Influence of Thermodynamic-Property Models on the Simulation of LNG Evaporation and Liquefaction Processes

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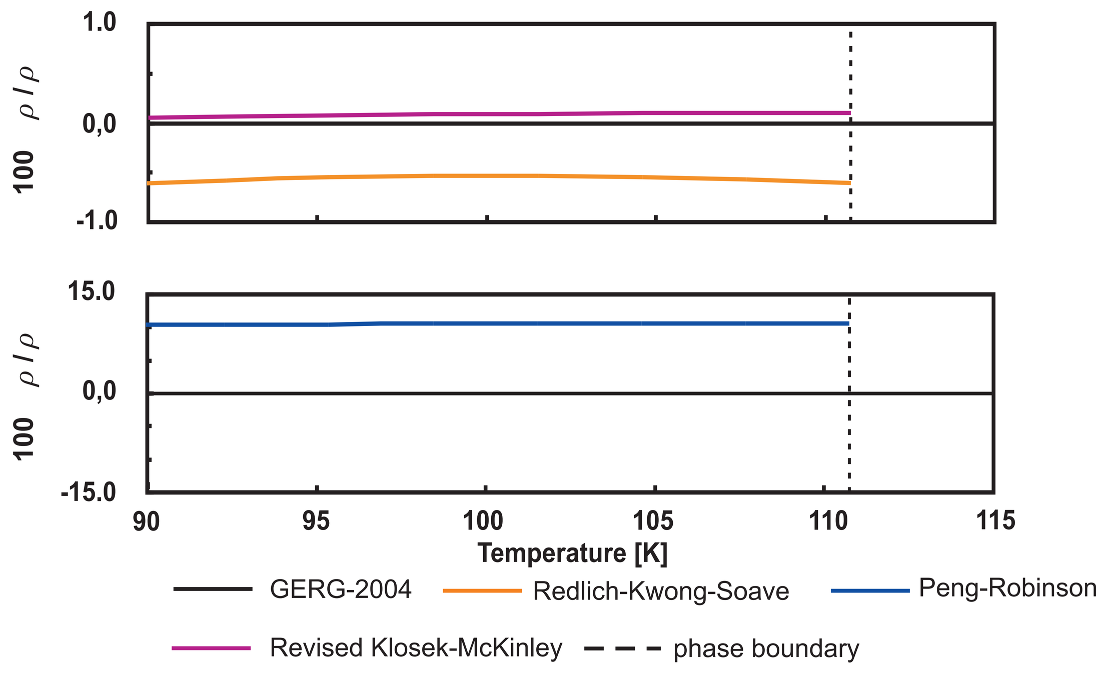
Category: LNG

