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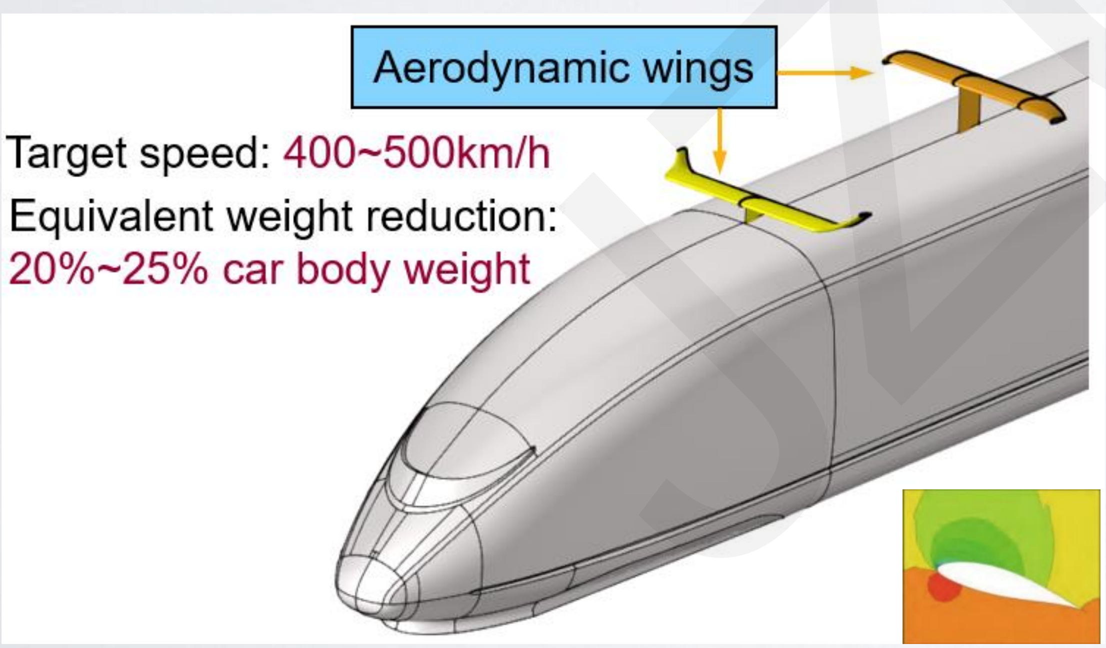
Numerical study of wheel–rail adhesion performance of new-concept high-speed trains with aerodynamic wings

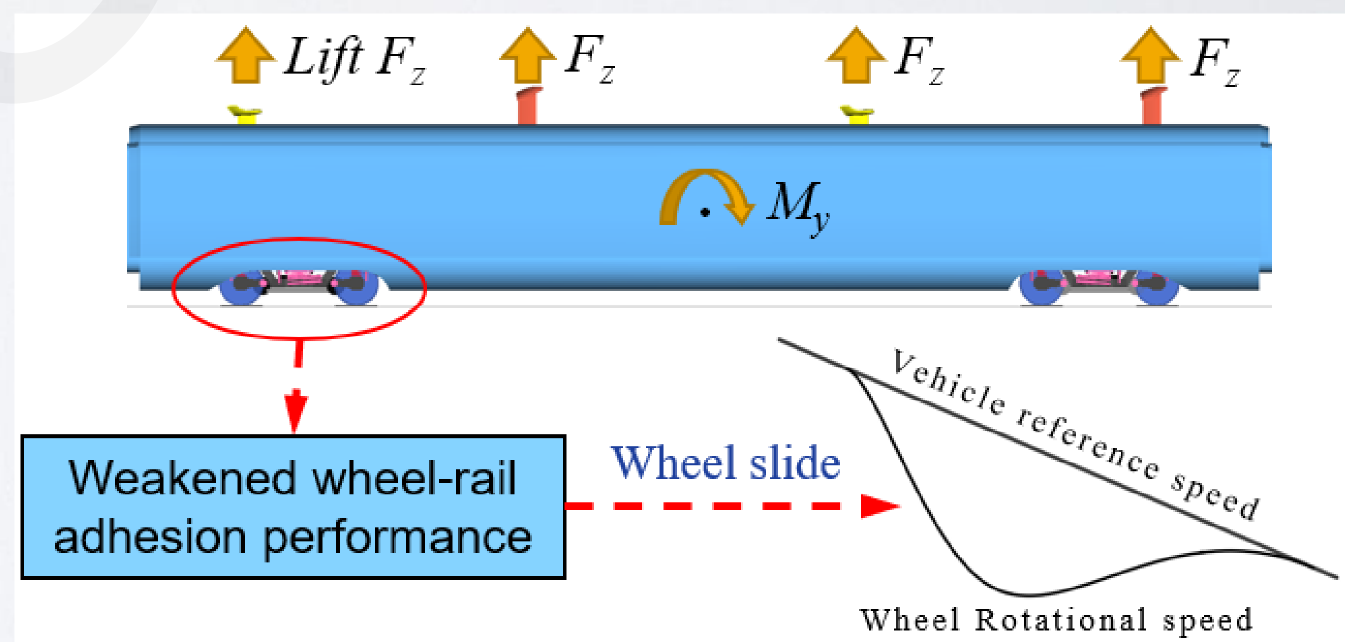
Key words: High-speed train; Wheel–rail adhesion; Aerodynamic wing; Multi-body dynamics (MBD)

