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Guided Wave Method for Detecting Rail Defects

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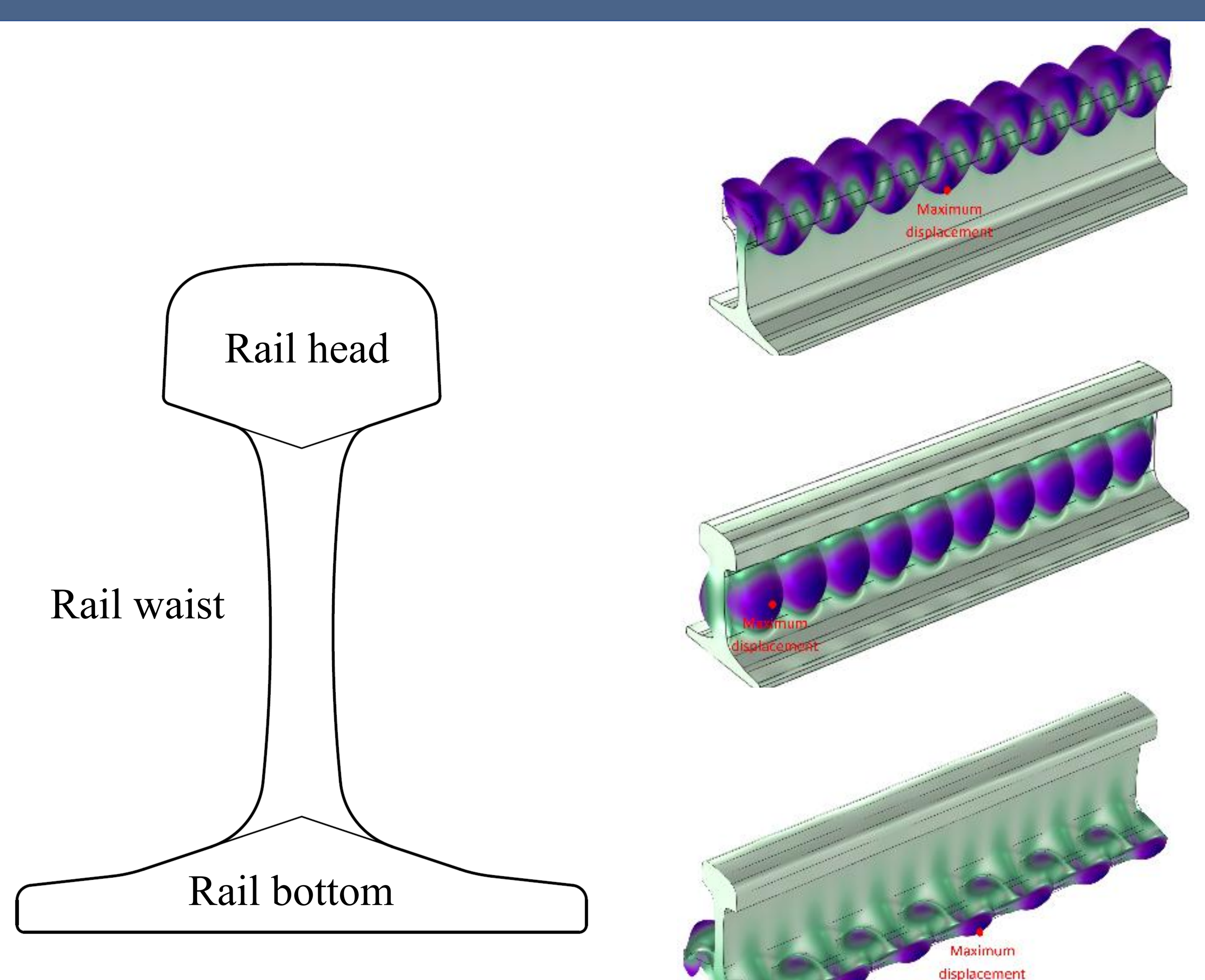
Introduction

