Cyclic Production of Carbon Dioxide-Rich and Hydrogen-Rich Gas in Underground Coal Gasification

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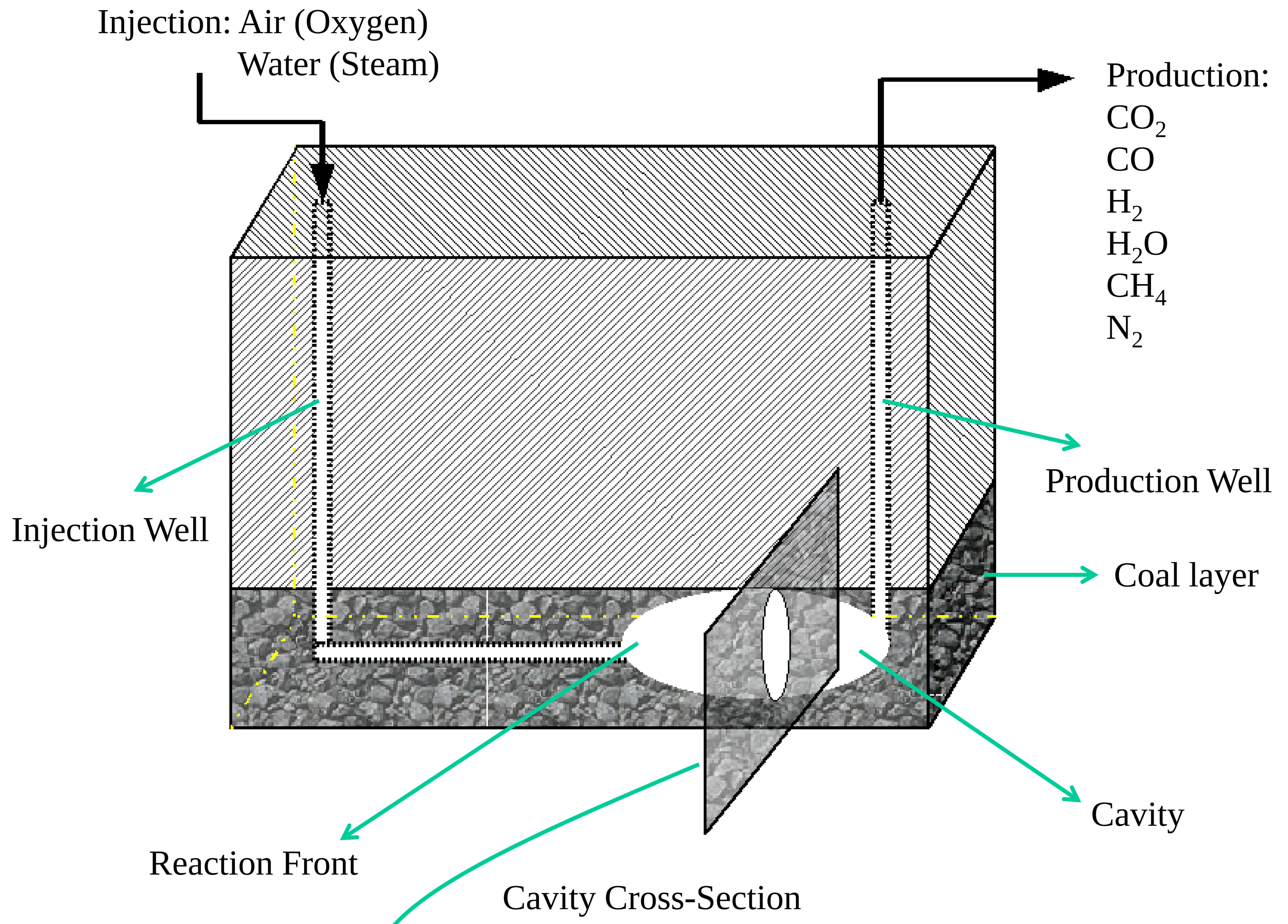
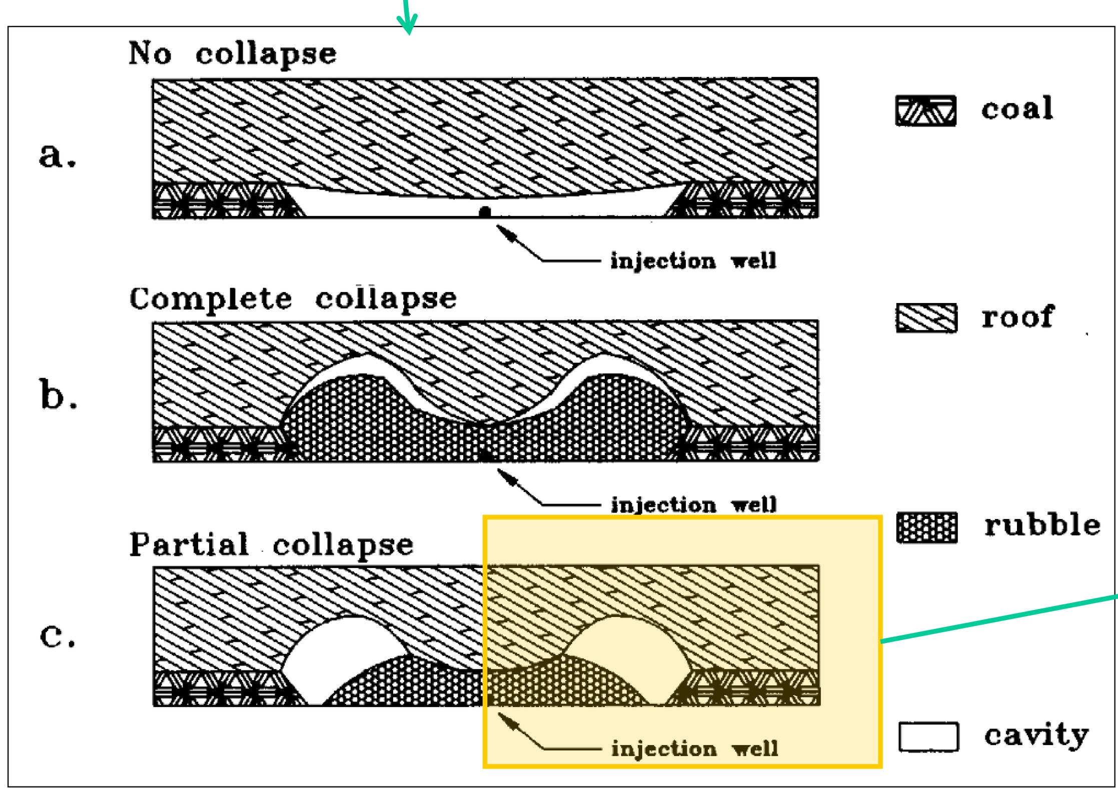
Introduction