Research Summary

The aerodynamic lift generated by wings on the roof of train can achieve the reduction of equivalent weight and increase the operation speed of high-speed train, but has the disadvantage of deteriorating wheel–rail adhesion performance.

This study proposes the available adhesion and adhesion margin as the evaluation index of wheel–rail adhesion performance, and presents a parametric analysis of the wheel–rail adhesion based on the Polach model.





Innovation points

- The research object of this study is a high-speed train with a brand new aerodynamic shape design, which is expected to achieve the reduction of equivalent weight and energy consumption.
- According to the typical wheel–rail adhesion-slip characteristic, wheel–rail available adhesion and adhesion margin are proposed as the evaluation indexes of adhesion performance.
- A MBD model of high-speed train with aerodynamic wings is established to investigate the influence mechanisms of various factors on wheel-rail contact force and wheel-rail adhesion performance.

Evaluation index of wheel–rail adhesion performance

- $F_{\mu max}$ is the wheel–rail available adhesion which represents the adhesion limit, determining the maximum torque that can be applied to the wheel.
- F_m is the difference between available and utilized adhesion, reflecting potential available adhesion or insufficient adhesion between wheel and rail.

Evaluation indexes:

$$F_{\mu max} = \max[F_{\mu}(s)] = \mu_{max} Q$$

$$F_m = \begin{cases} F_{\mu max} - F_{\mu} & \geq 0 \quad (s \leq s_{opt}) \\ F_{\mu max} - F_{ref} & < 0 \quad (s > s_{opt}) \end{cases}$$

