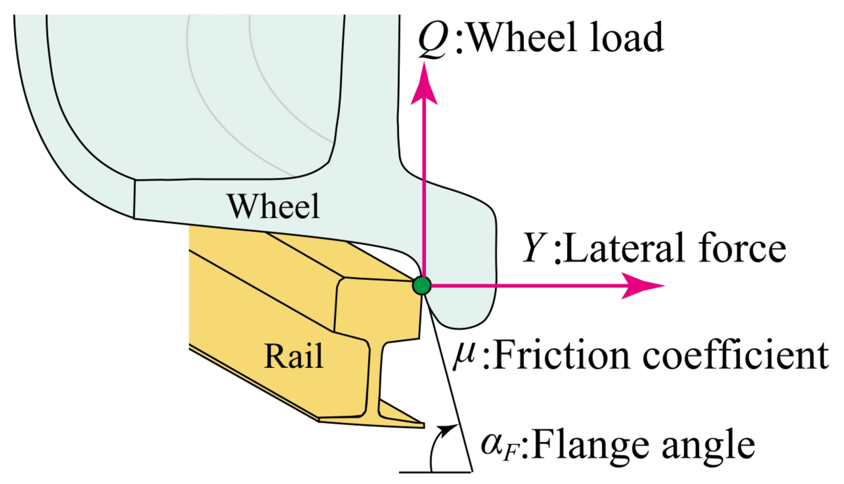
A New Method for Evaluating Running Safety Using Wheel/Rail Contact Conditions

Introduction

Running safety against flange-climb derailment is typically evaluated using the derailment quotient (Y/Q). While this method has proven reliable over time, there is a need to improve its accuracy due to its conservative nature. Incorporating wheel/rail contact conditions can help refine the safety thresholds associated with Y/Q, though this adjustment provides minimal benefit on sharp curves. This study proposes a new method for evaluating running safety against flange-climb derailment in railway vehicles, focusing directly on the wheel/rail contact conditions.

·Current running safety evaluation



Safety condition:

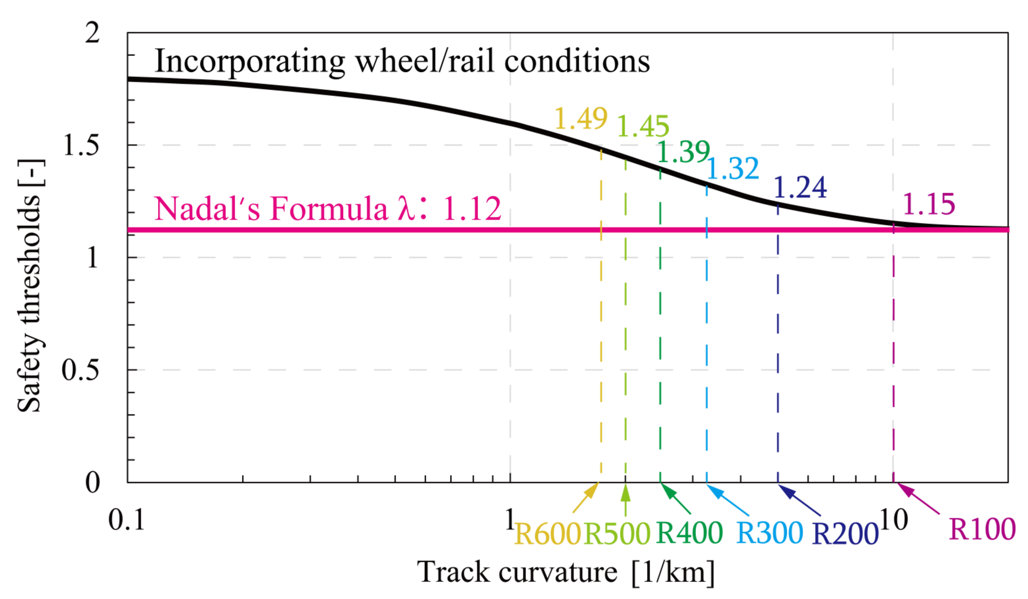
$$\frac{Y}{Q} < \lambda$$

※In practice, λ is divided by a safety factor.

$$\lambda := \frac{\tan\alpha_F - \mu}{1 + \mu\tan\alpha_F}$$

(Nadal's formula)