UCG in thin coal seams: a) No roof collapse; b) Complete roof collapse; c) Partial roof collapse [1]

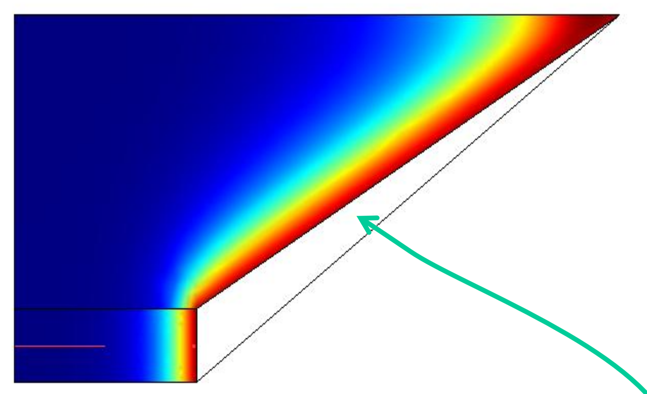
Boundary Layer Mass Transfer

Maxwell-Stefan equations:

$$\frac{dx_i}{dz} = \frac{RT_c}{P}\sum_j \frac{x_i(z)N_j - x_j(z)N_i}{D_{ij}}, \quad 0 \le z \le \delta$$

Analytical solution:
x(i) = x(0)exp(λz)
λ's are the Eigenvalues of x coefficients

Heat Transfer Model



Conduction heat transfer
In a moving coordinate with
the velocity of coal consumption

