VDEh-Betriebsforschungsinstitut GmbH

COMSOL Application To Estimate 3d Blast Furnace Hearth Wear Using Thermocouple Measurements

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COMSOL CONFERENCE
2018 LAUSANNE

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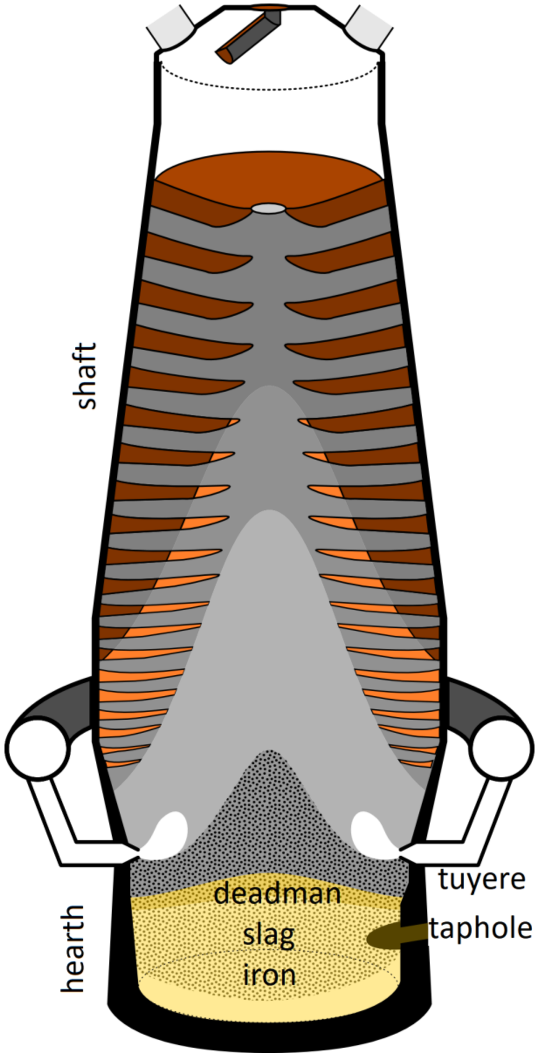
Stahl

Introduction



Blast furnace (BF) is a type of counter current shaft furnace used for iron ore reduction and smelting to produce industrial liquid iron.

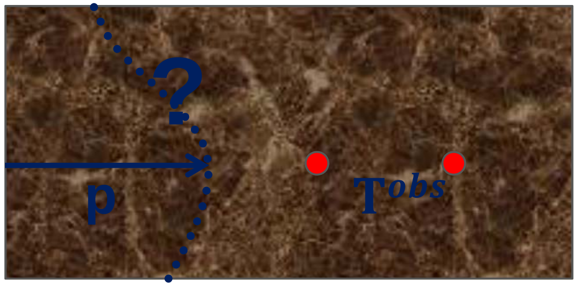
End products are molten iron and slag phases tapped from the bottom, and flue gases leaving from the top of the furnace.

Campaign life of BF is governed by erosion of hearth refractory.

It is essential to keep track of residual lining thickness not only for better planning of relining but also for operational safety to avoid dangerous hearth breakthrough incidents.

Theory
inverse heat transfer model

- It is an inverse geometry problem of finding the best fitting wear profile to observed temperatures
- Wear surface geometry is described by Kriging technique from a set of parameters **p**
- Optimization problem is stated as

