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Effect of tamping duration on mechanical properties of ballast beds: a DEM–MBD coupled investigation

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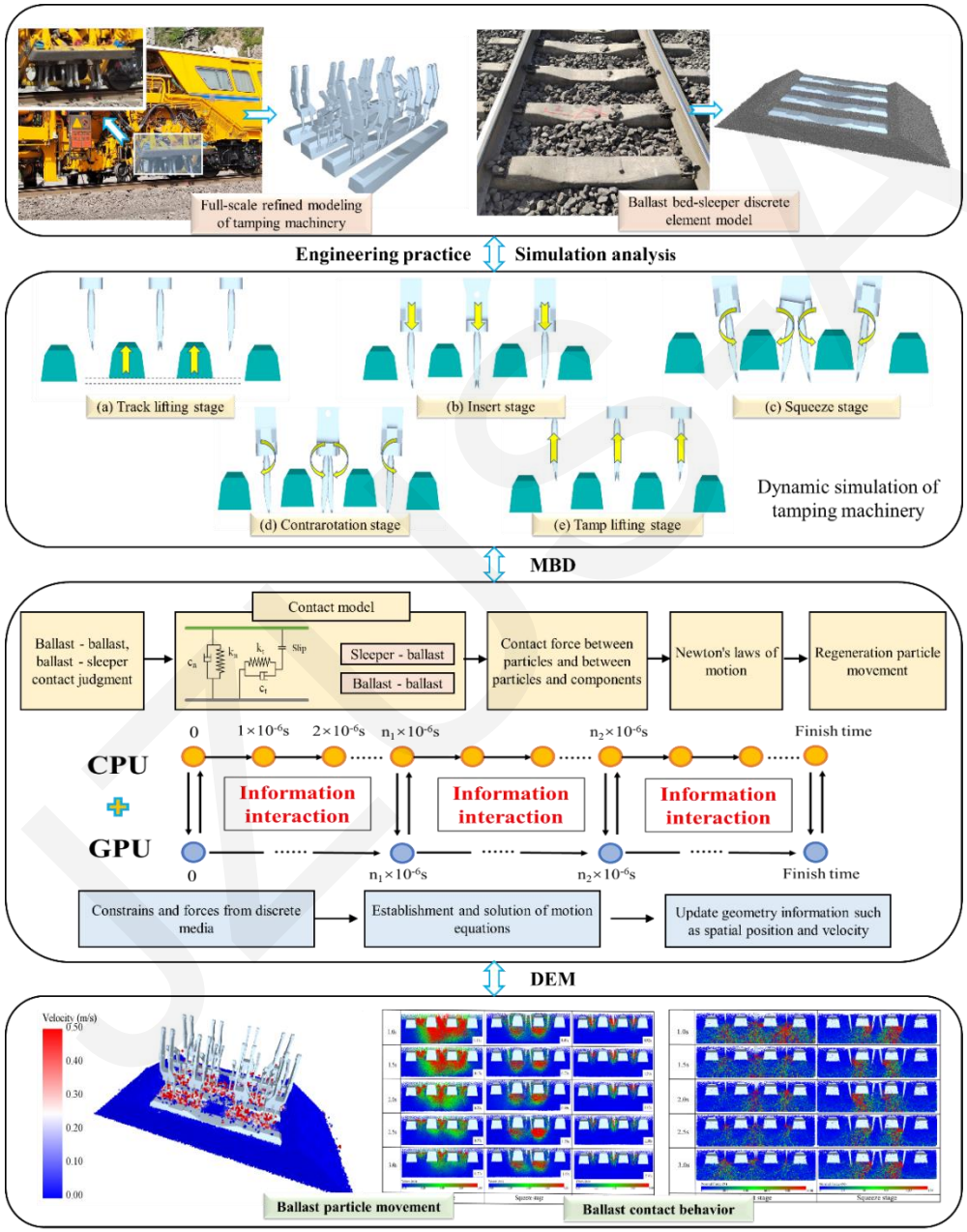
Research flow chart