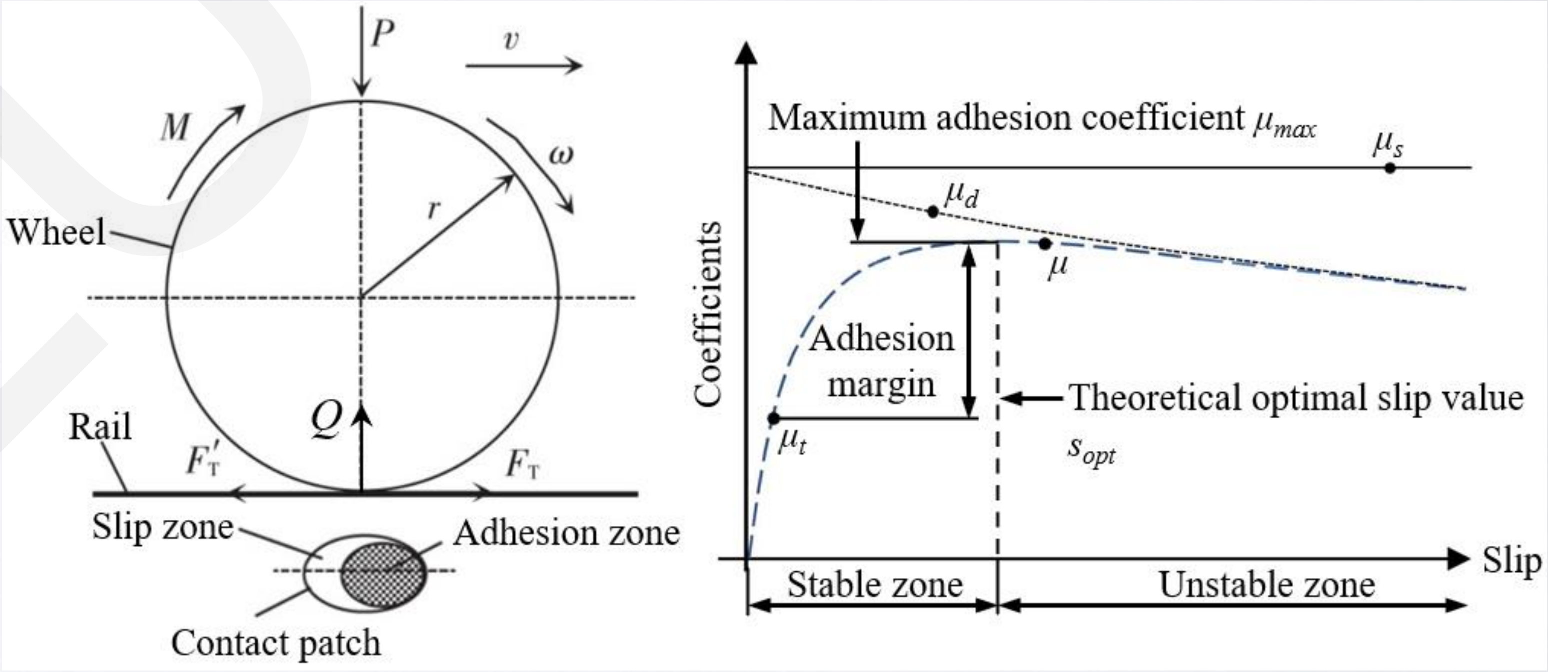


Fig. 4 Adhesion-slip phenomenon and adhesion-slip characteristic curve

Simulation results

- Deterioration of wheel–rail contact condition makes available adhesion inadequate to meet braking requirements under some operation scenarios.
- The safety curves which can be used to formulate aerodynamic lift and train speed adjustment strategies are obtained, and track irregularity has little influence on them.

