

Advances in the Particle Finite Element Method (PFEM) for Problems in Sea, Earth and Fire

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The Particle Finite Element Method (PFEM) is a general numerical procedure for the analysis of problems in fluid and solid mechanics combining techniques from finite element and particle methods. The key feature of the PFEM is the use of a Lagrangian description to model the motion of the nodes in both the fluid and the solid domains. Surface nodes are viewed as particles which can freely move and separate from the main analysis domain representing, for instance, the effect of water drops or disintegrated solid particles. The boundary of the analysis domain is defined at each step using the Alpha Shape method. A mesh connects the nodes defining the discretized analysis domain where the governing equations are solved using state of the art FEM. The PFEM is particularly suited for multidisciplinary coupled problems in mechanics such as FSI situations accounting for large motions of the free surface and splashing of waves, heterogeneous fluid mixtures and non linear problems in solids accounting for large deformations with multiple frictional contacts, material fragmentation and thermal coupling effects.

Basic steps of the PFEM

1. The starting point at each time step t_n is the cloud of points (${}^n C$) in the fluid and solid domains (Fig.1).
2. Identify the boundaries for both the fluid and solid domains defining the analysis domain ${}^n V$.
3. Discretize the fluid and solid domains with a finite element mesh ${}^n M$.
4. Solve the coupled Lagrangian equations of motion for the fluid and the solid domains. Compute the variables in both domains at the next (updated) configuration. A standard staggered scheme is used.
5. Move the mesh nodes of the fluid and solid domain to a new position ${}^{n+1} C$ is $n+1$.
6. Go back to step 1 and repeat the solution process for the next time step to obtain ${}^{n+2} C$.

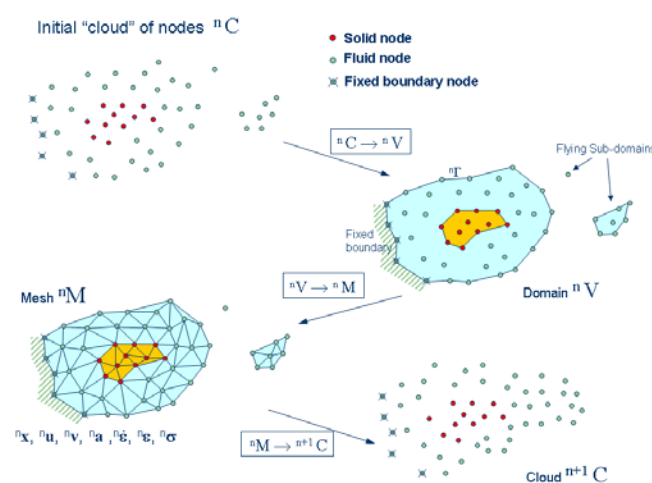


Figure 1: Application of PFEM to follow the motion of a continuum with fluid and solid domains

In the paper, we present advances in the PFEM for solving a wide range of problems including the study of water streams on structures accounting for erosion of the foundation, the analysis of the failure of earth dams in overtopping scenarios, the stability of harbour structures under large waves (Fig. 2), the study of excavation processes in soil and rock, the analysis of mixing processes in multi-fluids (Fig. 3), the study of the melting and burning of objects in fire (Fig. 4) and the simulation of industrial forming processes.

