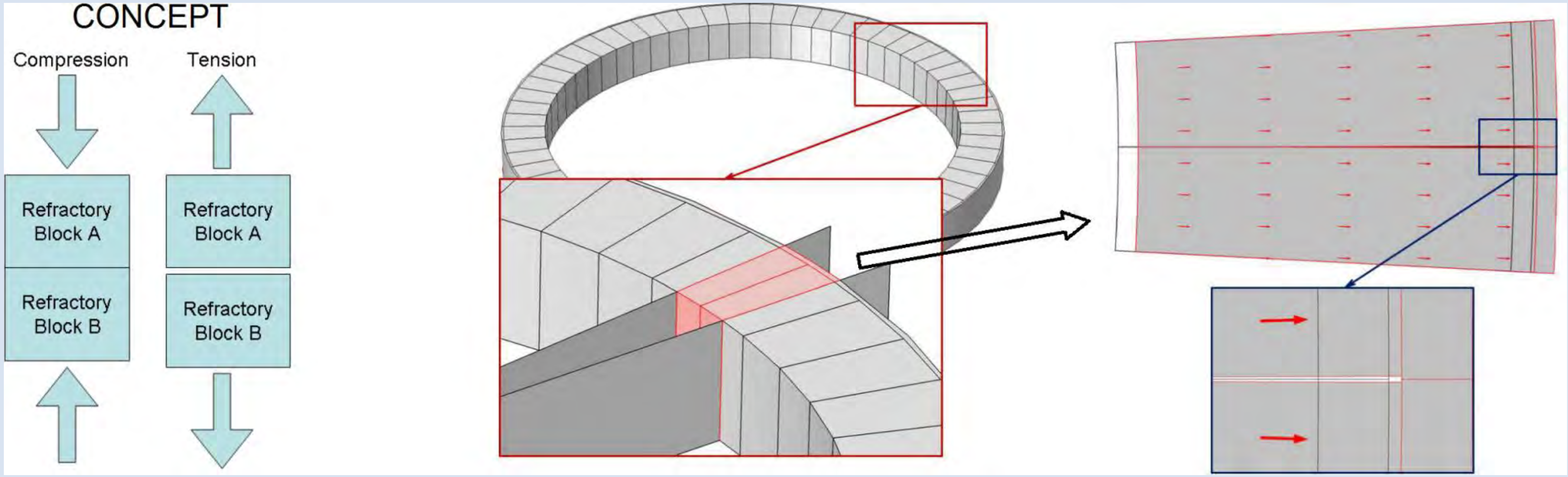


A Simplified Approach to the Contact in Thermo-mechanical Analysis of Refractory Linings