GERG-2004 Equation of State

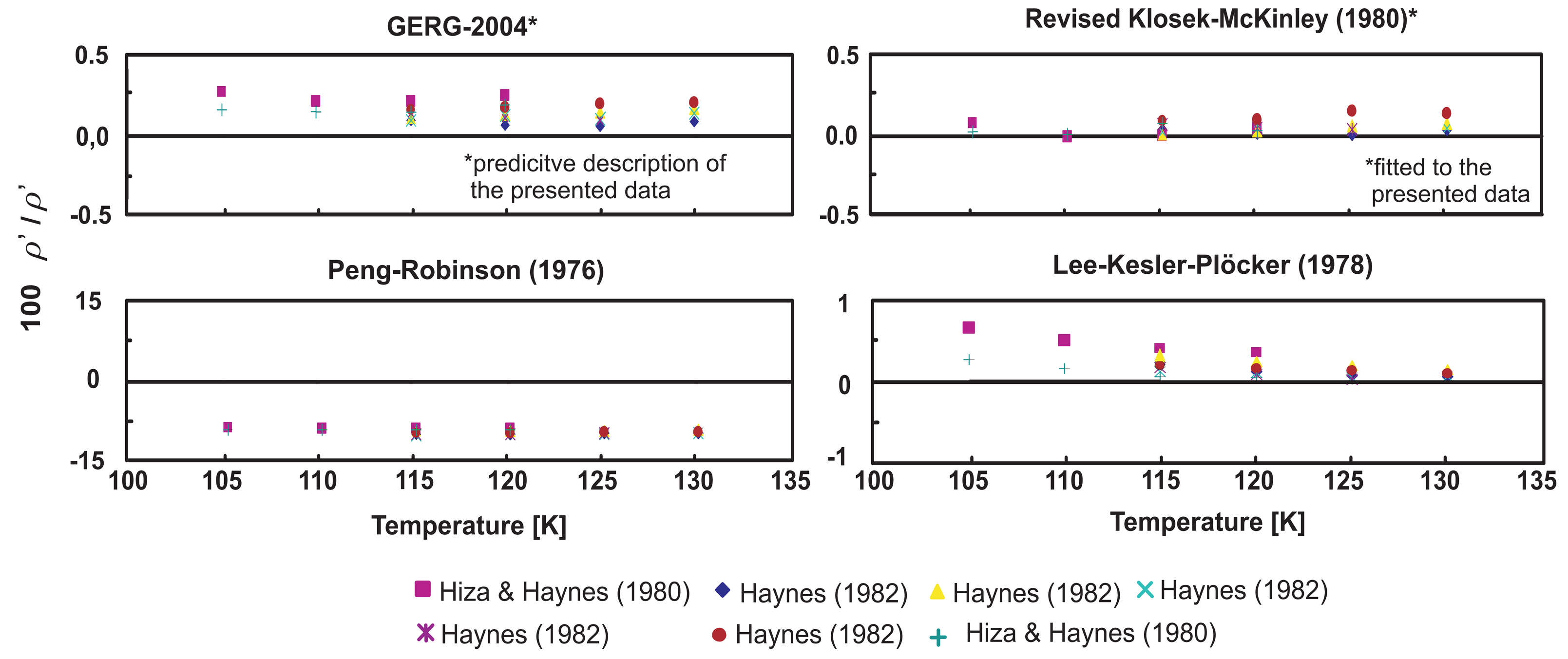
- *Kunz, O.; Klimeck, R.; Wagner, W.; Jaeschke, M.*: The GERG-2004 Wide-Range Equation of State for Natural Gases and Other Mixtures: GERG Technical Monograph 15 (2007) and Fortschr.-Ber. VDI, Reihe 6, Nr. 557, VDI Verlag, Düsseldorf 2007
- Covers wide ranges of temperature, pressure and composition
- Formulated as a fundamental equation in terms of the reduced Helmholtz energy as a function of temperature, density and composition, the GERG-2004 model allows for calculations of thermal and caloric properties just by combination of derivatives of the Helmholtz energy
- Valid in the gas phase, in the liquid phase, in the supercritical region and for the vapor-liquid equilibrium (including the vapor-liquid phase boundary)
- Developed using only data of binary mixtures
- Thermal and caloric properties can be calculated with the highest accuracy possible (reference quality) for natural gases and other multi-component mixtures consisting of any of the 18 natural gas components
- In the liquid region the uncertainty in density for natural gases is:
  $\rho\ \rho \leq 0.1\%$ 0.5%

Comparison of different Property Models

- Comparison of LNG densities calculated with the GERG-2004 and other equations of state:
  - Redlich-Kwong-Soave (*Redlich and Kwong (1949), Soave (1972)*); Peng-Robinson (*Peng and Robinson (1976)*)
    - cubic equations of state
    - valid for the whole fluid region
  - Lee-Kesler-Plöcker
    - empirical (BWR-Type) equation of state (*Lee and Kesler (1975)*)
    - also describing asymetric mixtures with an extended corresponding-states approach *(Plöcker et al.(1978))*
    - valid for the whole fluid region
  - Revised Klosek-McKinley (*McCarty (1980)*)
    - for calculations of densities only
    - only valid in the liquid region
    - calculation of densities without taking the compressibility into account
    - fitted to experimental saturated liquid densities of natural gases
    - industrial standard for the accounting of LNG



