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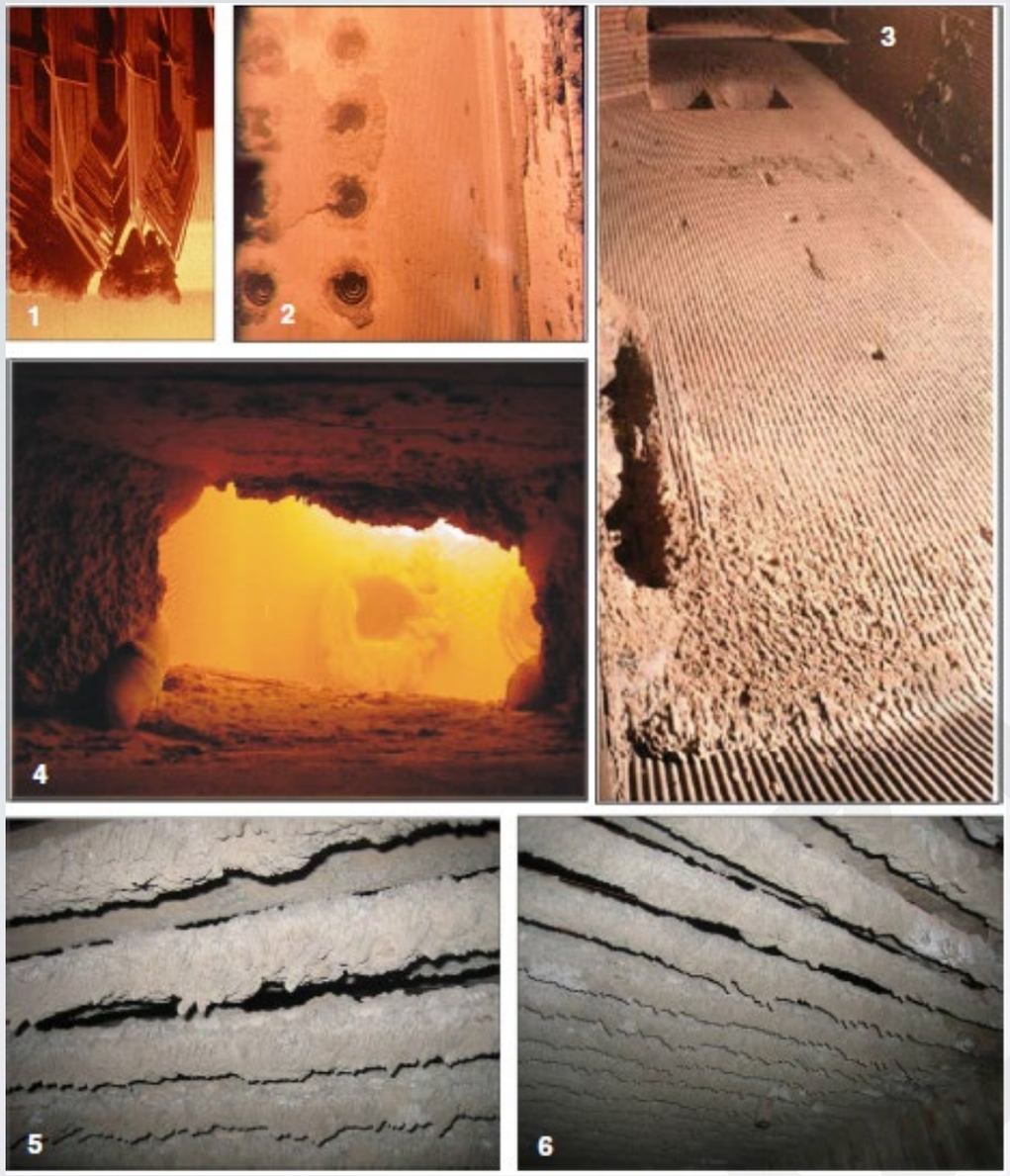
Simulation analysis of fracture process of slag deposits surrounding wall tubes during steam sootblowing

Key words:

Sootblowing; Boiler; Numerical model; Cohesive zone method (CZM); Deposit fracture

Backaground



Examples of ash deposits in different boiler regions
1 — superheater; 2 — burner area and boiler walls;
3 — boiler walls; 4 — burner quartz;
5, 6 —superheater tubes in waste incinerator

- Slag deposits on water wall tubes not only reduce the heat transfer efficiency in boilers but also degrade steam tubes by corrosion.
- Sootblowing is an effective and conventional method to overcome this problem, and it can be performed using high-pressure steam, air, or sound waves.
- To replicate the ash deposit failure due to sootblowing dynamically and comprehensively, we developed a novel 3D numerical model that combined the cohesive zone method (CZM) and coupled Eulerian–Lagrangian (CEL) analysis in this study.