Dr.-Ing. Yalcin Kaymak

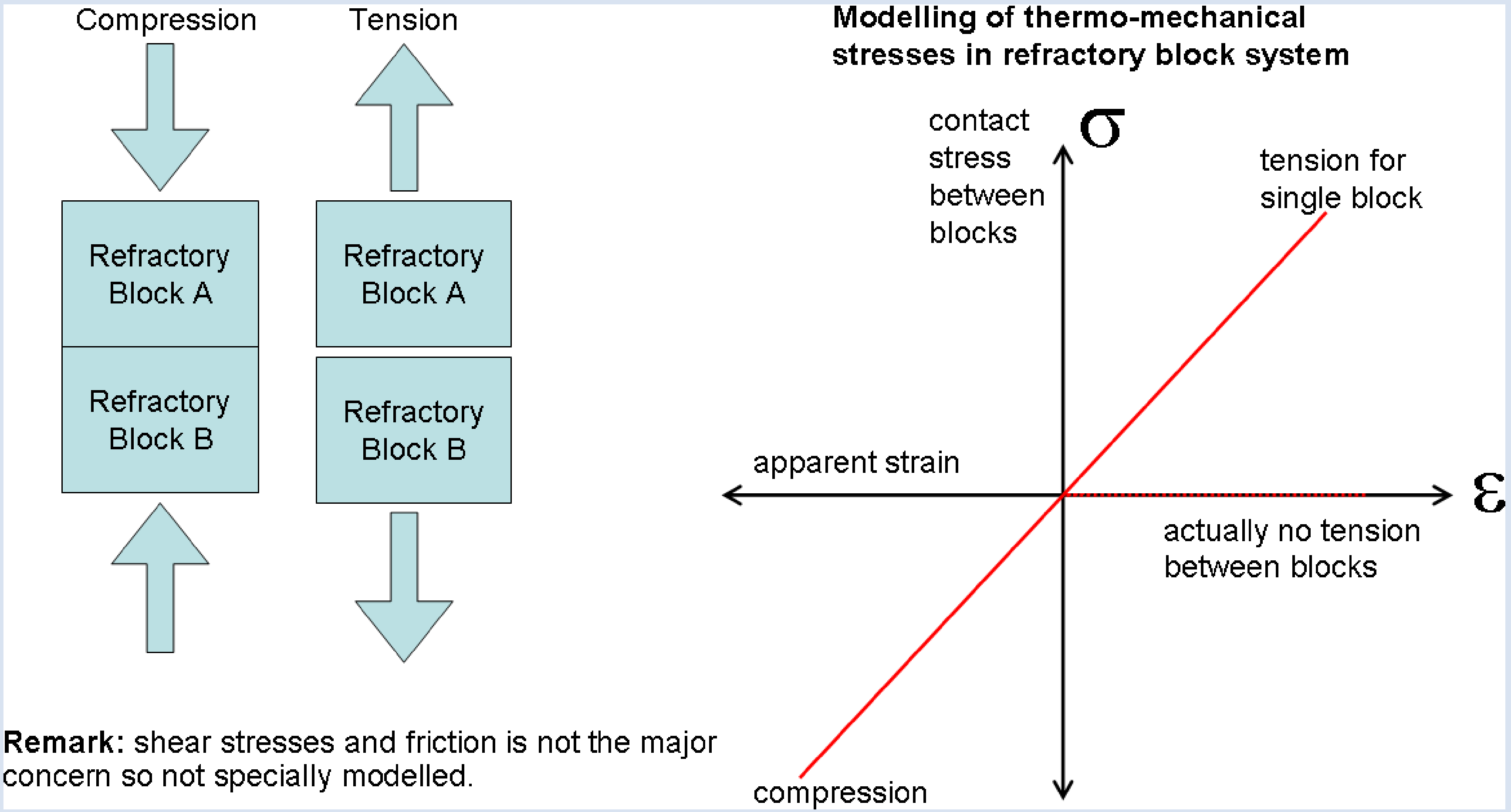
VDEh-Betriebsforschungsinstitut GmbH, Düsseldorf/Germany

Email: yalcin.kaymak@bfi.de, Tel: +49 211 6707 299

Key Point Given in the Abstract

- A complete understanding (via experiments or simulations) of the thermo-mechanical behavior of refractory blocks is essential for design and material choice.
- A tool is needed for fast and efficient computation of thermo-mechanical state of refractory linings under various conditions.
- Standard simulation models and their solutions suffer as the linings are composed of many refractory blocks in contact.
- A simplified approach to the contact in thermo-mechanical analysis of refractory linings and its implementation are introduced.
- This new method provides a much faster model preparation and solution than the traditional contact models with an excellent accuracy for particular application.
- The introduced technique is suitable to a wide range of industrial refractory linings such as blast furnaces, converters, ladles, etc.