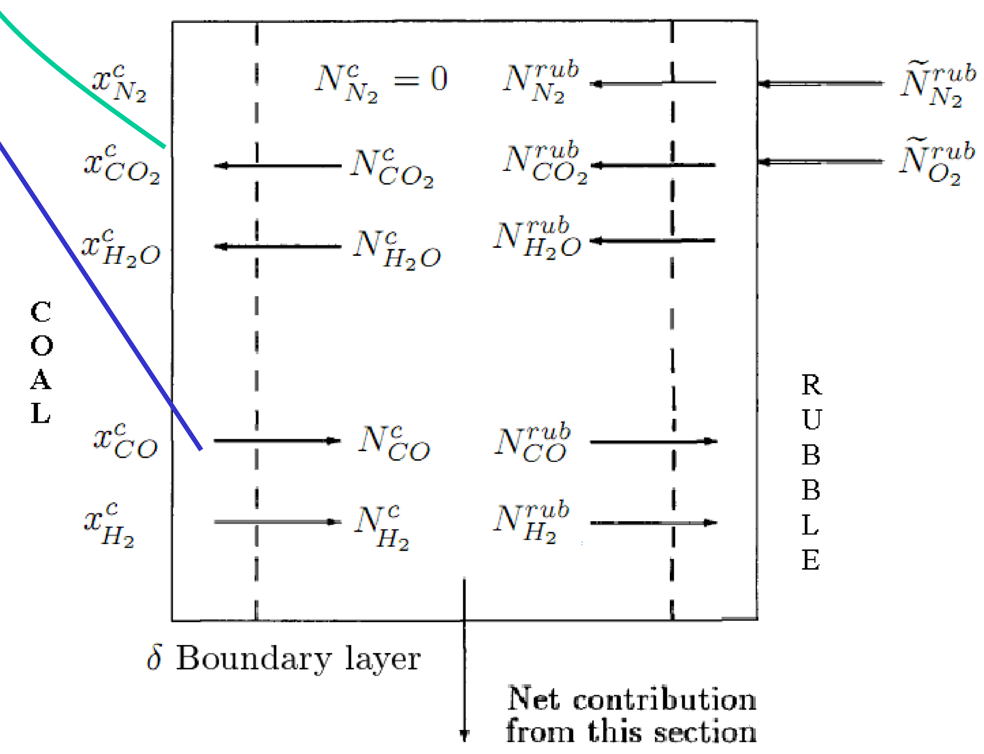
Coal Chemical Reactions

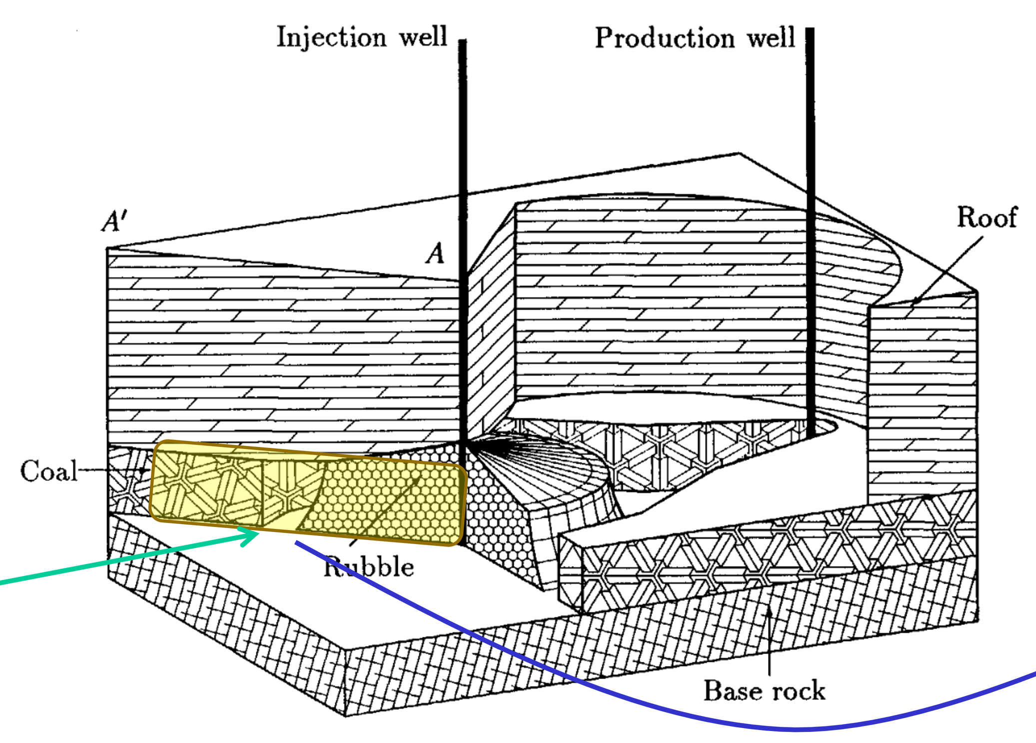
$$CH_aO_b + \left(1 - b + \frac{a}{2}\right) CO_2 \overset{K_1}{\rightleftharpoons} \left(2 - b + \frac{a}{2}\right) CO + \frac{a}{2} H_2O$$