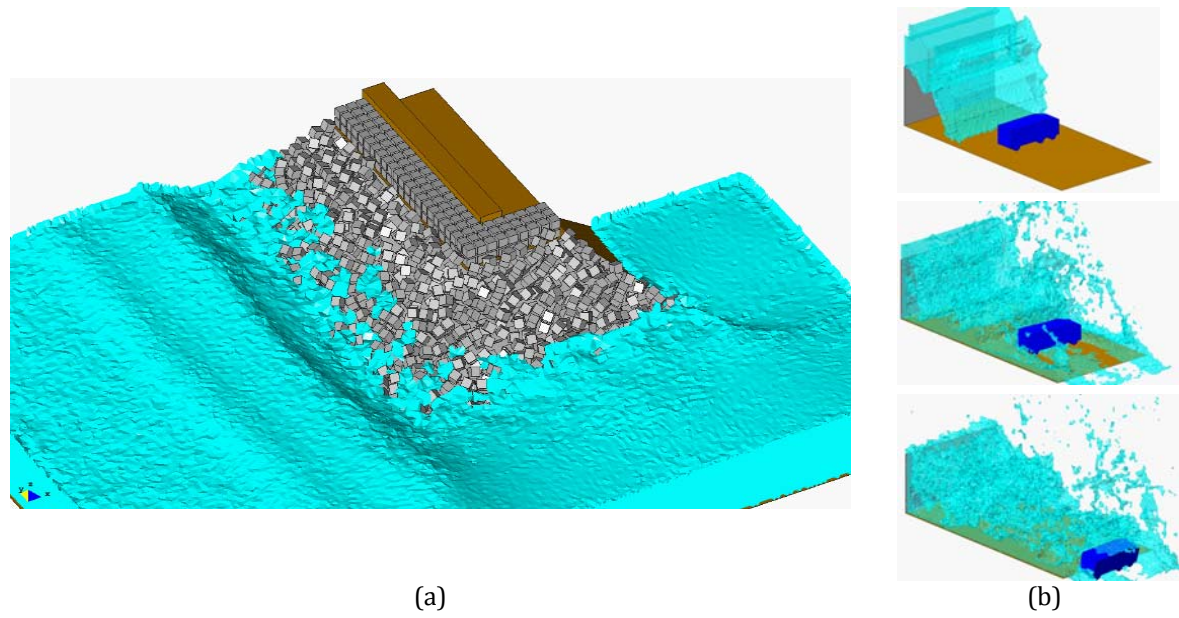


Figure 2: (a) Breakwater under sea waves. (b) Effect of overtopping wave on a truck passing by the perimetral road of breakwater

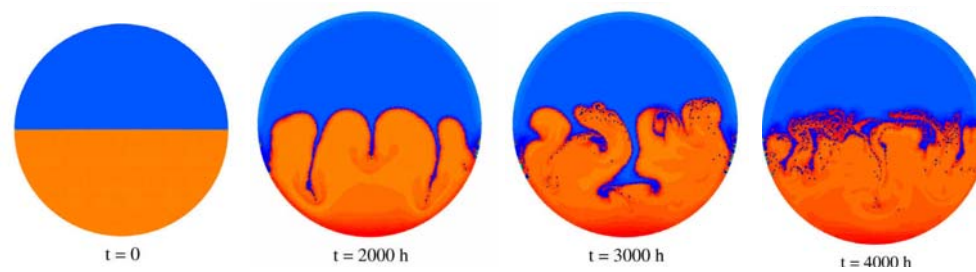


Figure 3: Mixing of two fluids. Temperature field at different times

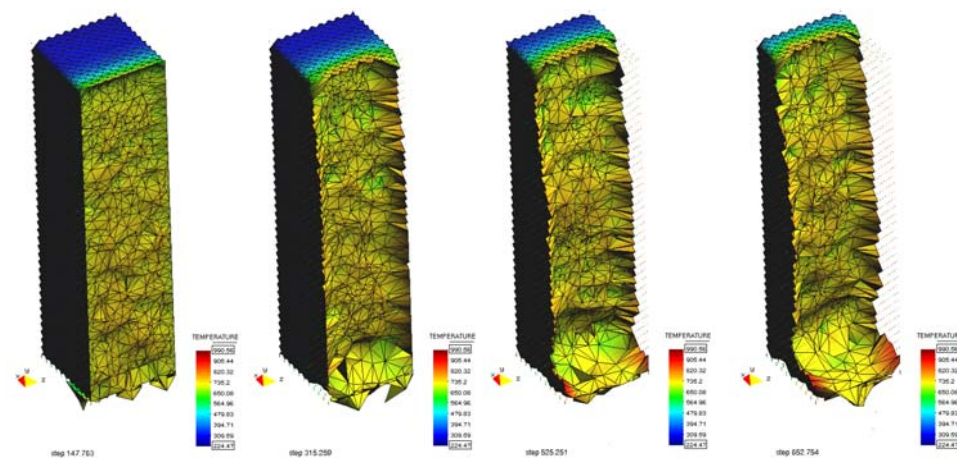


Figure 4: Simulation of a 3D polymer melt problem with the PFEM

References

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