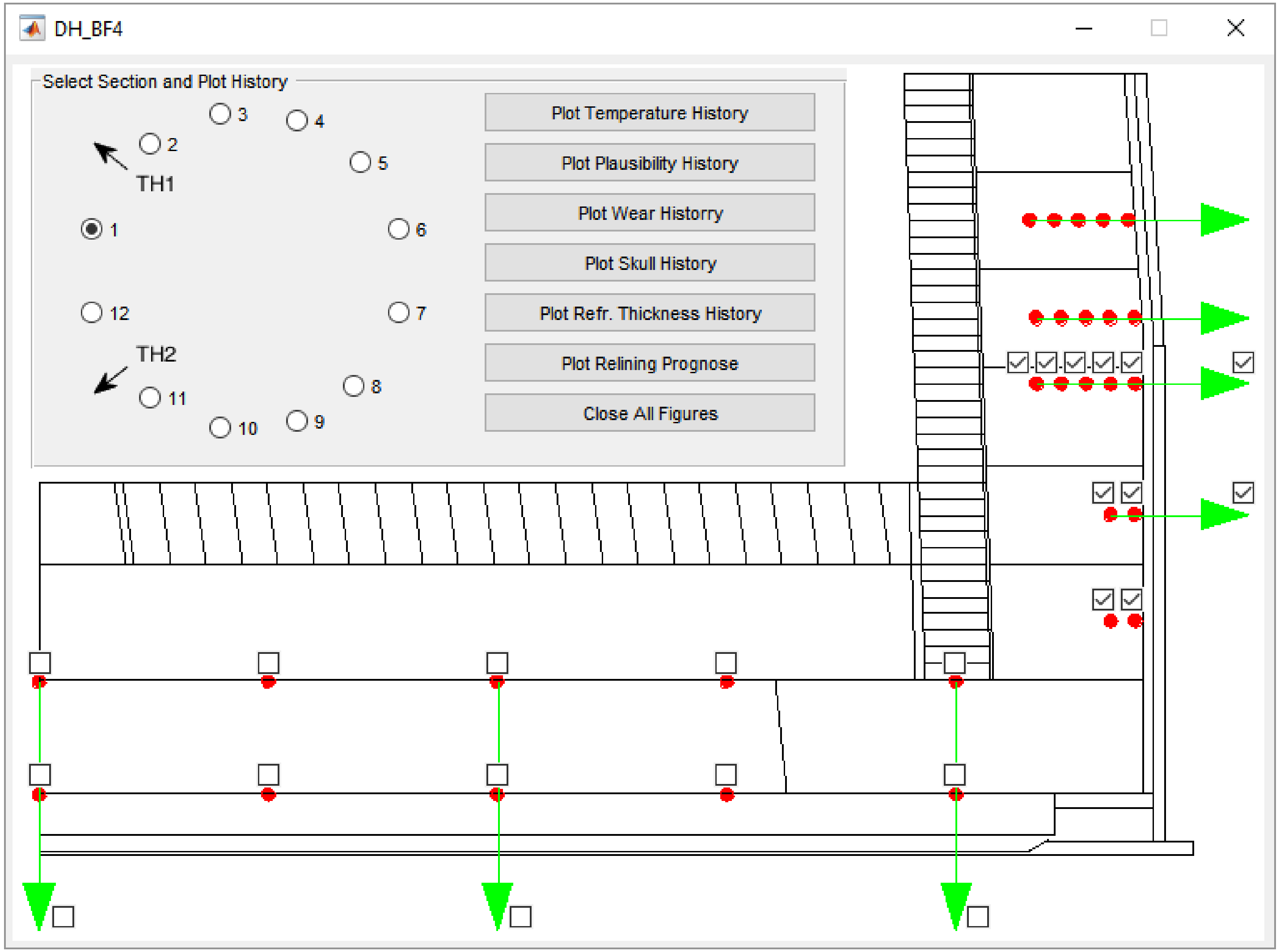


$$\mathbf{p}^{*} = \arg \min_{p \in \mathbb{R}^n} \frac{1}{2} \left\| \mathbf{T}(\mathbf{p}) - \mathbf{T}^{obs} \right\|$$

- It is solved using Levenberg–Marquardt algorithm (LMA)
- COMSOL Multiphysics is used to compute $\mathbf{T}(\mathbf{p})$
- In a daily scheduled way, wear parameters are computed and saved automatically for measured temperatures $\mathbf{T}^{obs}$