Simulation analysis model

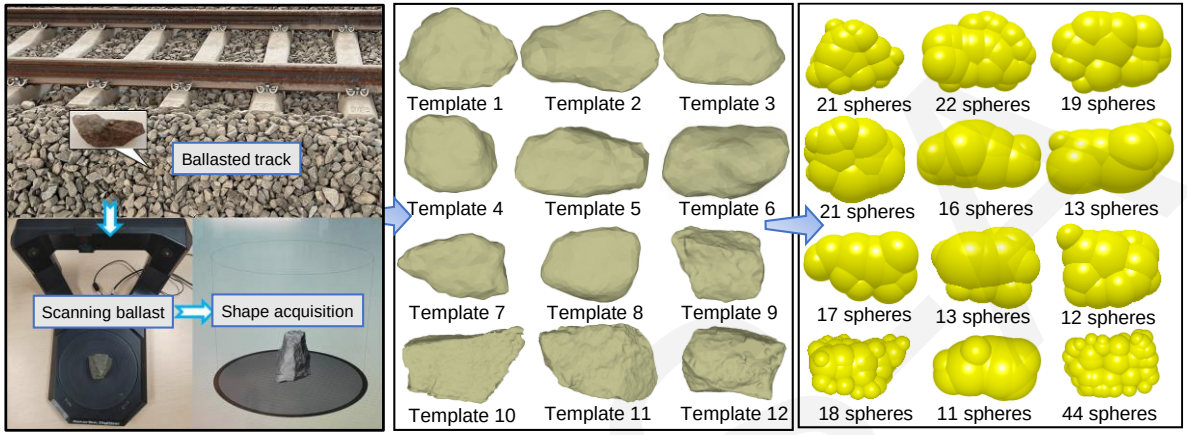


Fig. 1 Modeling process of ballast particles

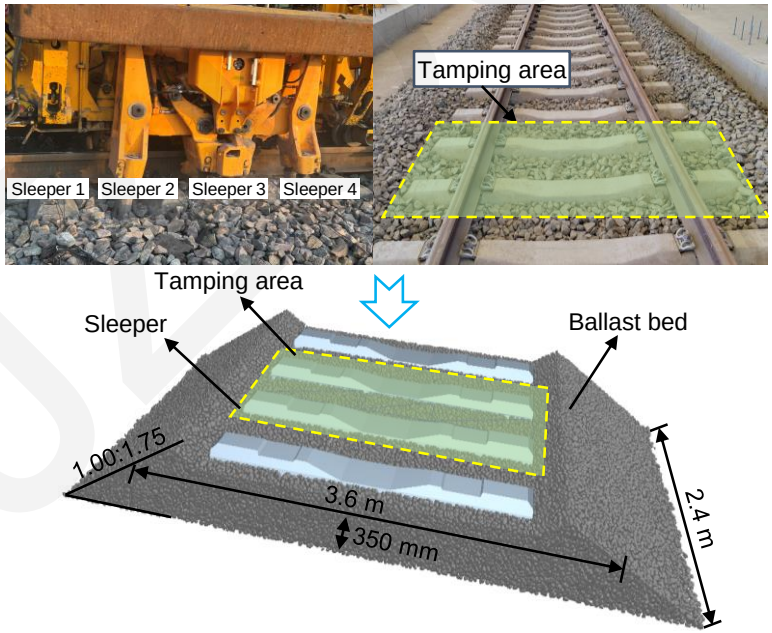


Fig. 2 Simulation model of a ballasted track