Concept of Modifying Stresses to Approximate Contact

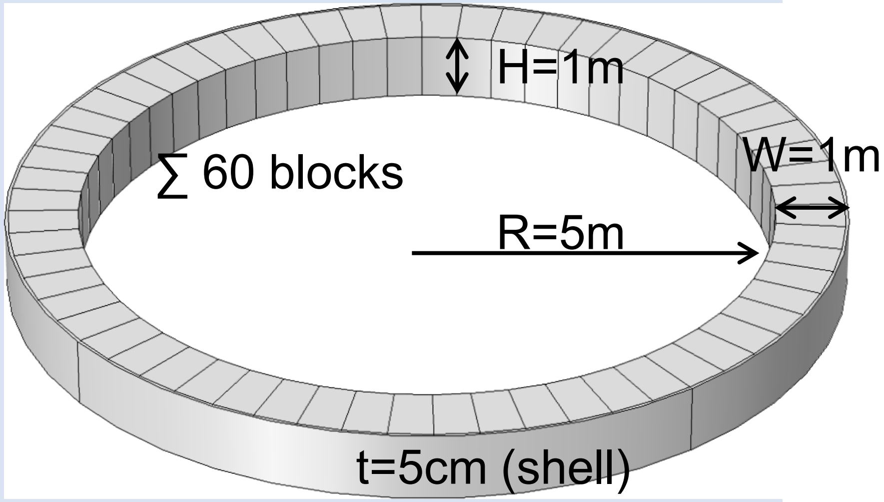


Remark: shear stresses and friction is not the major concern so not specially modelled.

- In comsol, such a constitutive equation can easily be introduced by using initial stress which eliminates the tensile stresses in a chosen domain.

Geometry and Material Properties Used in Benchmark Study

- Physical Geometry: consider a shaft furnace. The steel shell has a 5cm thickness. There are 60 refractory blocks in a layer. Refractory wall thickness in 1m, layer height is also 1m. Internal radius of the shaft is 5m.



- The material properties are given in the table on the right side.

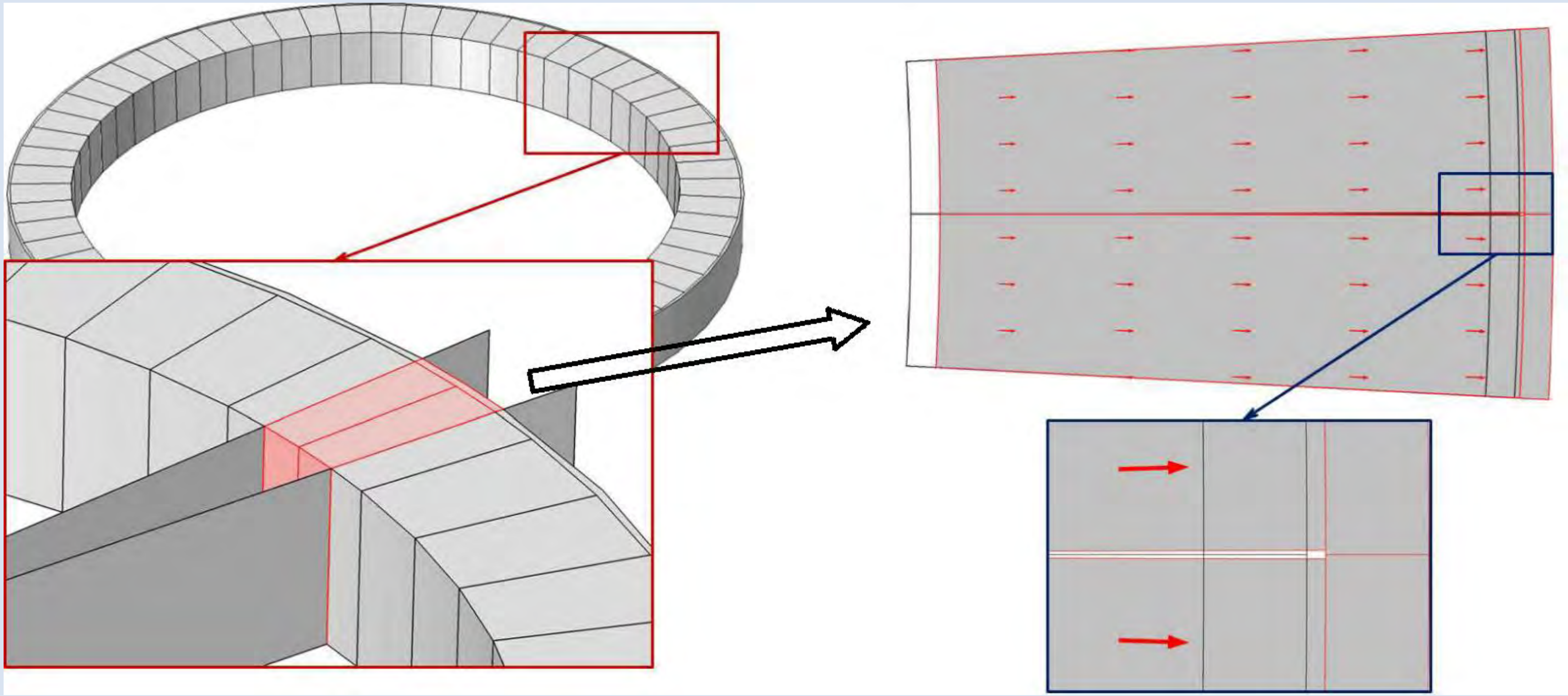
Table 1: Material properties.