Percentage deviation of calculated LNG densities for p = 1.01325 bar

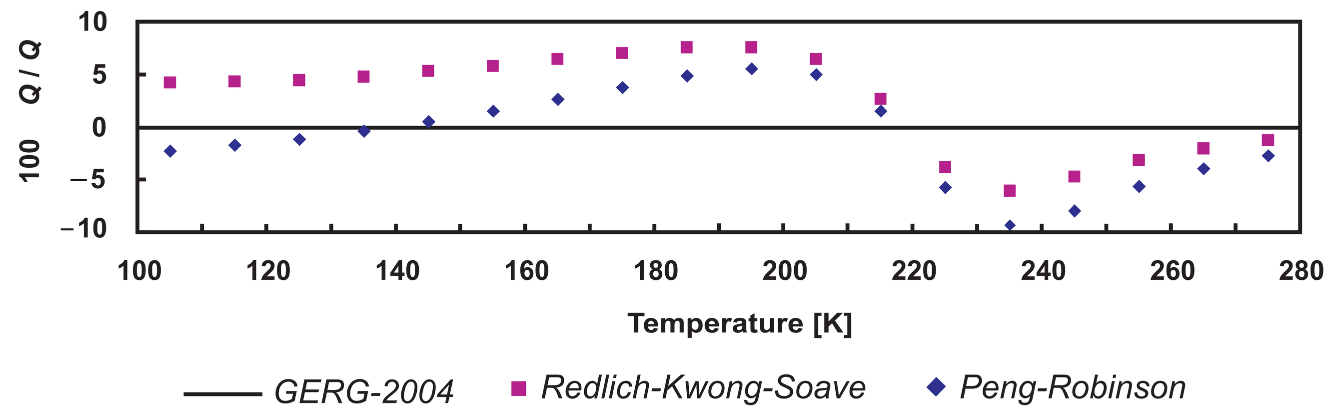


Percentage deviation of measured saturated LNG densities from calculated data

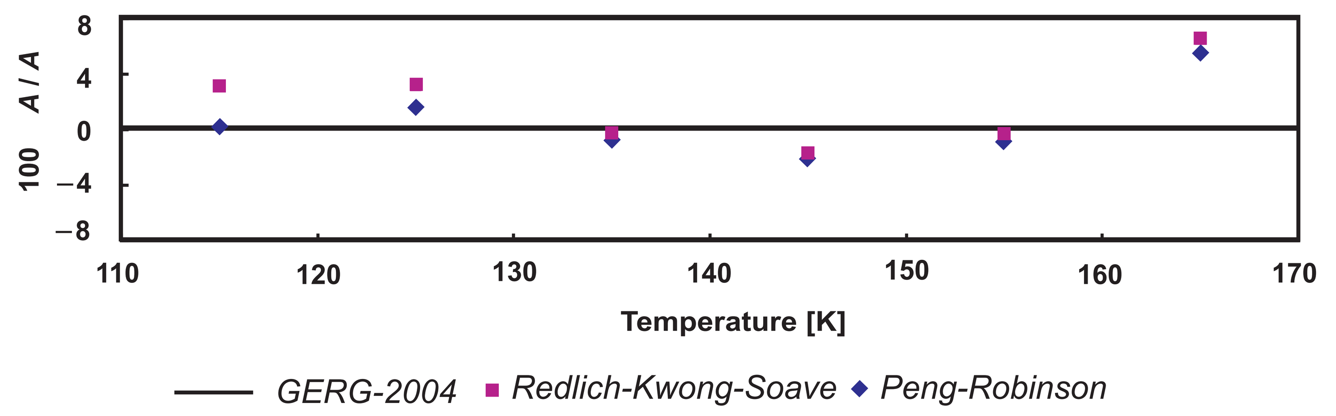
- GERG-2004 shows similar accuracies for the density of LNG as the Revised Klosek-McKinley equation
- The GERG-2004 has the same range of validity as the cubic equations and the extended corresponding-states model
- With the GERG-2004 even calcoric properties can be calculated easily and with high accuracy