·Calculation example: Safety thresholds for Y/Q

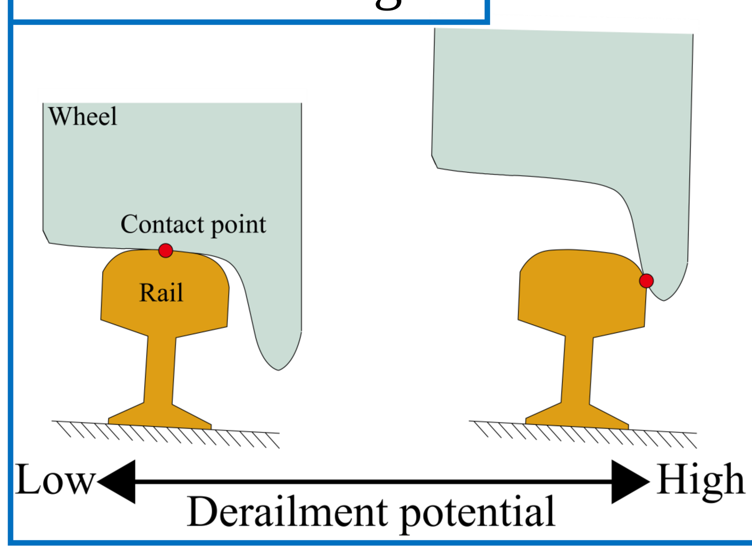


Calculation conditions:
- Wheel profile: JP modified arc …Flange angle α_F: 65deg
- Friction coefficient μ: 0.3
- Angle of attack: Geometric value assumed
- Creep force: Kalker theory and Levi-Chartet law assumed

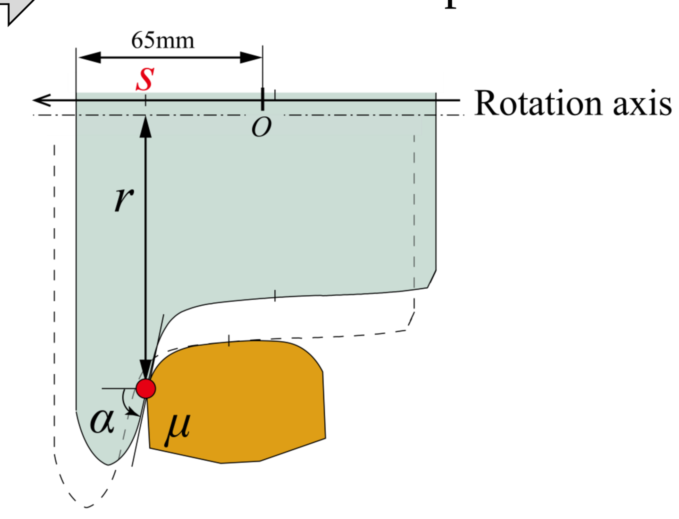
Evaluation indicators

Using two margins from the current state to the flange-climb state.