Change of ballast bed compactness

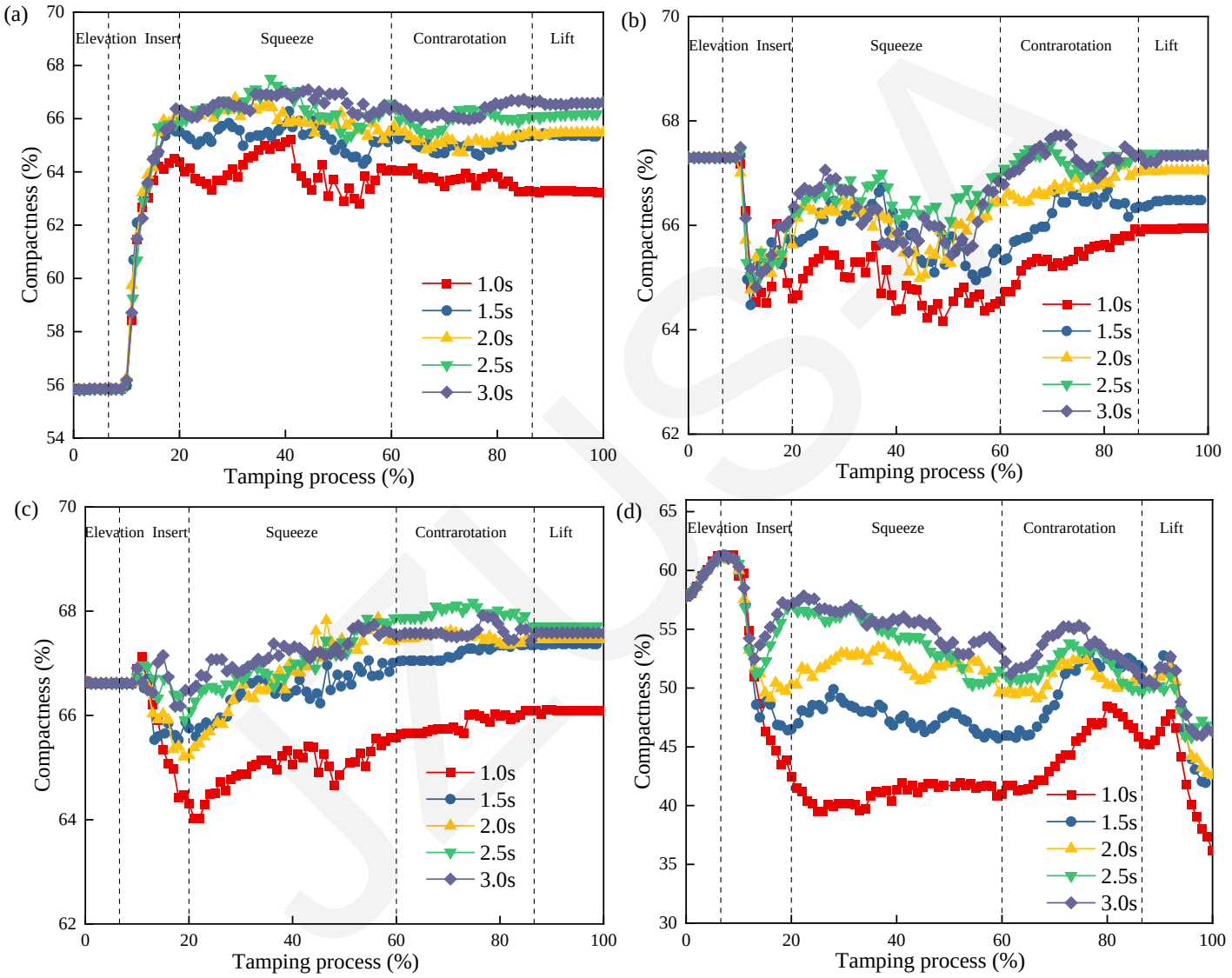


Fig. 3. Variation in ballast bed compactness: (a) area U1, (b) area U2, (c) area U3, (d) area V0.