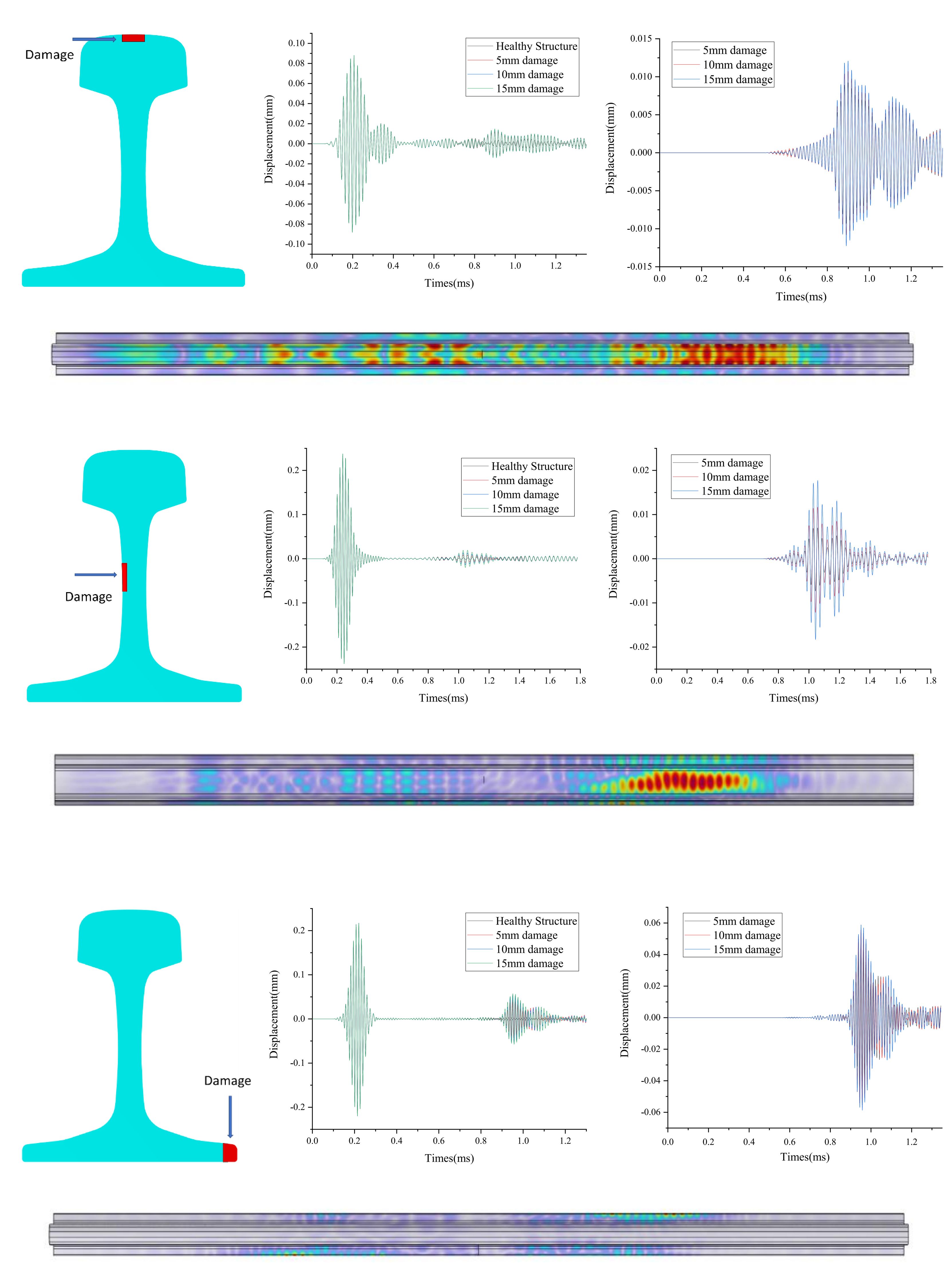
Rails are safety-critical components; hidden defects in the head, waist and bottom can lead to fracture and service interruption. Guided waves are attractive for rail inspection because they propagate over long distances and interrogate the full cross-section. However, complex rail geometry produces strong multimodal and dispersive propagation, which complicates mode selection and signal interpretation.

Methods

- SAFE analysis calculates dispersion and phase-velocity curves for the CHN60 rail by combining longitudinal analytical wave terms with cross-sectional finite elements.
- Integrated selection criteria combine displacement concentration ratio P, phase-velocity gradient G and wavelength constraint k.
- Thresholds: $P \geq 0.9$, $G \leq 0.01$ m/s/Hz and $k \geq 125.7$ rad/m for detecting defects of 5 mm and above.
- Region-specific components: vertical displacement for rail head and bottom, lateral displacement for rail waist.

Graphics / Images





Conclusions

The SAFE-based multi-parameter criterion provides a practical basis for selecting guided-wave modes and frequencies in complex rail structures.
The proposed wavelength-matched excitation selectively excites the target mode and reduces multimodal interference.
The method detects defects of 5 mm and above in rail head, waist and bottom regions in numerical simulations.
Region-specific interpretation is necessary: the bottom is most sensitive, the waist is most stable and the head shows stronger modal coupling.
Future work will focus on experimental validation and on the influence of fastening systems and environmental effects.