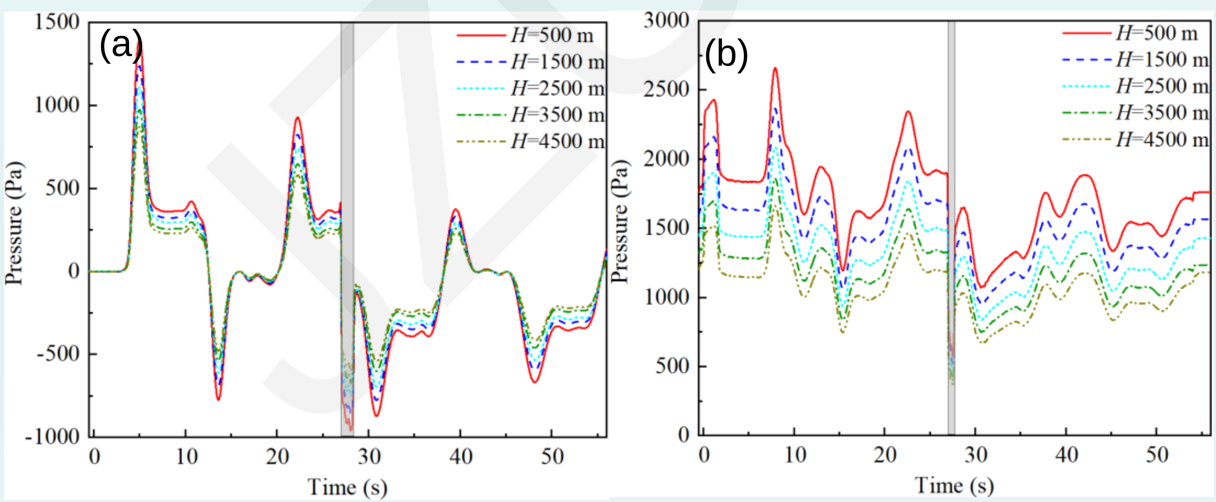


Fig. 10. Curves of pressure variation at observation points on the tunnel and train when two trains pass each other in high-temperature tunnels at different altitudes: (a) TU_25; (b) TR_1

conclusions

- Compared to the condition at normal ambient temperature, a high-speed train passing through high ground temperature tunnel, results in earlier and lower peak pressures on both the tunnel and train surface.
- During tunnel intersections in high ground temperatures, P_{max} on the tunnel surface moves toward the tunnel entrance, and the symmetry of the distribution of P_{min} is weakened.
- As altitude increases, pressure waveforms during both tunnel passage and intersection remain unchanged, but the peak pressure decreases linearly.
- In long tunnels with high altitude and high ground temperature, the overall pressure amplitude on the train and tunnel surfaces decreases, while temperature variations affect the locations of pressure peaks, necessitating careful attention in tunnel design and maintenance.