Property	Refractory	Steel	Unit
E	70	200	GPa
nu	0.25	0.30	-
rho	2500	7800	kg/m^3
k	15	70	W/m/K
Cp	800	450	J/kg/K
alpha	8e-6	12e-6	1/K

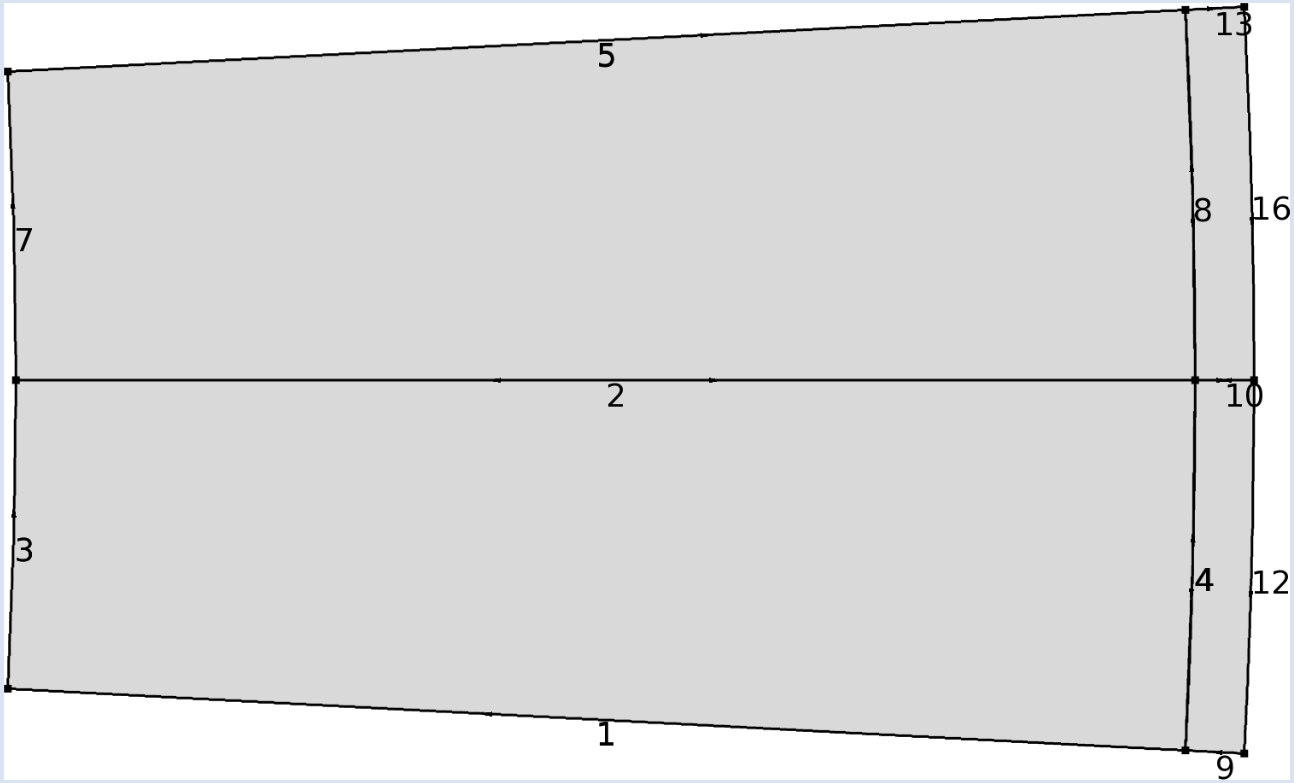
- Thermal BC:
  internal (hot) side is convection with h=500W/m^2/K and T=1500°C;
  external (cold) side is convection with h=50W/m^2/K and T=20°C.