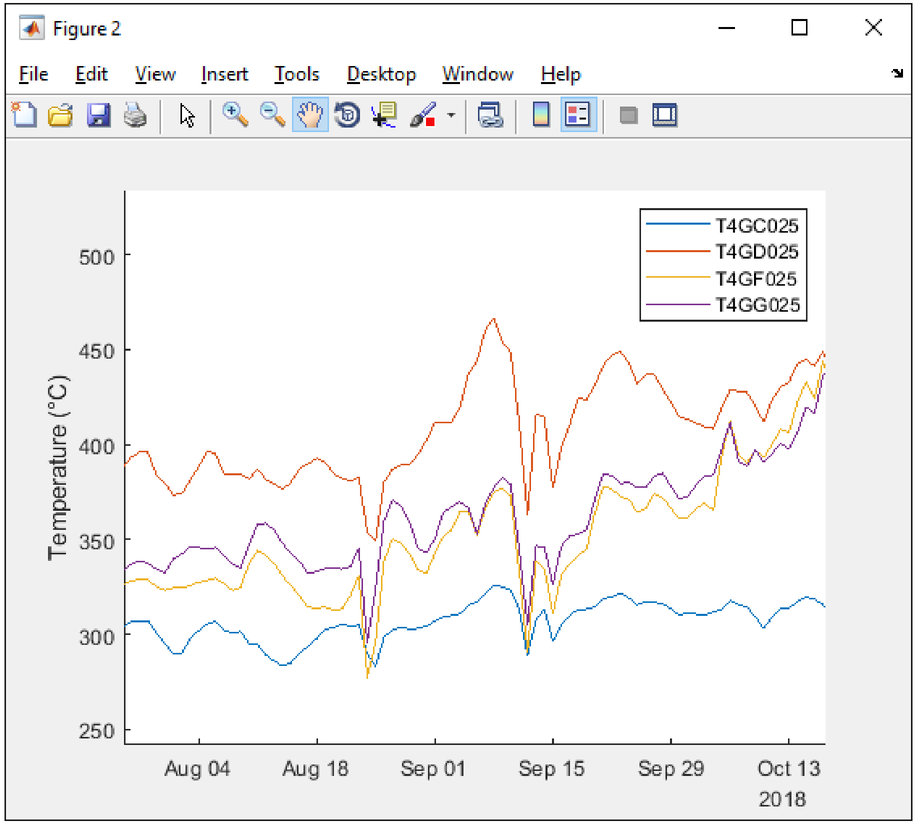
Application User Interface (UI)

