A Coupled Thermal-Hydraulic-Mechanical-Chemical Model for Methane Hydrate Bearing Sediments

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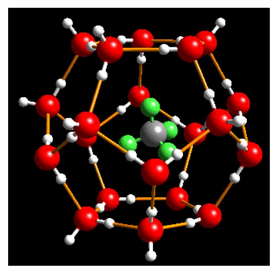


Abstract

- Methane hydrate, a form of clean energy also called combustible ice, has drawn a global interest as an alternative energy resource of traditional fossil energy.
- Methane gas extraction by a deep well installed in natural hydrate bearing sediments (MHBS) found in deep subsea and permafrost regions is a coupled thermo-hydro-mechanical-chemical (THMC) processes.
- It is necessary to propose a coupled THMC model to estimate the amount of gas production, improve the efficiency of production and guarantee the safety of production.

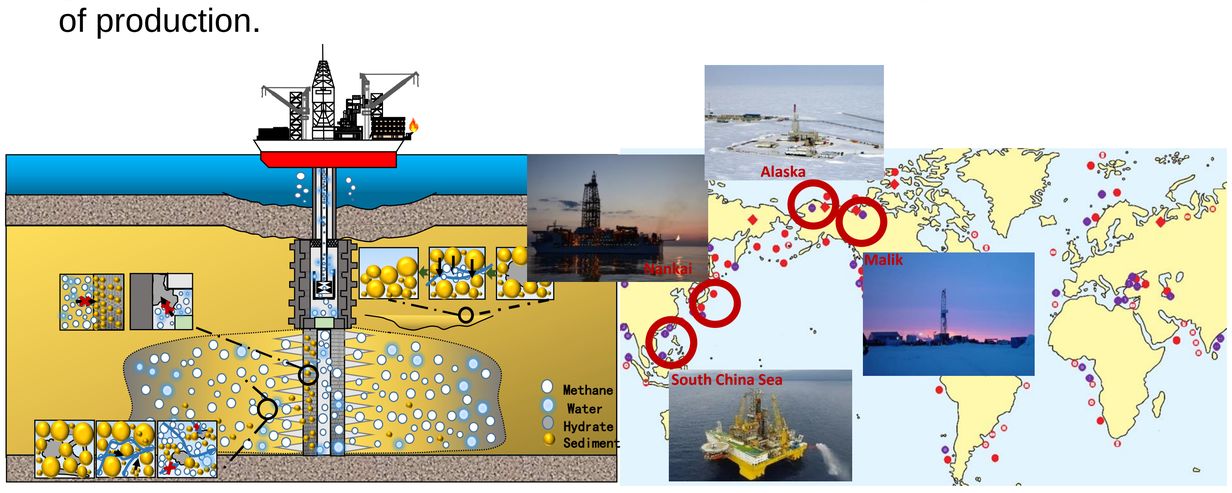


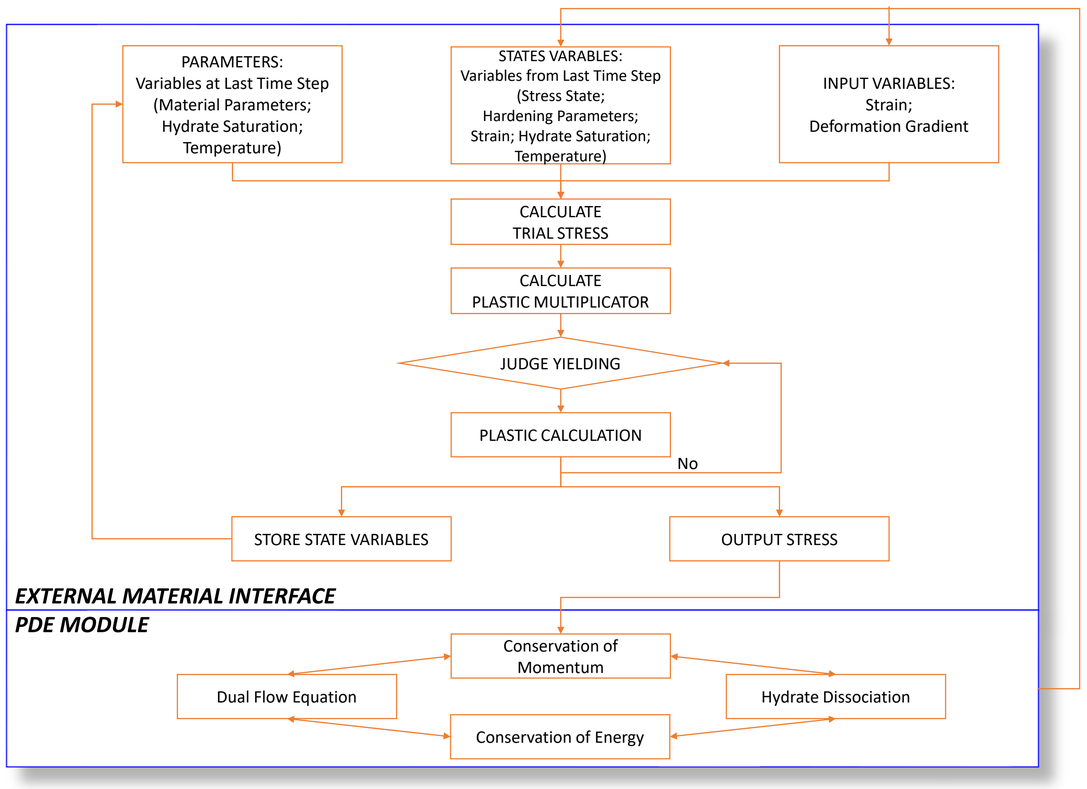
Fig.1 Hydrate distribution and gas production trial test