Methods

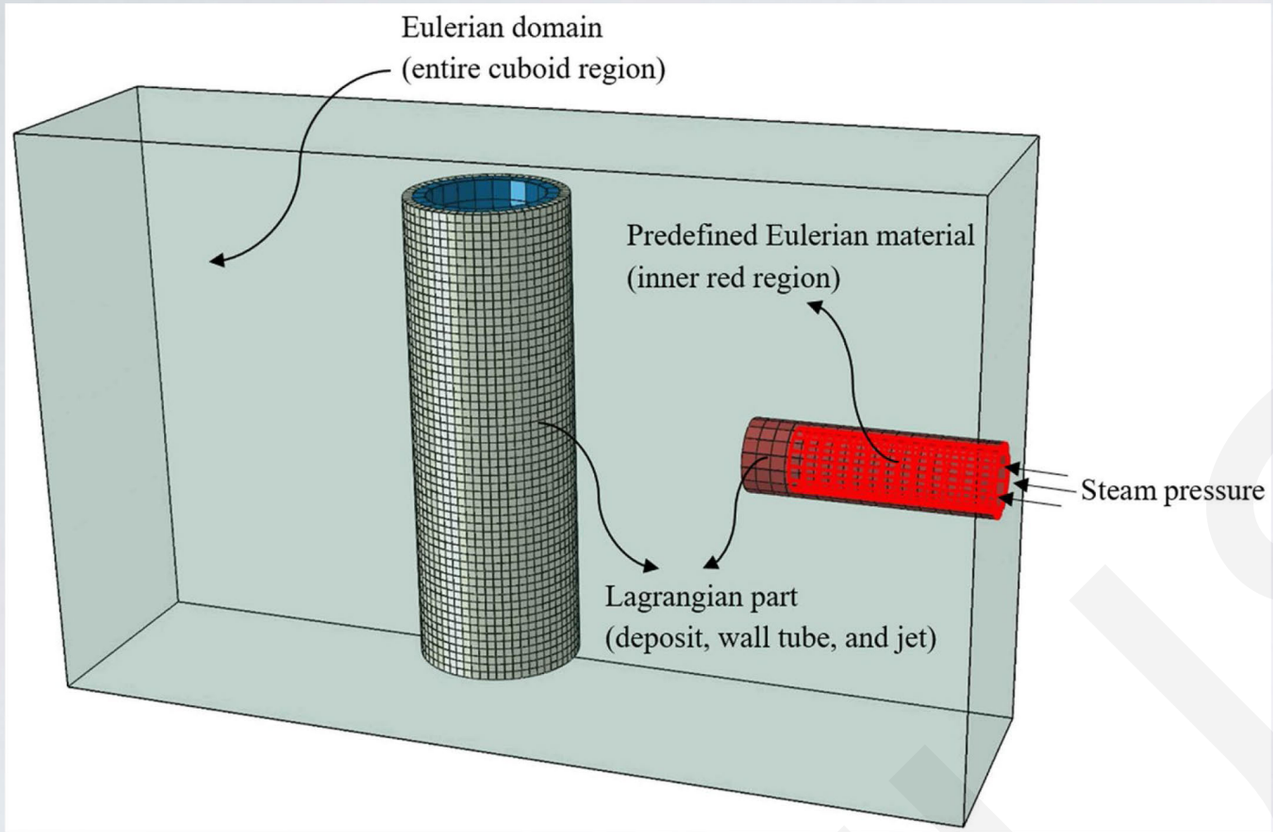


Fig. 2 Diagrammatic sketch of the entire CEL model

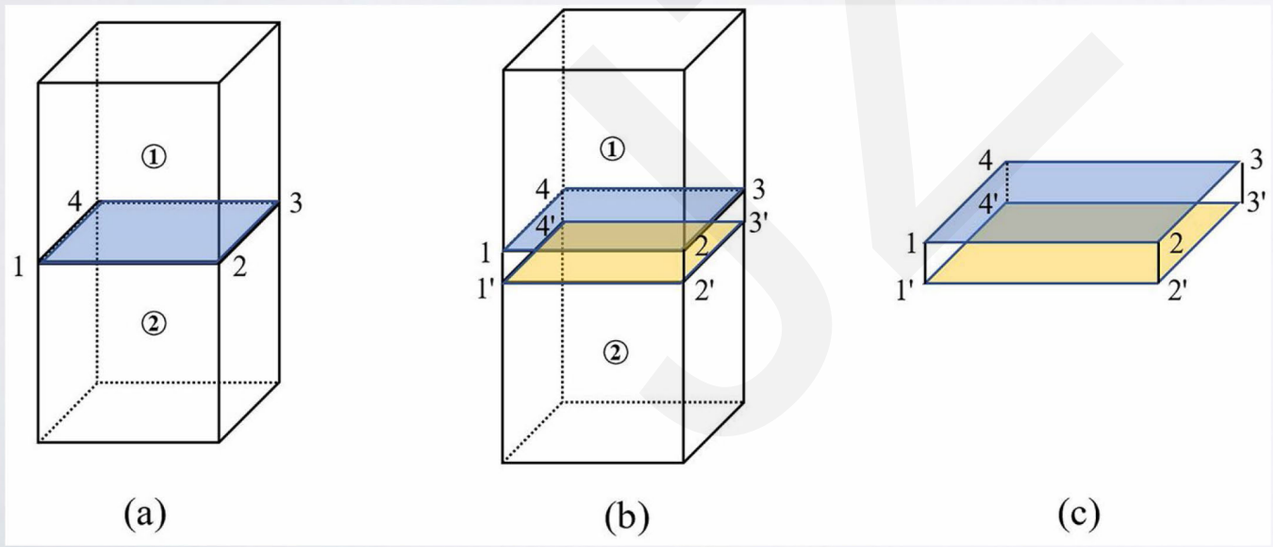
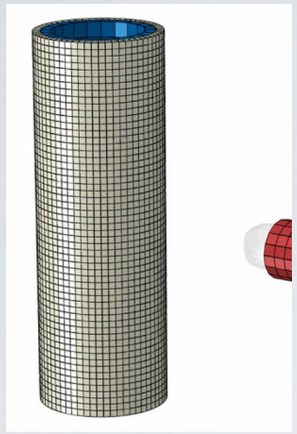


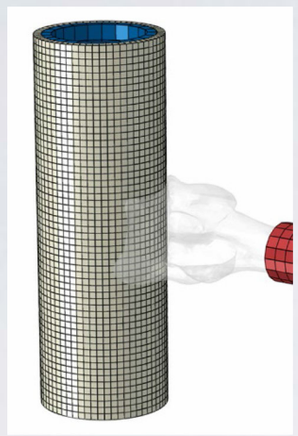
Fig. 3 Schematic of insertion of eight-node cohesive element between two hexahedral elements

- a 3D numerical model that including ash deposit, wall tube, and sootblowing steam was developed in the simulations.
- In CZM approach, a certain type of element (i.e. cohesive elements) and evolution laws were implemented among the solid elements in the initial deposit mesh to model potential cracks.