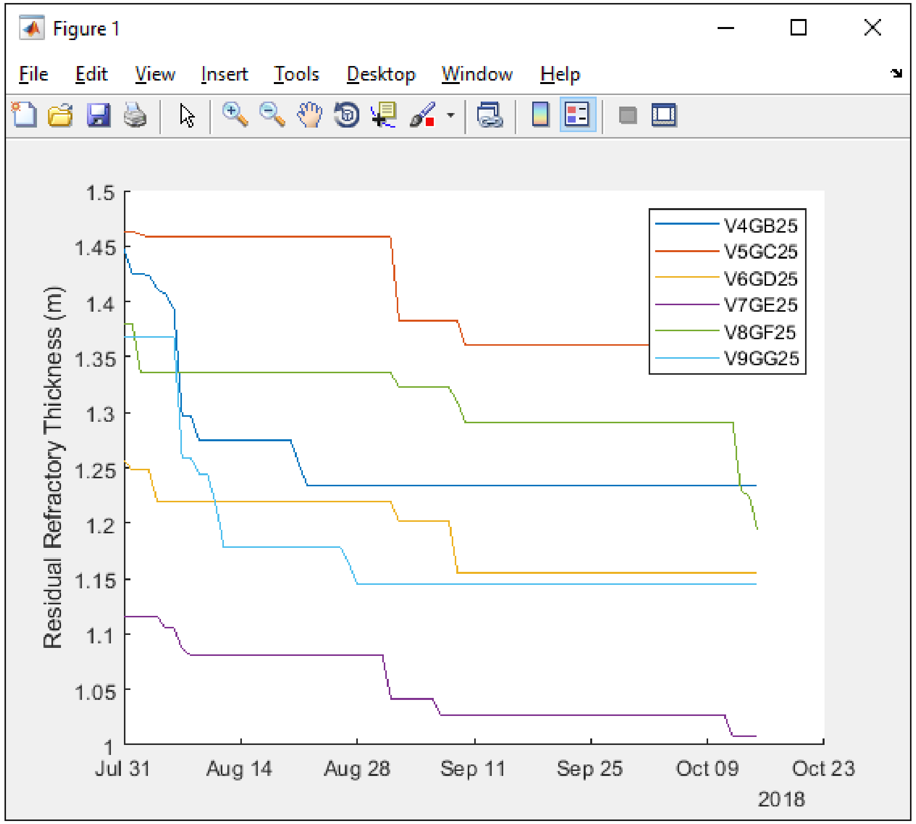
Matlab UI to view time evolutions



Results
Temperature and residual wall thickness evolution

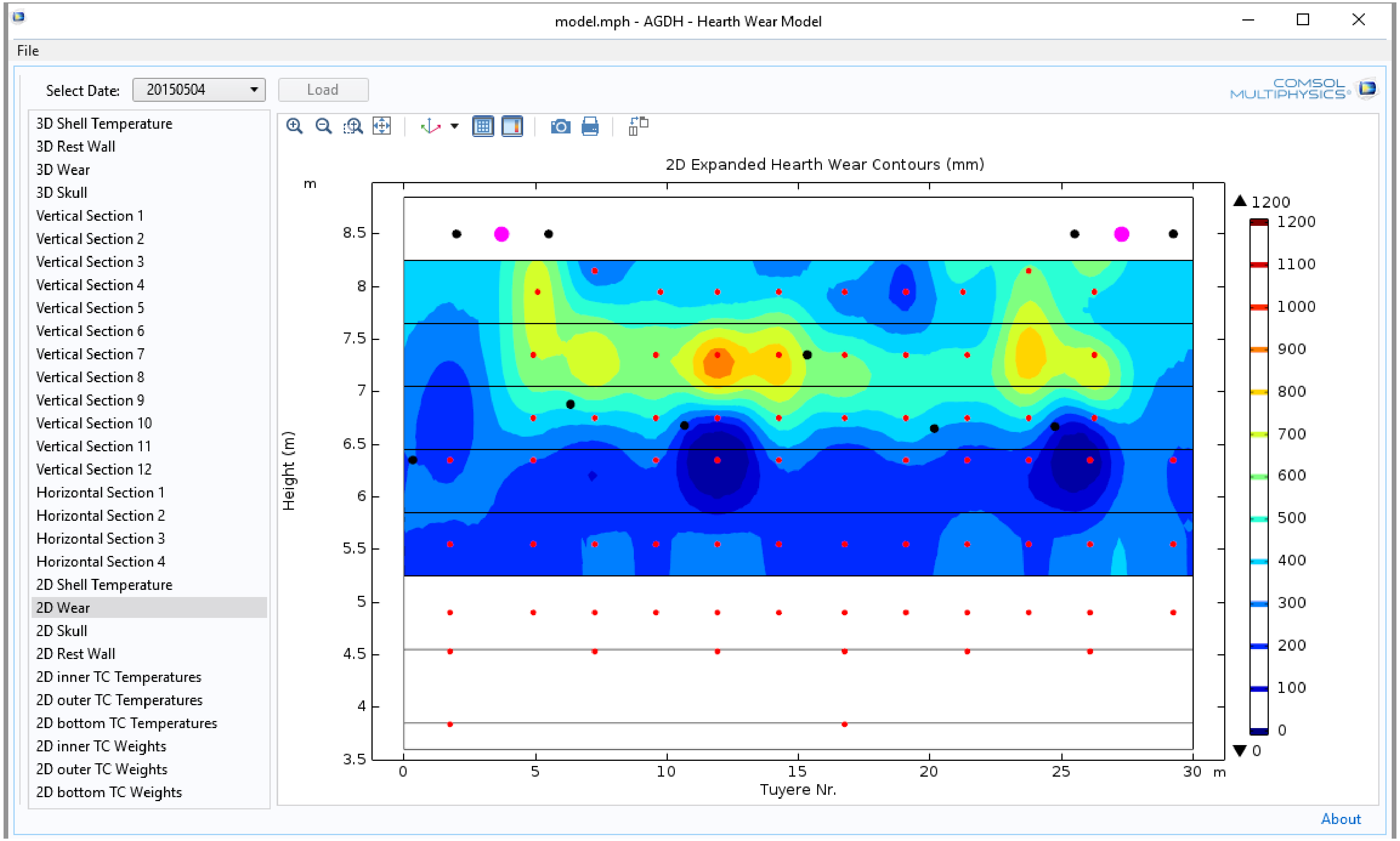
- Temperature evolutions of 4 TC at a particular vertical section
- Residual wall thickness evolutions at geometry parametrization points