Geometry Reduction by Using Symmetries and System Behavior under Thermal Loads

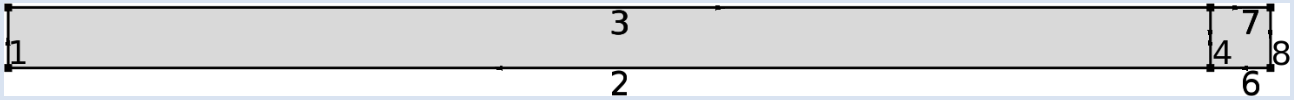
- In this case, the contracts between the refractory blocks are identical due to complete symmetry. The interaction between the horizontal layers are assumed to provide a plane strain situation in this model.



Boundary Conditions
(Edge Numbering in Assambly Mode)



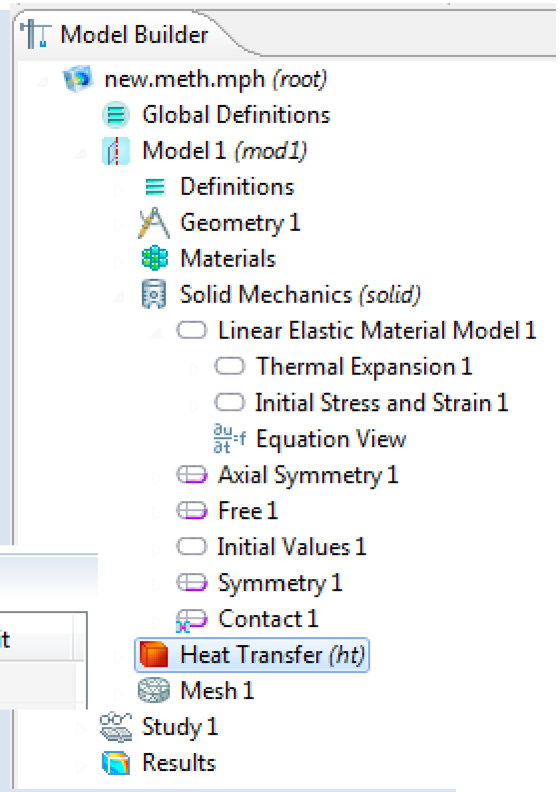
- 1,5,9&13 symmetry
- 2,4,8&10 contact
- 3&7 hot side
- 12&16 cold side



- 2.3.6&7 symmetry
- 4 contact
- 1 hot side
- 8 cold side

Main Modelling Steps

- Standard modelling steps apply (i.e., geometry and material definitions, phsics: heat transfer and solid mechanics seperately, thermal expansion should be included in solid mechanics).



- Additionally, the stress component which will be modified by no-tension concept needs to be seperately competed and stored in a variable.

Variables

Name	Expression	Unit
s22	solid.D12*solid.eel11+2*solid.D24*solid.eel12+2*solid.D26*solid.eel13+solid.D22*solid.eel22+2*...	Pa

- The easiest way to implement the no tension concept is by using initial stresses