Research objectives

- Modeling the coupling process
- Verifying the model using laboratory data and field data
- Implementing the simulation in the field work using the verified model and calibrated parameters
- Optimizing the production method to improve the efficiency of production and guarantee the safety of production

Scheme for the THMC model

- To describe the behavior of the coupled mutiphysical process, the following scheme is implemented:



Model verification

1) Simulation results vs. laboratory experimental data

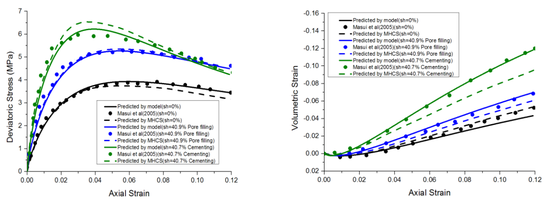


Fig 2 Stress-strain relation and dilatancy curve

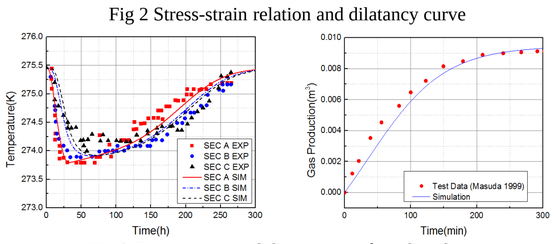


Fig 3 Temperature and the amount of produced gas

- The model is well verified
- Trend in temperature change is well predicted
- The predicted amount of gas is lower than the real one due to the presence of free gas in the experiment
- Stress-strain relation is matched better using our model than others by introducing two new parameters

2) Simulation results calculated using our model vs. most widely used codes in the world. The predicted gas saturations are different using different codes, but hydrate saturation and temperature are identical.

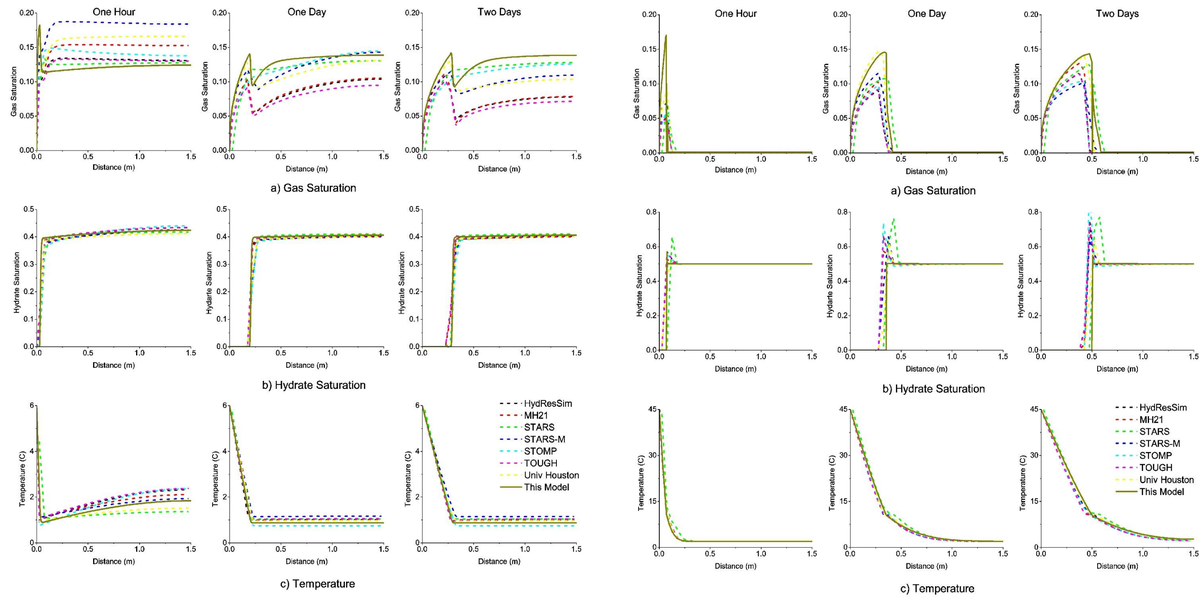


Fig 4 Comparison of simulation with different codes in depressurization case

Fig 5 Comparison of simulation with different codes in heat injection case

Simulation on field work

- Heat convection and conduction lead to the increase in temperature after hydrate dissociation in heterogeneous hydrate layers
- All the coupled physical properties are changing during gas production
- Stress relaxation and concentration due to hydrate dissociation exists around the wellbore. It potentially results in a geohazard.