Application User Interface (UI)

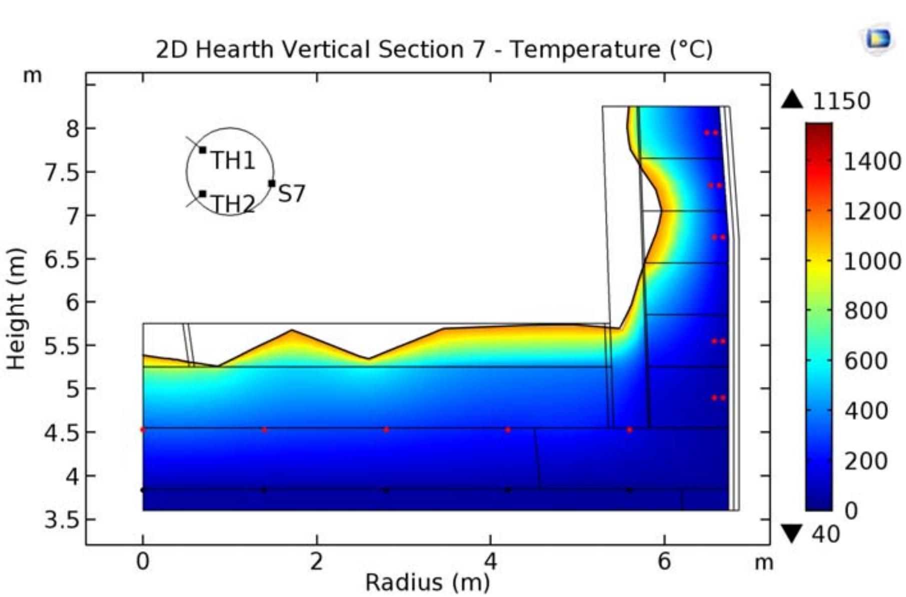
COMSOL® UI to view daily results

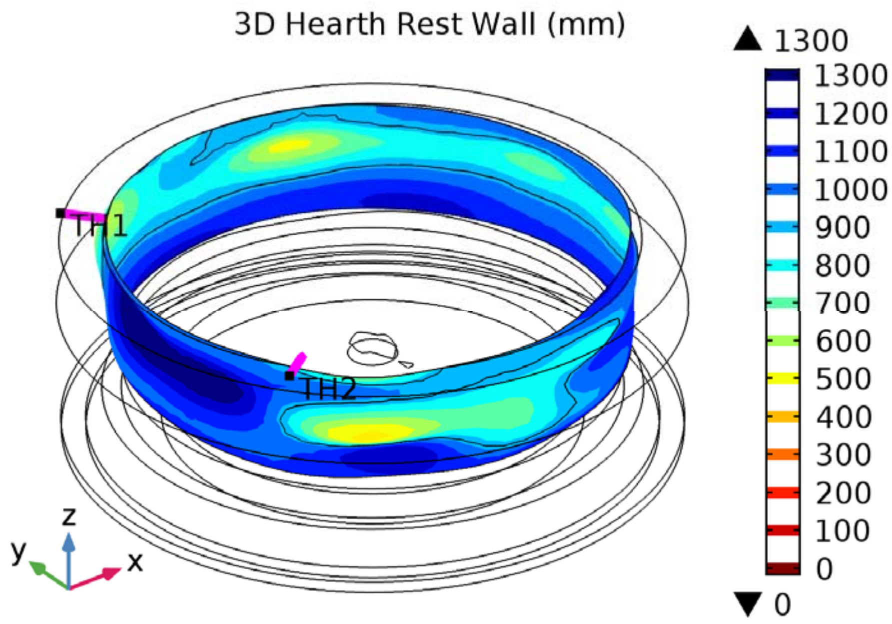


Results

2d vertical section or 3d surface plots

- Temperature contours for vertical section 7 with initial configuration plotted at background
- Residual wall thickness contours plotted on the inner surface
- Note that TH positions are highlighted for orientation