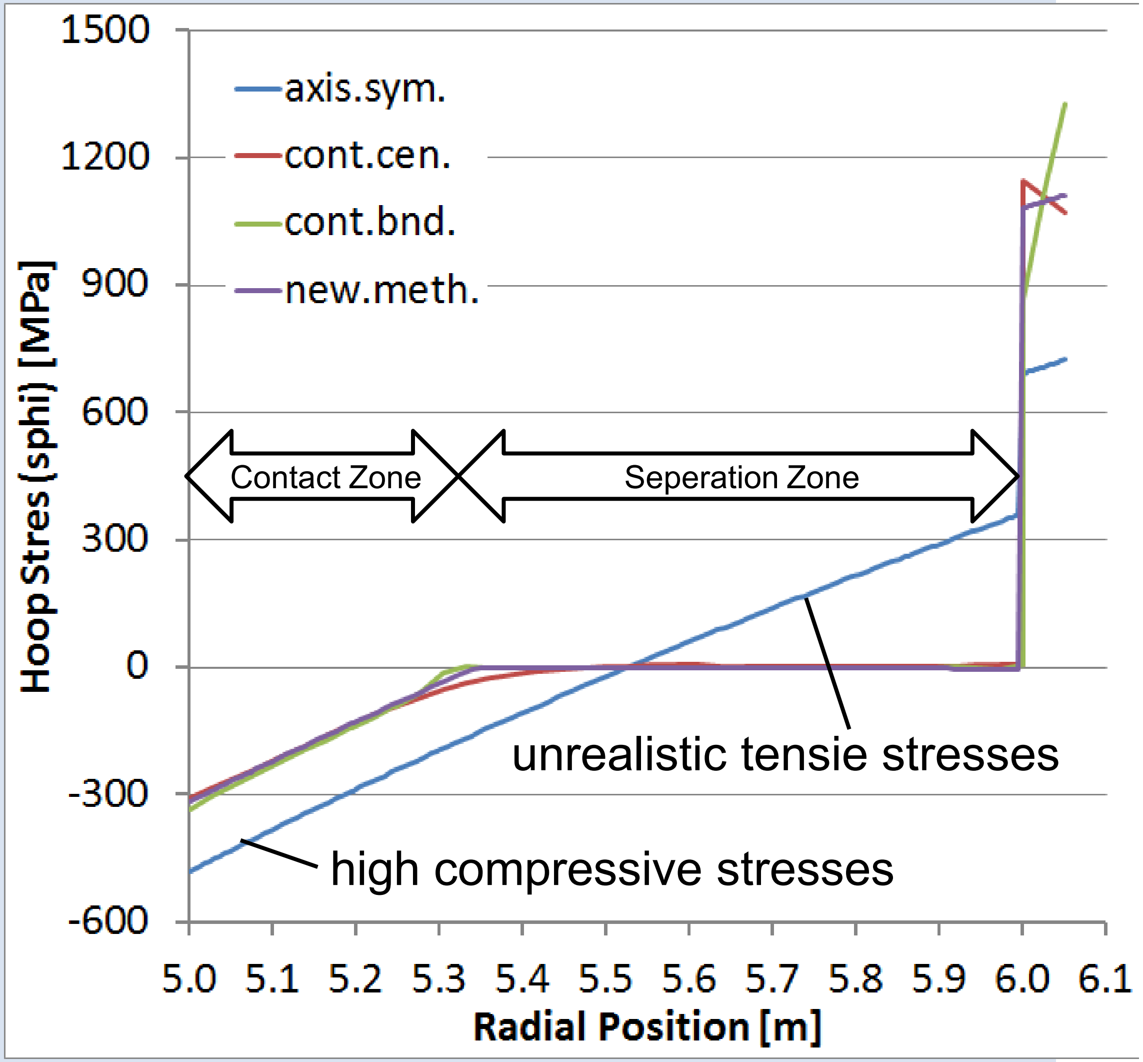
Initial Stress and Strain

Initial stress material local coordinate system:

	0	0	0	
S_0	0	-S22*(S22>0)	0	N/m^2
	0	0	0	

Comparison of Computed Stresses

- The hoop stress obtained from three different models are compared.
- Simple axis-symmetric model without any contact between refractory blocks compute unrealistic tensile stresses and high compressive stresses in the refractory blocks.
- If the contact of blocks are includes using standard contact model or the new method, the unrealistic stresses are avoided.



 · Dr.-Ing. Yalcin Kaymak · · yalcin.kaymak@bfi.de

COMSOL CONFERENCE
OCTOBER 26–28
STUTTGART 2011

Conclusions

- COMSOL can be effectively utilized with the introduced method as an efficient tool for the computation of thermo-mechanical state of refractory linings under various conditions for blast furnaces, converters, lathes, etc.
- As the new method is very fast, the engineers can analyze the behavior of the lining for various geometries design and materials to develop better refractory lining concepts.
- Plastic material models can be used (i.e. for the steel shell) in the model without any problem.
- The introduced solution is applicable to all two- or three-dimensional simulation models without any restriction.

Acknowledgement

- This work was carried out with a financial grant from the Research Fund for Coal and Steel of the European Community with project number: RFSR-CT-2007-00001.

- I would like to thank Dr. Thorsten Hauck, Dr. Rongshan Lin, Dr. Harald Rausch, and Dr. Alex Sami Zaimi for their supports, fruitful discussions and valuable comments during the project.