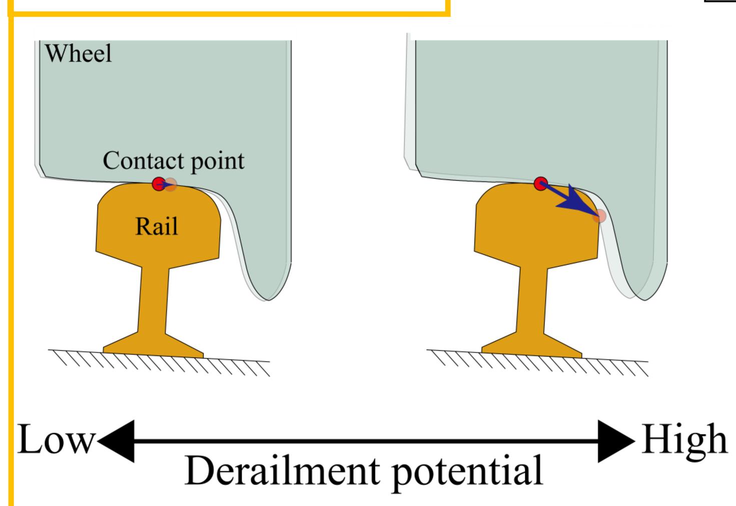
Geometric margins



Indicator: Contact position s

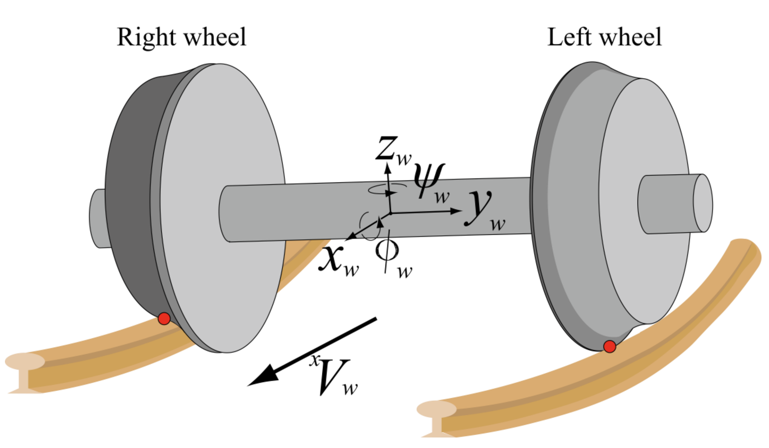


Dynamic margins



Indicator: Normalized transverse creepage ξ

$$\xi := \frac{v_y}{\psi_w} = \underbrace{-\frac{r}{r_0\cos\alpha}}_{\xi_S\text{: Geometrical Elements}} + \underbrace{\frac{\dot{y}_w + r\dot{\phi}_w}{\psi_w\,{}^xV_w\cos\alpha}}_{\xi_F\text{: Dynamical Elements}}$$

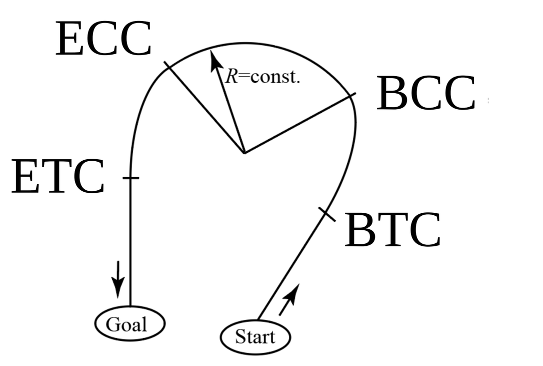


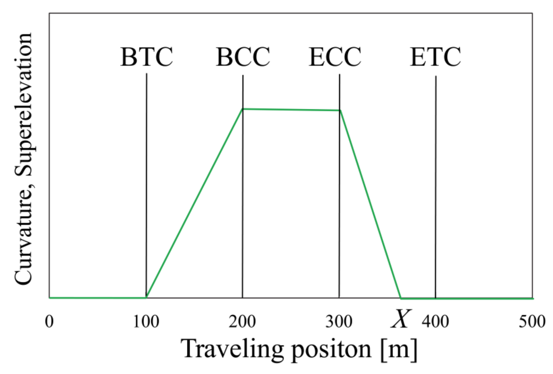
v_y: Transverse creepage
r: Wheel rolling radius
r_0: Wheel rolling radius in neutral state
ψ_w: Wheelset angle of attack
$\dot{y}_w$: Wheelset lateral velocity
$\dot{\phi}_w$: Wheelset roll angular velocity
${}^xV_w$: Wheelset running velocity
α: Contact angle

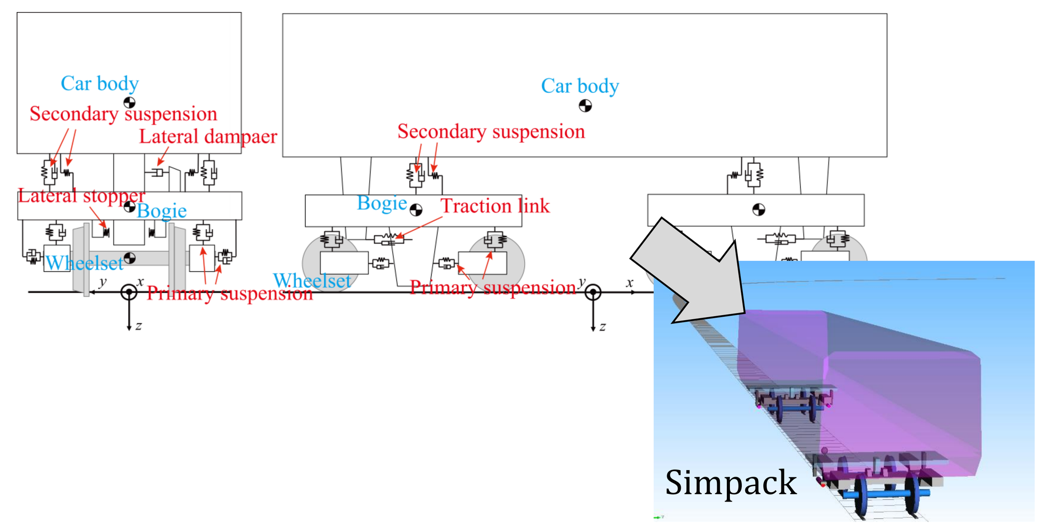
Simulation

◇Simulation conditions

- Software: Simpack
- Vehicle: JP meter-gauge train
- Running speed: Low
- Single circular curve passage