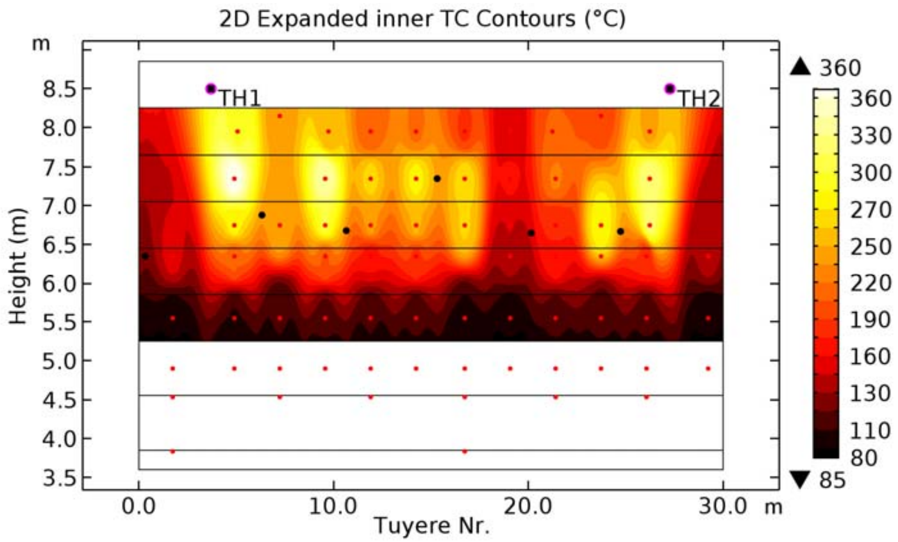


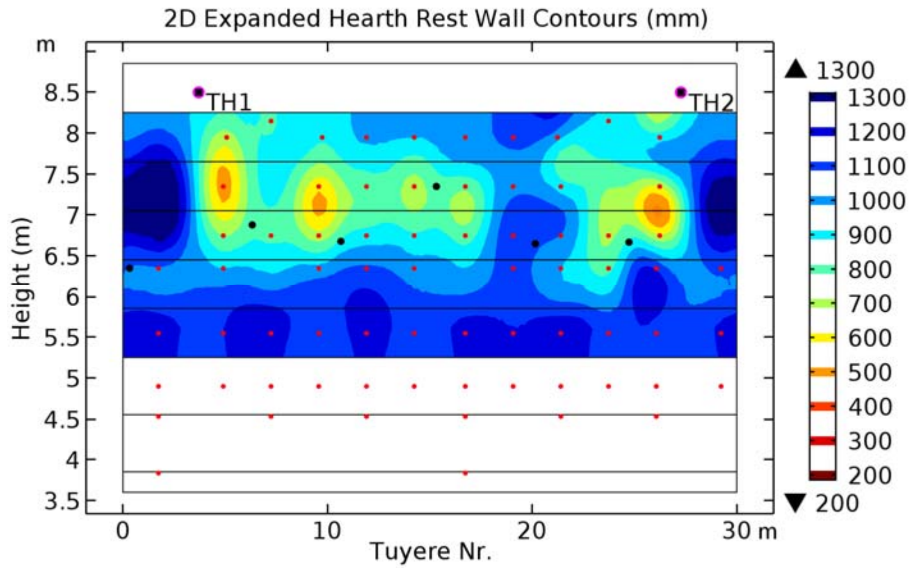


Results

2d unrolled contour plots for measured temperature and residual wall thickness

- Wall has mostly double TCs. Interpolated temperature at hot side to show hot spots with high wear
- 2d unrolled residual wall thickness contours fit good to hot spots