Simulation of LNG-Processes

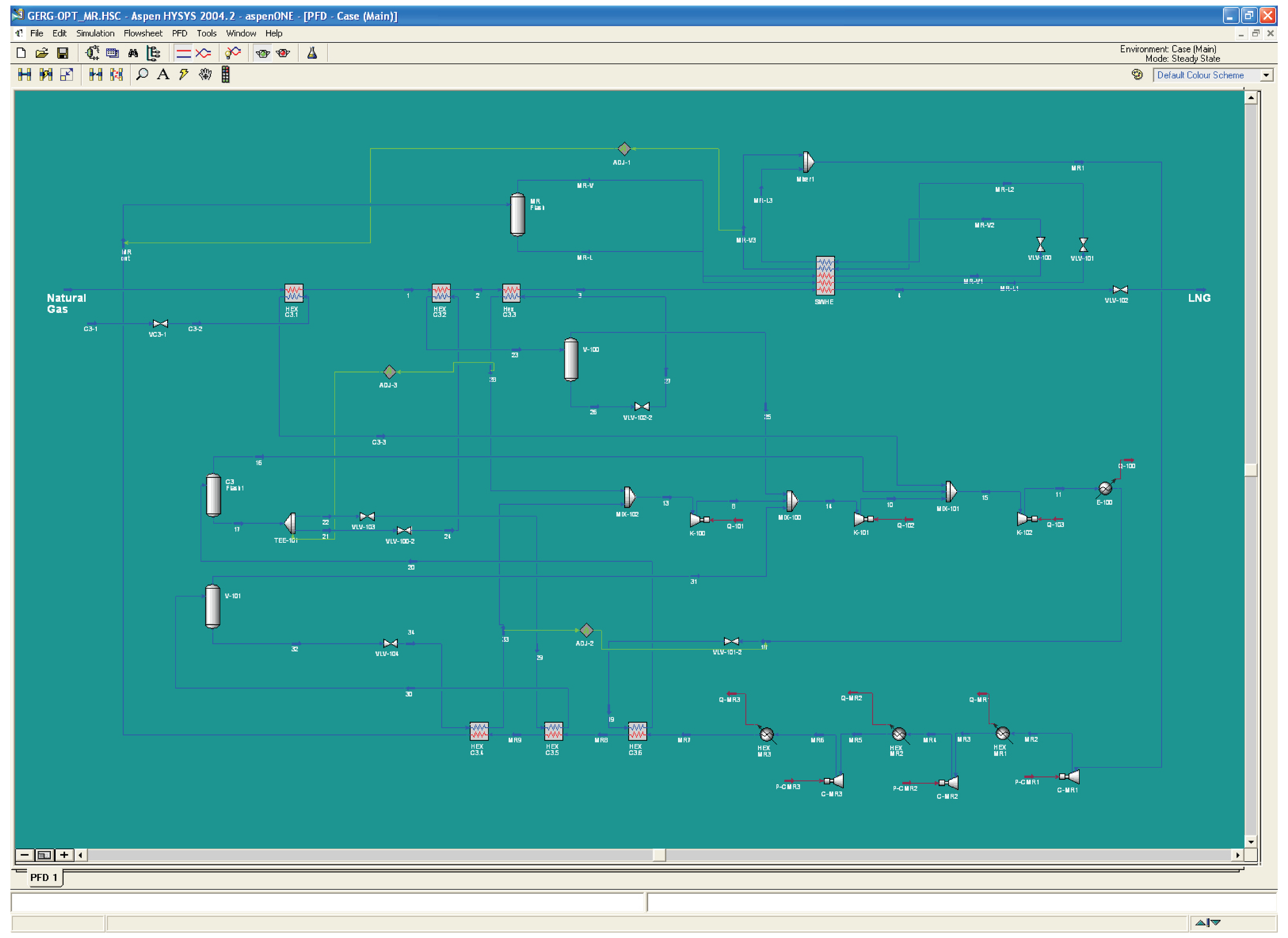
- High expectations regarding economic efficiency, product quality and environmental safety lead to increasing demands on the LNG vaporization and liquefaction processes
- Fundamental contributions to optimization and operation of a system are expected from the simulation of processes
- Accurate representation of thermophysical properties and energy balances of the simulated process are essential
- New highly accurate equations of state for natural gas and LNG represent an unused potential for accurate process modelling
- The GERG-2004 has been implemented successfully in Aspen-Plus, Aspen Hysys, ChemCAD, Pro/II and in several other simulations tools using the CAPE-OPEN Standard
- Research of the property models influence on the design data of LNG processes
  - simulation of a simplified LNG evaporation terminal
  - simulation of a complex natural gas liquefaction process (C3MR)
    - most widely used liquefaction process
    - cooling with propane (C3) and a mixed refrigerant (MR)



Percentage deviation of calculated heat flows for a simulated overcritical multi-stage LNG evaporation process



Percentage deviation of calculated heat transfer areas for a simulated multi-stage flash LNG evaporation process



Natural gas liquefaction process (C3MR) as displayed on the graphical user interface of Aspen-Hysys

Conclusion

- Comparison of the GERG-2004 with the cubic equations and the equation of state of Lee-Kesler-Plöcker for calculated design data of a C3MR process:

	Lee-Kesler-Plöcker	Redlich-Kwong-Soave	Peng-Robinson
partial mass flows of the mixed refrigerant:	- 15 %	+ 1.7 %	- 1.2 %
power of the compressors:	- 1.7 %	- 1.7 %	+ 0.9 %
UA / Cryogenic Heat Exchanger:	- 1.1 %	+ 5.2 %	- 5.6 %

- Significant differences for the modeled design data of the LNG processes are based on the uncertainties of the cubic equations and the Lee-Kesler-Plöcker equation in the vapor-liquid equlibrium
- The influence of property models with different qualities on the simulation of processes in the natural gas industry should not be underestimated
- Data for operating liquefaction processes are required to prove the advantages expected for the application of the GERG-2004 model in process simulations

Acknowledgment

This work is carried out as part of the "competence centre thermodynamics of gases" initiative jointly financed by e.on Ruhrgas and by the Ministry of Innovation, Science, Research and Technology of North Rhine-Westphalia.

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