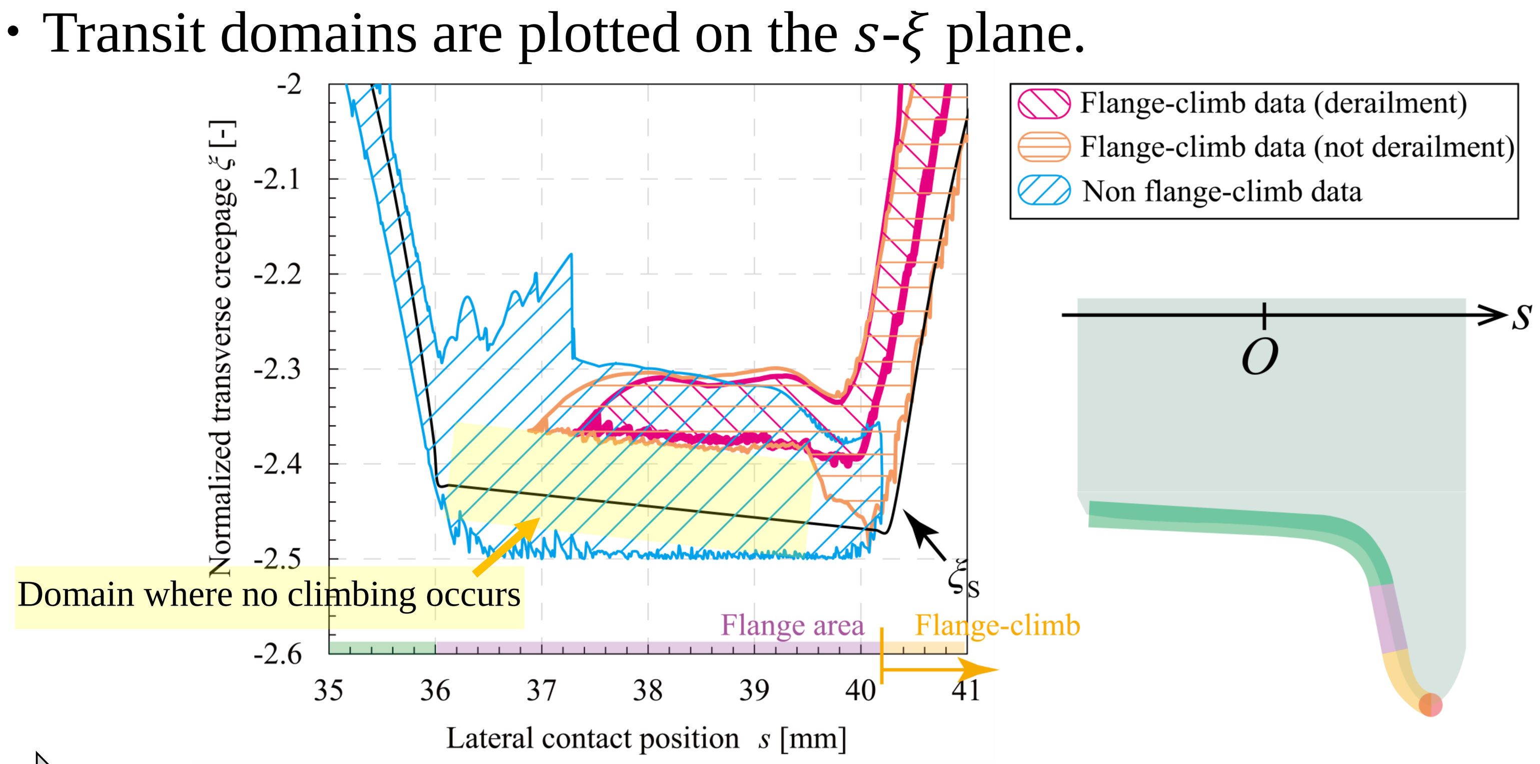


変数	内容
Wheel load imbalance ΔP	0%, 15%, 30%（Decrease rate of outer side）
Circular curve radius R	100m, 160m
Friction coefficient μ	0.1～0.7
Superelevation runoff rate	300, 400, 600, 1000
Running speed ${}^xV_w$	10km/h, 30km/h (R=100m) 10km/h, 40km/h (R=160m)

※Superelevation and slack are fixed at 105mm and 0mm, respectively.