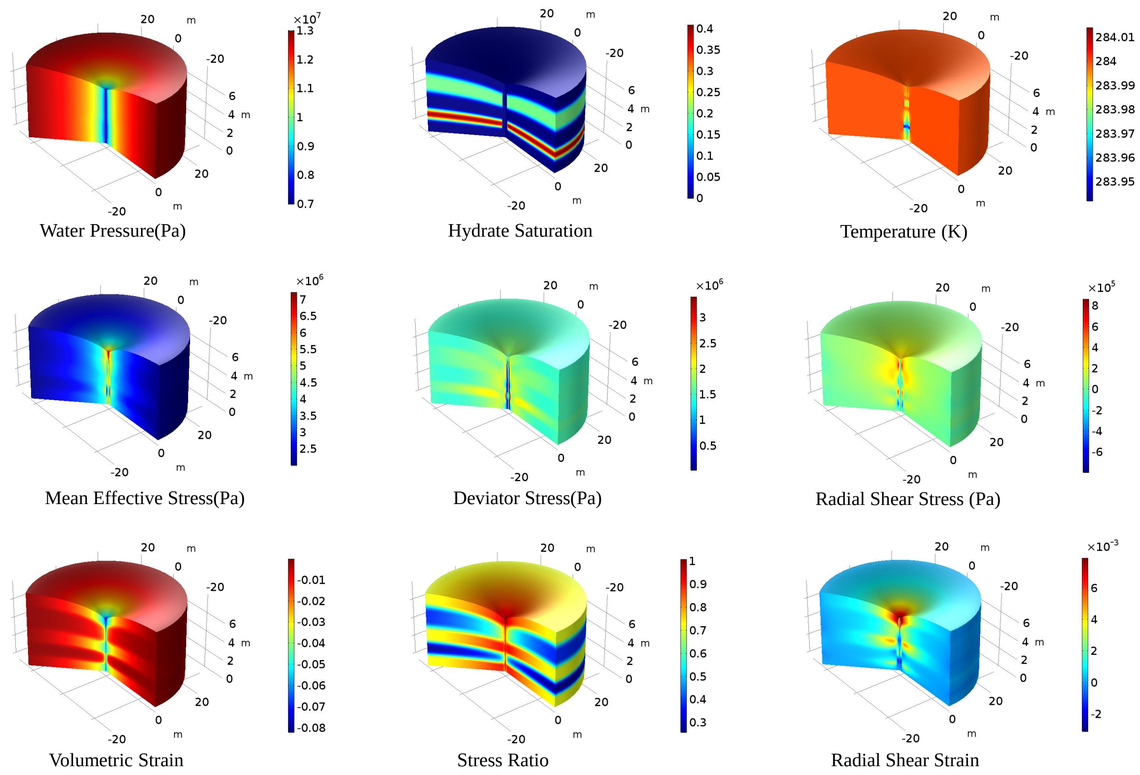


Fig 6 Gas production at time of 5 days

- Hydrate dissociates with depressurization from the wellbore to far field.
- The pressure drop in high permeability layer is faster than low permeability layer.
- The hydrate dissociation in high permeability layer is faster than low permeability layer
- The porosity of the sediments has an impact on the permeability.

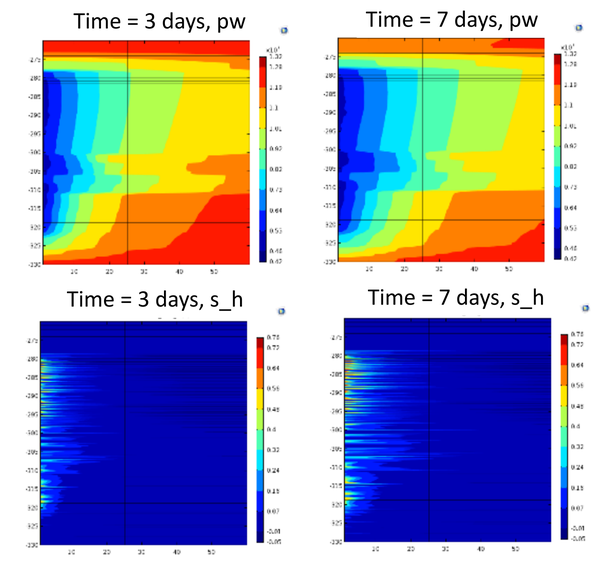


Fig 7 Simulation on heterogeneity of the hydrate layer in Nankai, Japan

Ongoing research

- Enhancement of the coupling model
- Additional field simulation
- Optimizing the production method to improve the efficiency of production and guarantee the safety of production

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