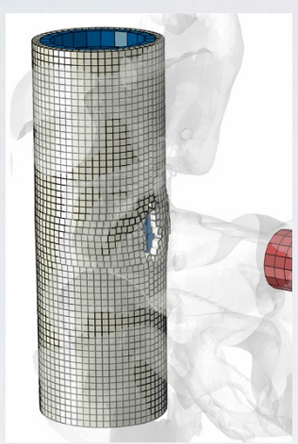
Results and discussion



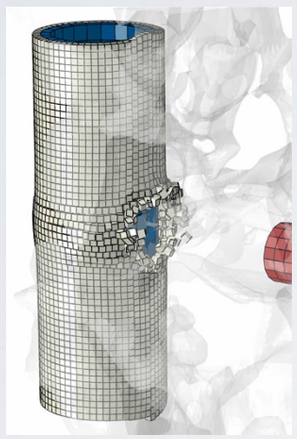
t=0.1ms, η_t=0%



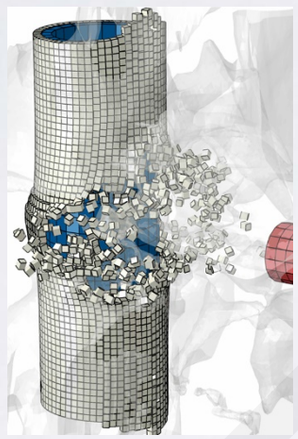
t=0.15s, ηt=0.66%



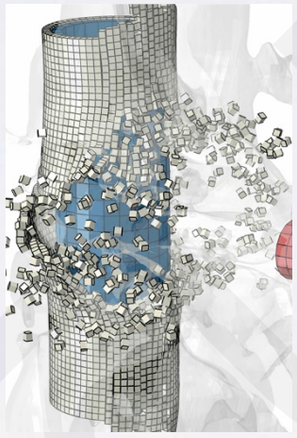
t=0.3s, η_t=18%



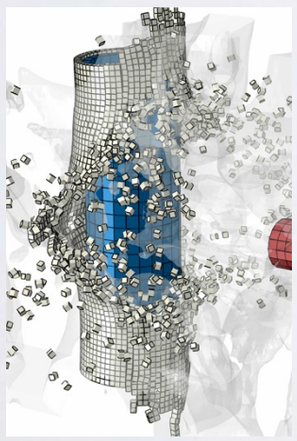
t=0.4ms, η_t=29%



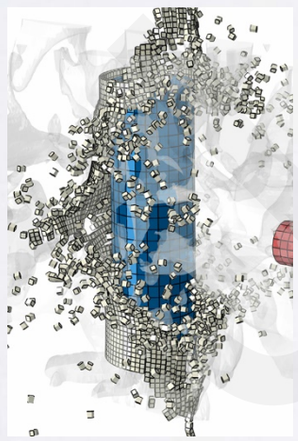
t=0.6ms, η_t=52%



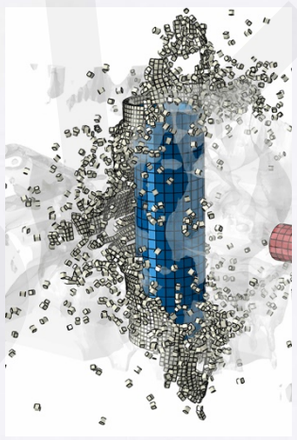
t=0.8ms, η_t=69%



t=1.0ms, η_t=80%



t=1.3ms, η_t=89%



t=1.5ms, η_t=94%

Fig. 7 Dynamic results during sootblowing processes

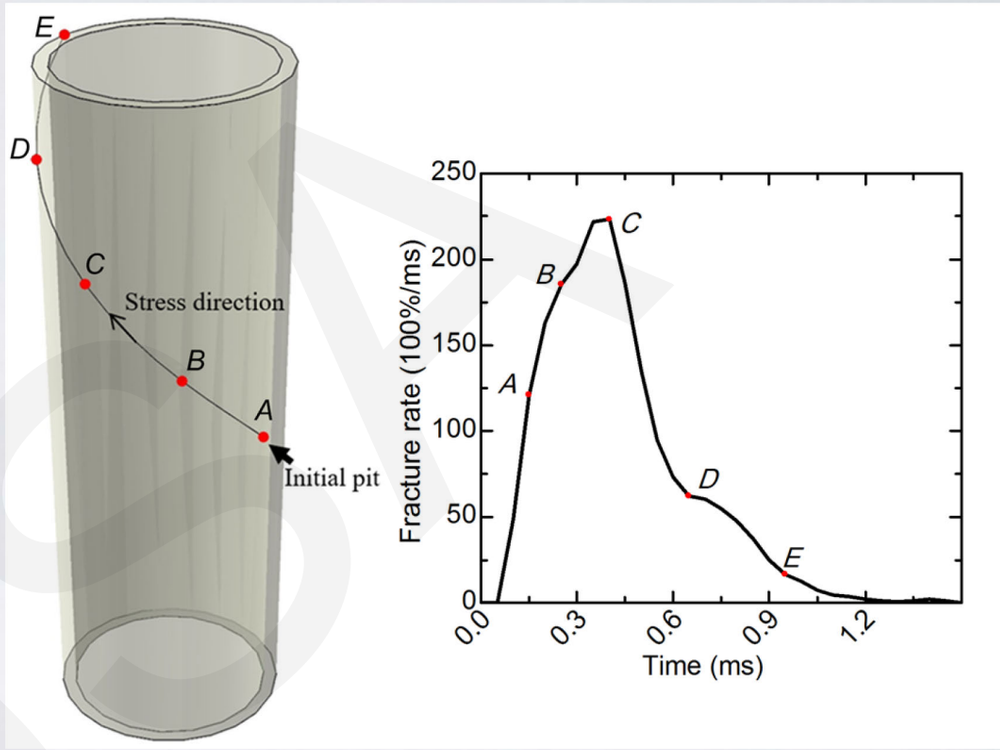


Fig. 9 Fracture rate of points of interest on deposit under 1.8-MPa steam pressure

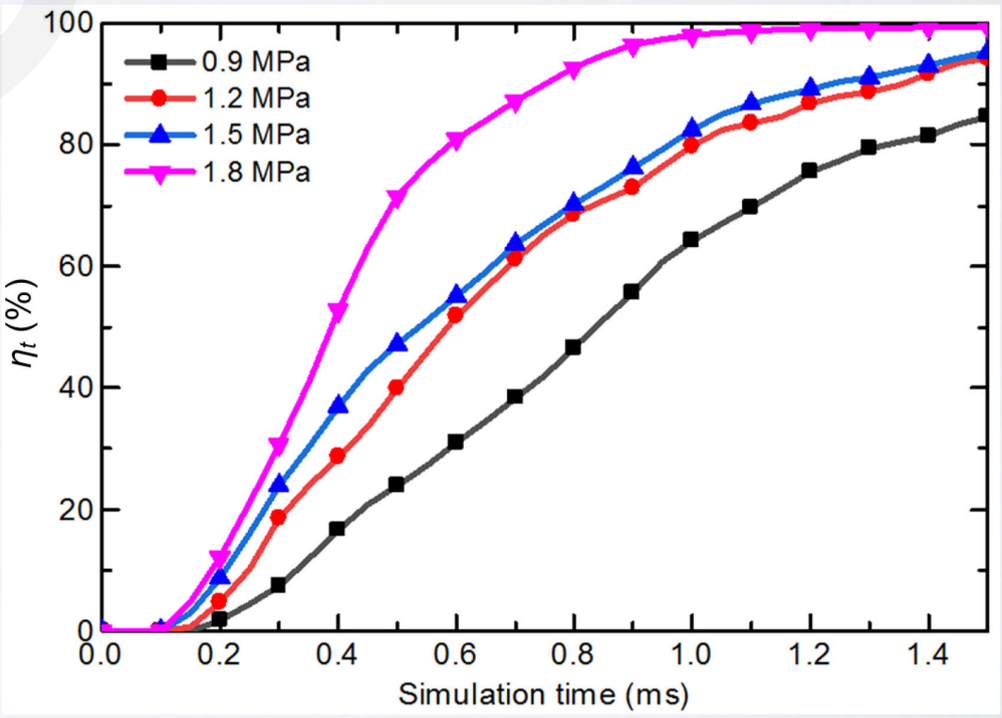


Fig. 10 Extent of deposit failure under different sootblowing pressures

Conclusions

- The dynamic details and mechanism of deposit failure by steam sootblowing were revealed by the proposed model.
- The spread of transverse normal tension caused by steam jets was the primary contributor to deposit fracture, and direct steam impact on the deposit formed the initial source of transverse normal tension, which played a subsidiary role after initiation of the deposit fracture.
- The deposit began to break nearly simultaneously for all pressures, and subsequently, the breaking process firstly presented an accelerated tendency followed by a decelerated one. Higher sootblowing pressure led to quicker deposit fracture, and the deposit failure was complete over 1.0–1.5 ms due for different pressures.
- The simulation results indicated that the sootblowing pressure of 1.2 MPa was suitable and economical for boiler/furnace operation.