$$CH_aO_b + (1-b) H_2O \overset{K_2}{\rightleftharpoons} CO + \left(1 - b + \frac{a}{2}\right) H_2$$

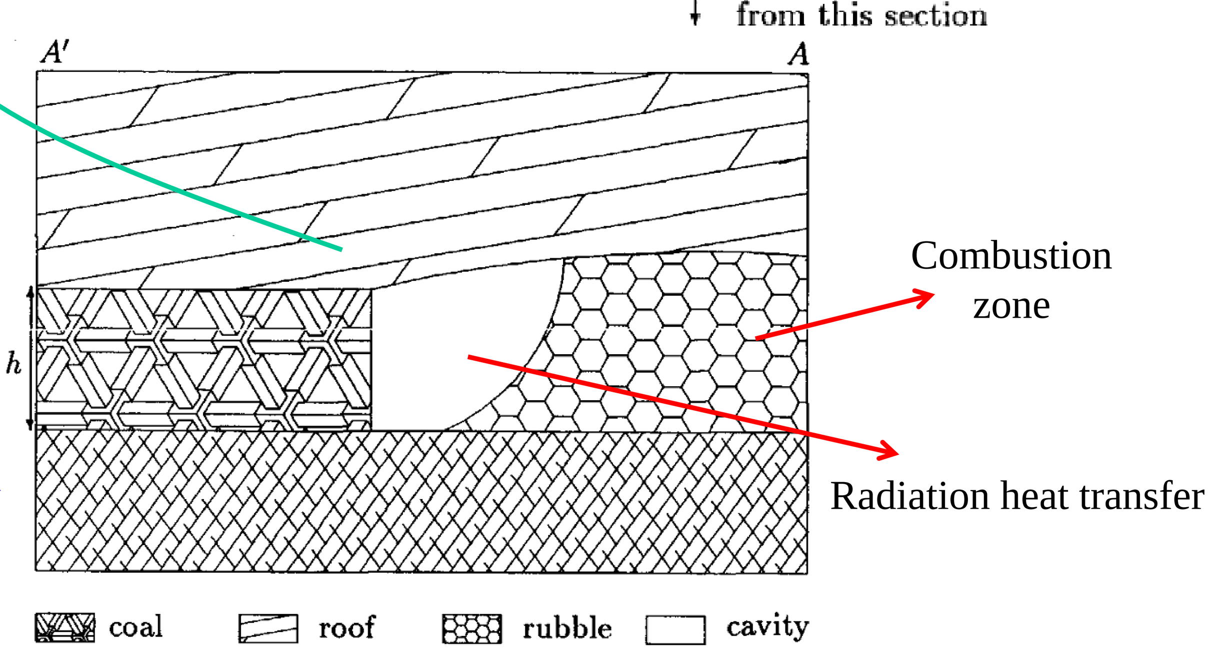
$$CH_aO_b + \left(2 + b - \frac{a}{2}\right) H_2 \overset{K_3}{\rightleftharpoons} CH_4 + bH_2O$$

Mass Fluxes





A 3-D representation of UCG with partial roof collapse [1]