◇Simulation results

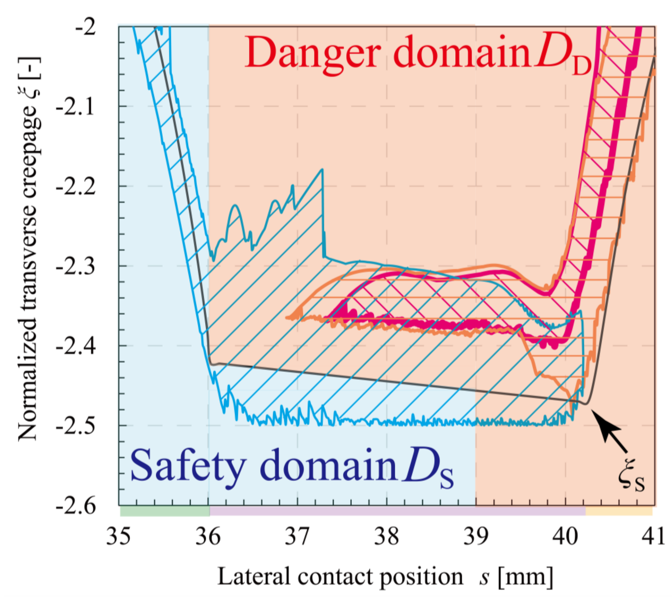
- Classification based on simulation results after entering the ECC.
- Transit domains are plotted on the s-ξ plane.



When ξ is small (i.e., near ξ_S), flange-climb does not occur.

◇Proposal of evaluation method

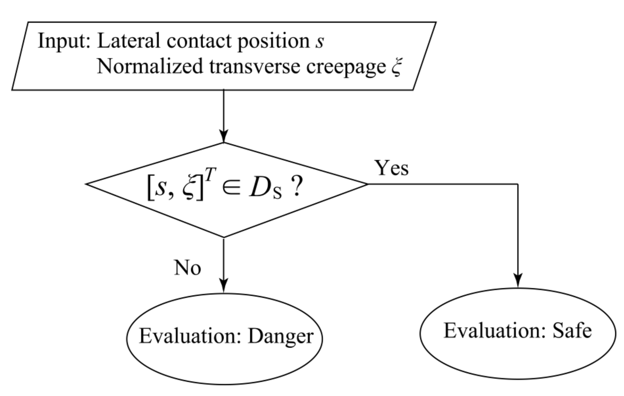
- Definition of safety evaluation diagram



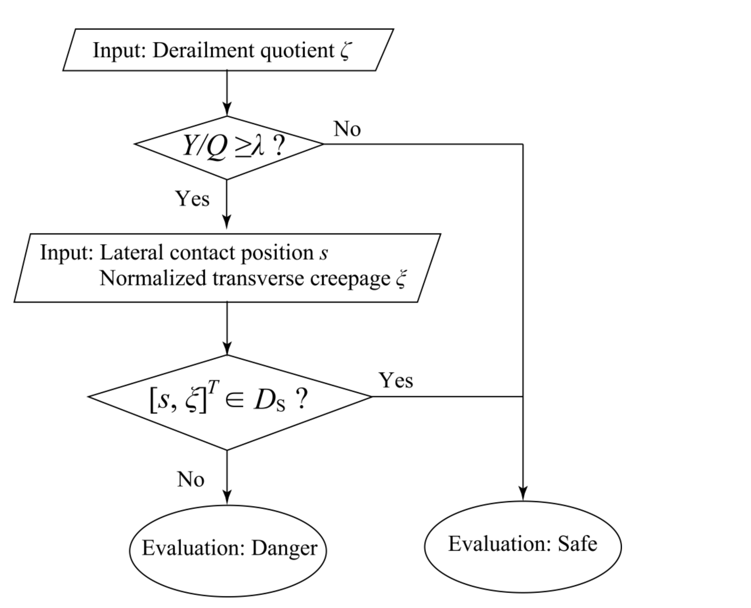
Design concept

Dividing into cases based on contact position:
- Tread area contact: Safe
- Flange area contact: Evaluate based on the magnitude relationship between ξ and ξ_S
- Area beyond the flange area: Dangerous

- Evaluation Flowchart



(a) Using only proposed method



(b) Combining with conventional evaluation method

Conclusion

- Even with the same contact position, the risk of derailment varies depending on ξ.
- The proposed method demonstrated the potential to enable evaluations that reflect actual conditions.

More accurate evaluation

Publications

S. Kuniyuki and K. Nakano: "Evaluation method for flange-climb derailment focusing on contact position and transverse creepage between wheel and rail in railway vehicle," Transactions of the Japan Society of Mechanical Engineers (in Japanese), Vol. 91, No. 942, 2025.