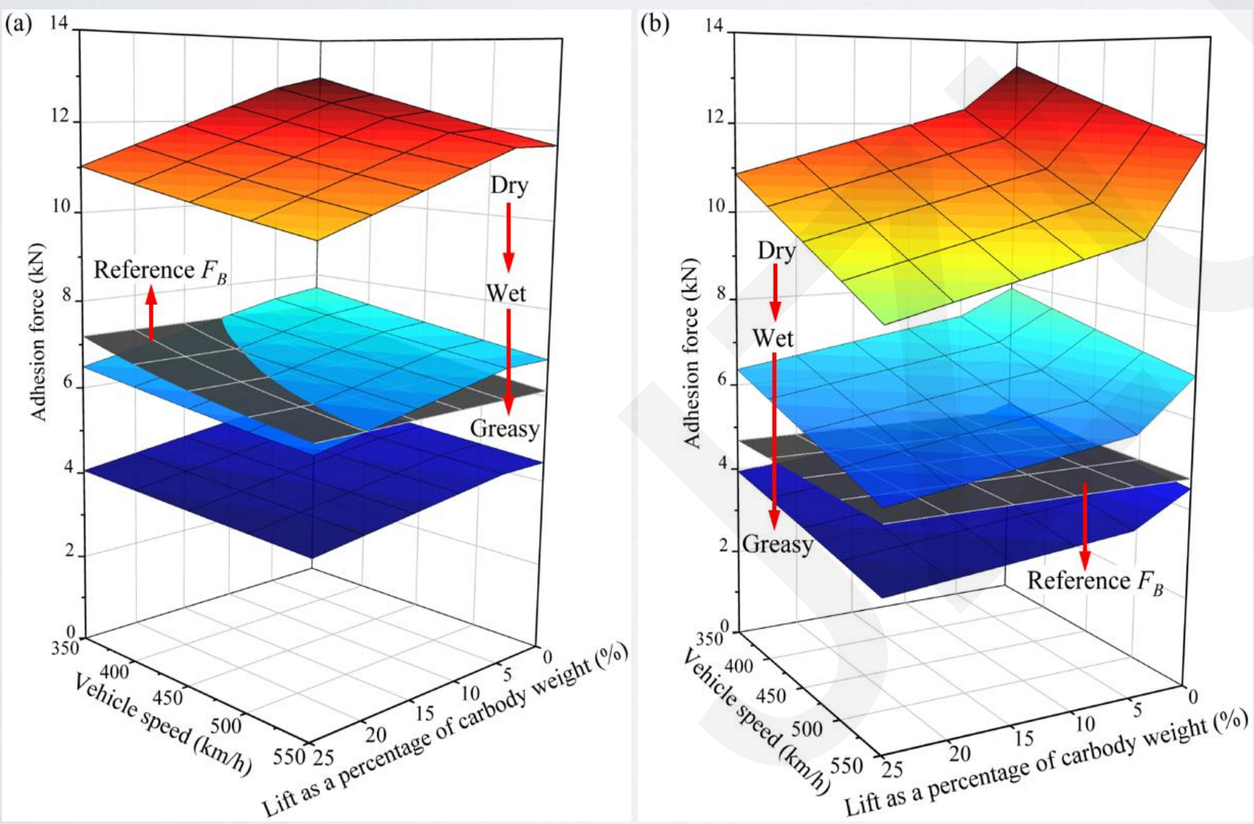
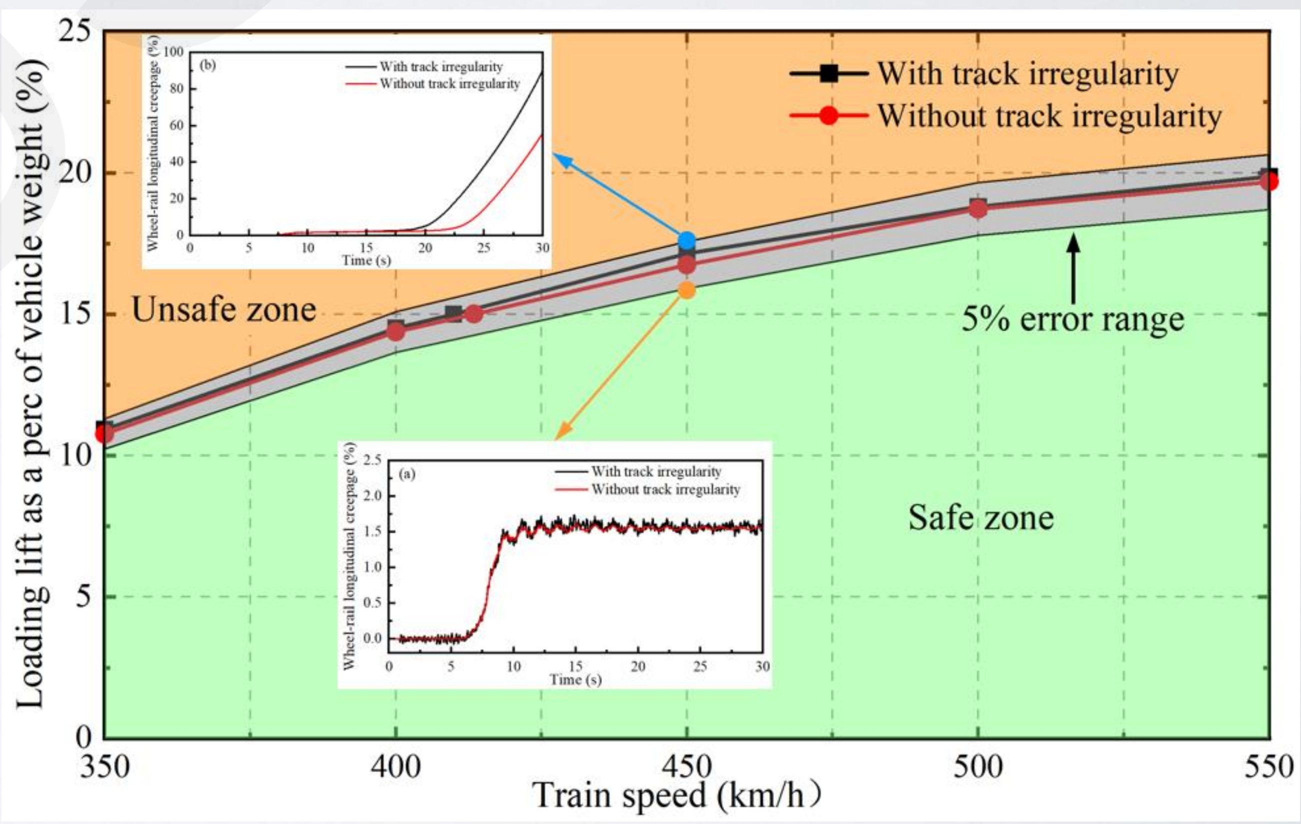


Fig. 13 Influence of contact conditions on wheel–rail available adhesion: (a) No. 4 vehicle; (b) No. 8 vehicle



Comparisons of train operation safety curves with and without track irregularity and relevant verification

Conclusions

- The load transfer caused by the action of aerodynamic load and braking torque are the main reason for the inconsistent adhesion condition of four wheelsets.
- Aerodynamic lift and train speed have coupling effects on wheel–rail available adhesion and adhesion margin.
- The pollution from a ‘third-body medium’, such as water and oil on the wheel–rail interface, reduces the wheel–rail adhesion performance dramatically and results in the unloaded wheelset reaching adhesion saturation.
- Within a certain error range, the track irregularity only weakly affects the evaluation of wheel–rail adhesion performance.