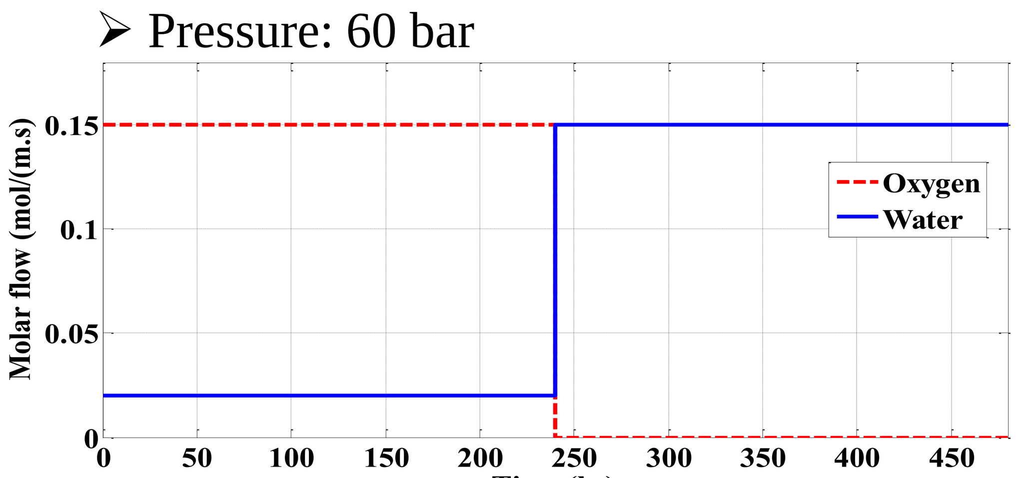
A simplified model of partial roof collapse scenario in UCG process; The overall process is mass-transfer limited [1]

Model Assumptions and Results

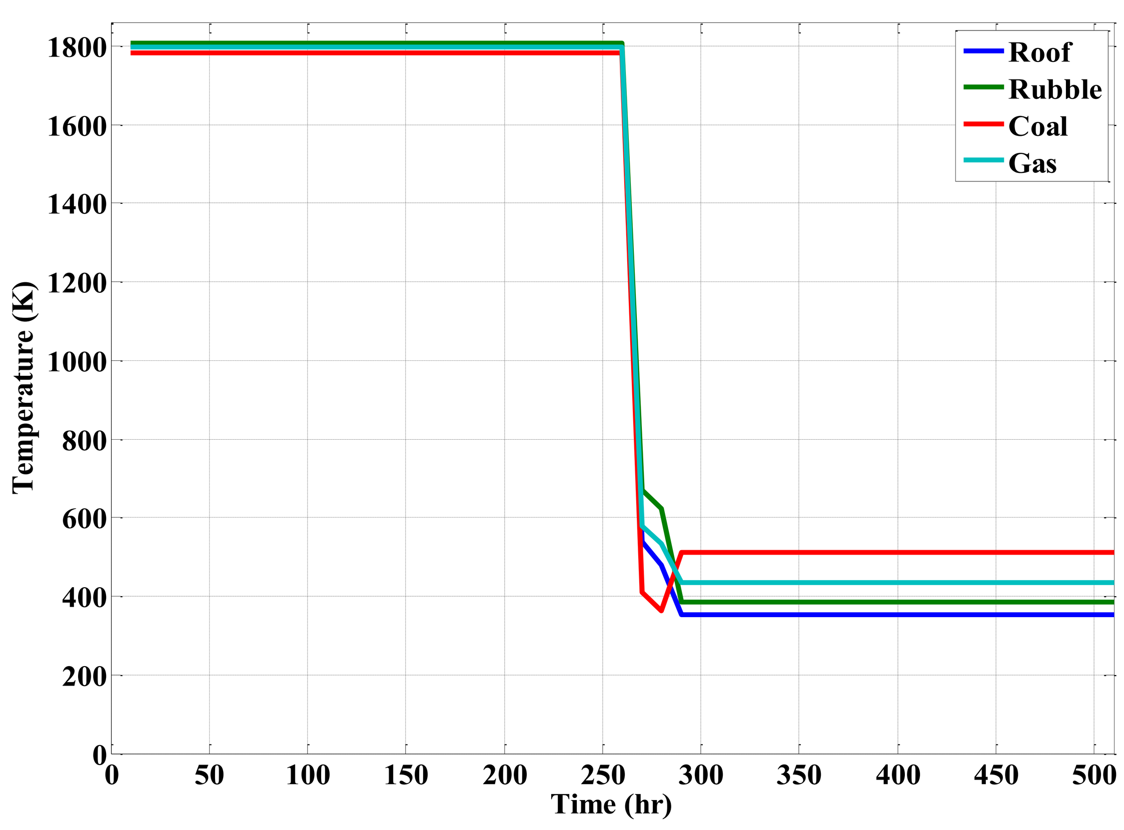
- The process is semi-steady sate.
- Mass transfer from the bulk gas to the coal surface is the rate-controlling step.
- At the coal surface, the gas composition is calculated by the chemical equilibrium equations.
- Injected O_2 immediately reacts with combustible gases.