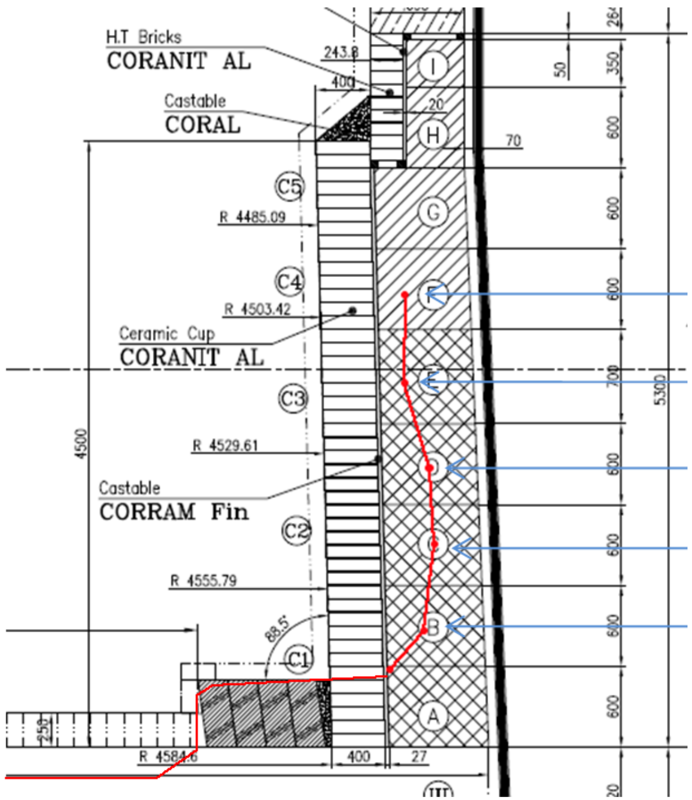


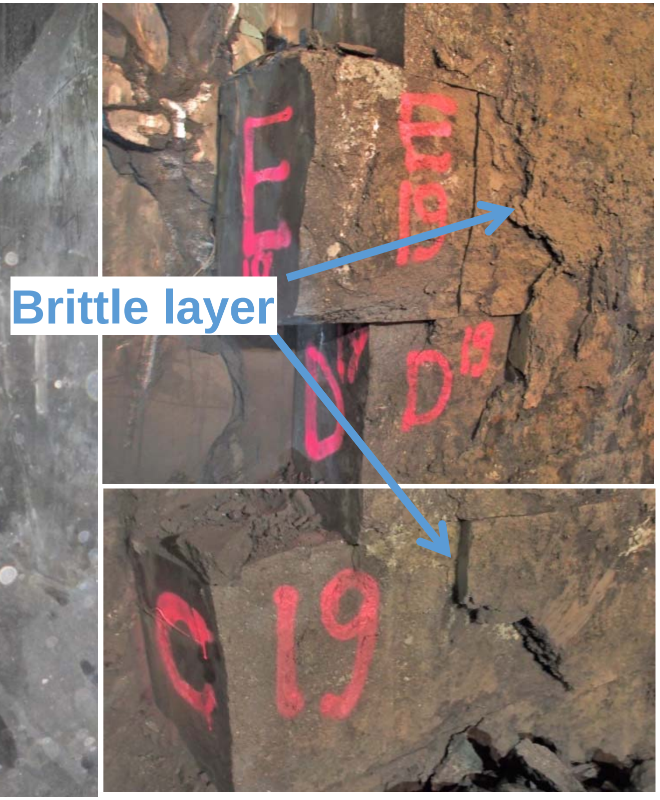


Model Validation

Estimated & observed wears compared

Direct comparison of estimated and observed residual wall thickness is only possible during a relining, which is done during relinings at Dillingen and Eisenhüttenstadt in 2016.





Conclusions

- Monitoring BF hearth lining state is essential not only for better planning of relining but also for operational safety.
- Modern BFs are equipped with many thermocouples (TC) in hearth refractory to monitor temperature level which increases with refractory wear.
- Inverse 3d heat transfer model has been developed to estimate hearth wear profile which fits best to TC measurements.
- COMSOL Multiphysics® and LiveLink™ for MATLAB® have been utilized to interpolate 3d wear profile and to solve temperature field.
- Model is daily solved using COMSOL Server™ with MATLAB®.
- Many different results accessible using COMSOL® app UI and MATLAB® UI.
- Model has been calibrated and validated by comparing estimated and measured residual wall thickness during relinings at Eisenhüttenstadt and Dillingen.

Thank you for your attention
Incase you need to contact us

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Acknowledgements: the work presented here has been carried out with a financial grant from the Research Fund for Coal and Steel (RFCS) of the European Community with Grant Agreement No: RFSR-CT-2015-00001 and project title "Optimizing Blast Furnace Hearth Inner State“ (OPTIBLAFINS).

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