Change of ballast movement

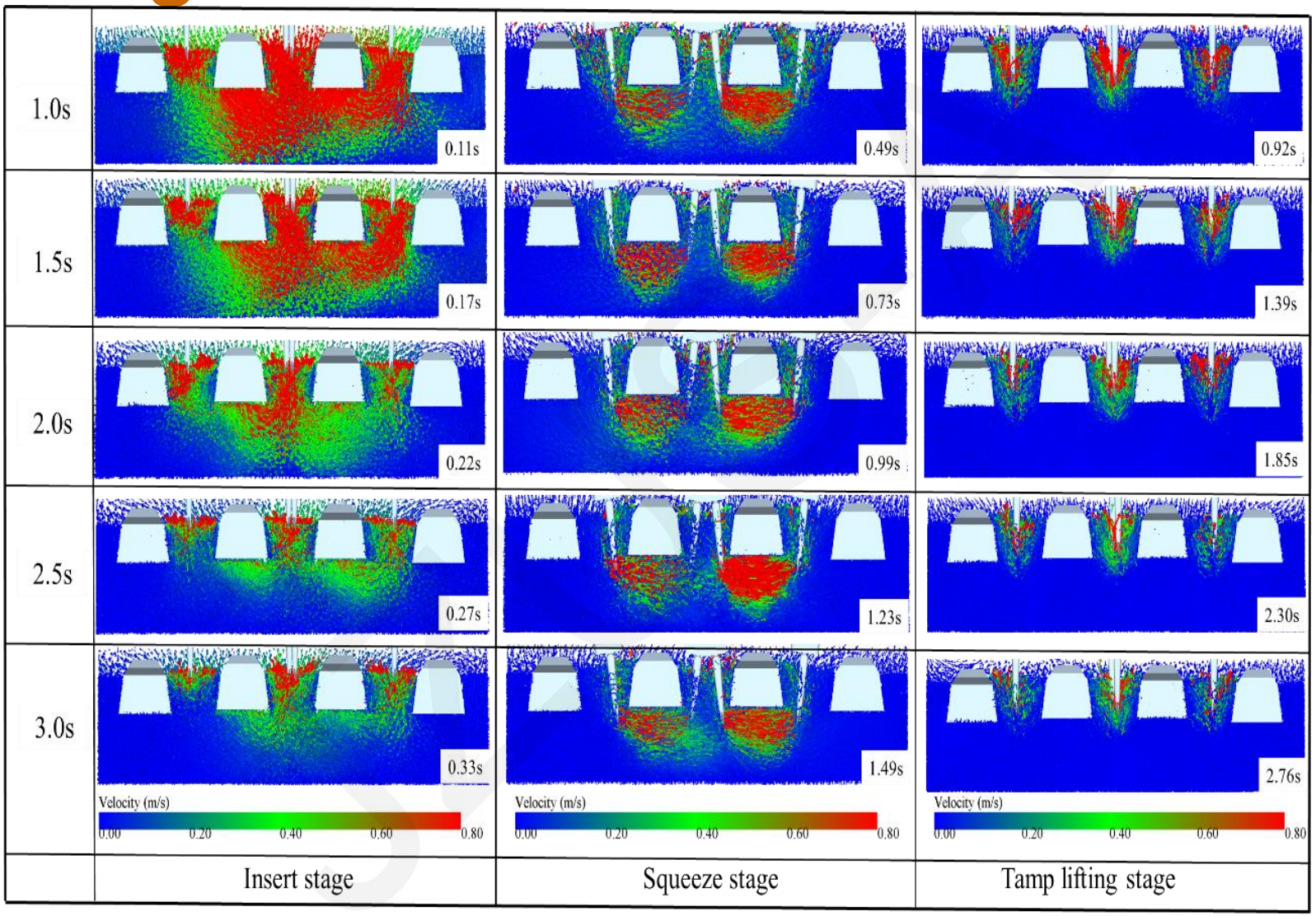


Fig. 4. Velocity distribution of ballast movement

Conclusions

- The variation in tamping duration significantly affects ballast particle velocities. During the inserting stage, prolonging the tamping duration from 1 to 3 s results in a 72.6% reduction in the velocity of ballast particles beneath sleepers and a 62% decrease in the inter-sleeper region. The squeezing stage shows a gradual 7% velocity decline beneath sleepers, while the tamp lifting stage exhibits a 69% velocity reduction in the inter-sleeper region. The inter-sleeper region shows the highest sensitivity to tamping du-ration. Angular velocity evolution patterns in the ballast bed align closely with velocity changes.
- The patterns of evolution of translational and rotational kinetic energy in ballast particles are closely correlated with their motion characteristics. Mechanical energy exhibits the most significant oscillatory variations in the squeezing stage.
- Prolonged tamping duration significantly reduces contact forces in ballast particles during the inserting stage while remaining minimally affected in the squeezing stage. The coordination number of ballast particles shows a positive correlation with the tamping duration.
- Increased tamping duration enhances ballast bed compactness, improves uniformity in compactness distribution, and increases post-tamping resistance, support stiffness, and long-term deformation resistance capacity.