Feed Injection Scenario

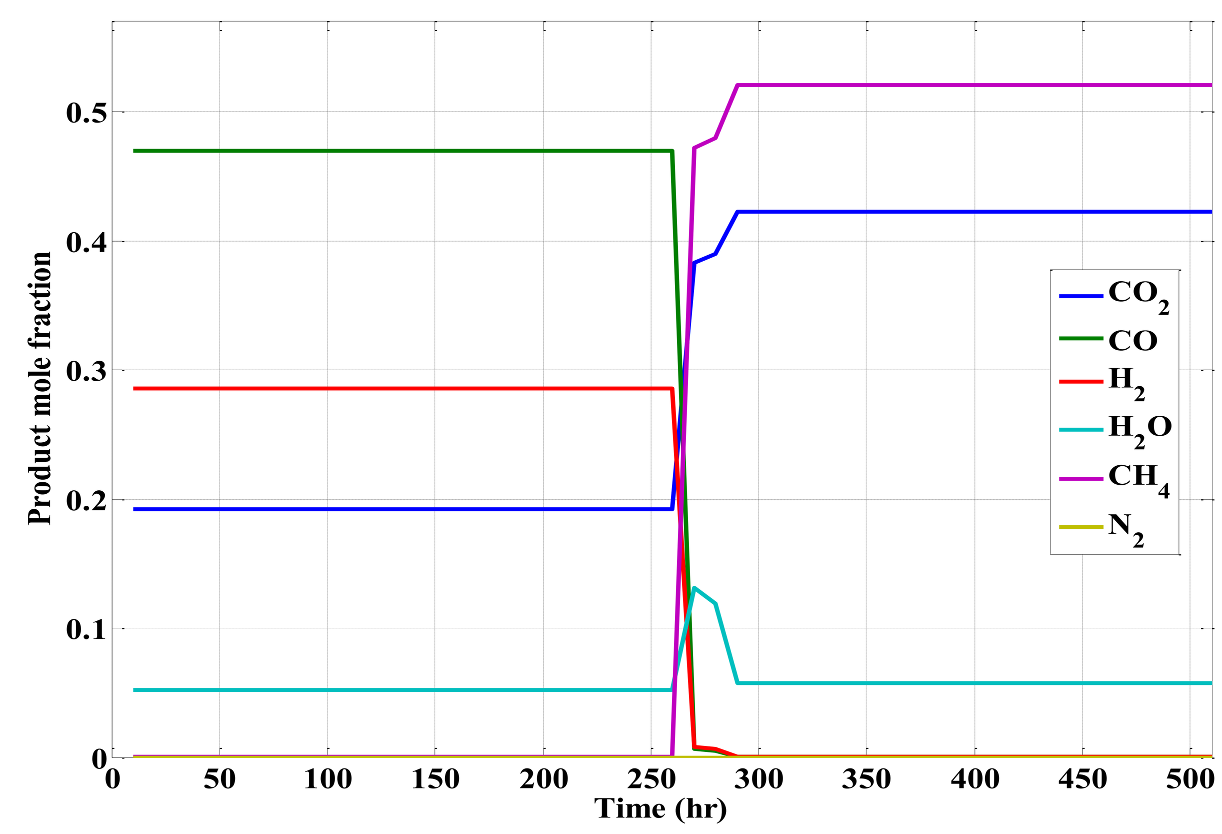
- 0 < time < 10 days:
  O_2 injection rate: 0.15 mol/(m.s)
  Water injection rate: 0.02 mol/(m.s)
- 10 days < time < 20 days
  O2 injection rate: 0.15 mol/(m.s)
  Water injection rate: 0.02 mol/(m.s)
- Pressure: 60 bar



Temperature Profile



Composition Profile



Conclusion

- Roof collapse is not detrimental to UCG process but leads to efficient processes
- Due to the low temperature in the water-injection cycle, the mass transfer is not the controlling step anymore; the reaction rate must be considered
- Reaction rates must be considered in the model
- Optimal injection rates, water/oxygen injection ratio, and switching time can further improve the product composition

Acknowledgement

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Reference

(1) van Batenburg, D. W., Biezen, E. N. J., Bruining, J., (1994): *A new channel model for underground gasification of thin, deep coal seams*, In Situ, 18:419.

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