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A FLOATING FRAME OF REFERENCE APPROACH TO STUDY FRACTURE IN MULTIBODY SYSTEMS USING PERIDYNAMICS

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Summary: Classical continuum mechanics relies on partial differential equations (PDEs) that struggle to accurately model cracks and structural discontinuities. To address this limitation, the peridynamics (PD) theory was developed, replacing PDEs with integrodifferential equations. In PD, each material point interacts with its neighbors within a prescribed length scale. PD is particularly effective for analyzing fractures and complex multiscale, multi-physics phenomena.

A prior study by the authors introduced a methodology integrating bond-based PD theory with planar multibody dynamics (MBD). This approach effectively models nonlinear and discontinuous deformations, enabling autonomous crack initiation and propagation. Key equivalences between PD and MBD were established: PD point masses were treated as rigid bodies, and bond forces were represented by nonlinear force elements. The meshless nature of the methodology aligns well with PD principles. Benchmark comparisons and examples demonstrated the capabilities of the approach, although its computational efficiency for complex engineering problems was hampered by the large dimension of the equations of motion and the disparity between time scales of rigid and deformable body motions.

To address these challenges, the authors propose an enhanced hybrid approach to manage evolving deformation states—ranging from small linear elastic to nonlinear elastic and fracture. This approach employs a floating frame of reference (FFR) formulation with a linear PD-based description for the deformation, ensuring unique deformation displacement fields by enforcing mean axis conditions. These conditions are derived by minimising the deformation kinetic energy, effectively decoupling rigid and deformable motions.

Numerical efficiency is further improved using component mode synthesis. Under the assumption of small, linear-elastic deformations, modal coordinates replace the numerous coordinates linked to each PD point mass. For nonlinear deformations and fracture, the previously implemented methodology is retained. Structural deformations are represented relative to a floating frame of reference moving with the body. Benchmark case simulations verify the implementation and highlight the enhanced capabilities of the methodology. Preliminary results show time-dependent deformations and discuss the impact of horizon size on structural behaviour. The cases studied range from simple mechanisms to complex systems such as a deformable railway bogie frame under extreme loading conditions. These results indicate improved accuracy and efficiency, laying a solid foundation for transitioning from linear to nonlinear deformation descriptions.