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

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INTRODUCTION: The residual refractory lining thickness at blast furnace hearth has to be monitored not only for the better planning of the relining but also for the operational safety and avoiding dangerous hearth breakthrough incidents [1].

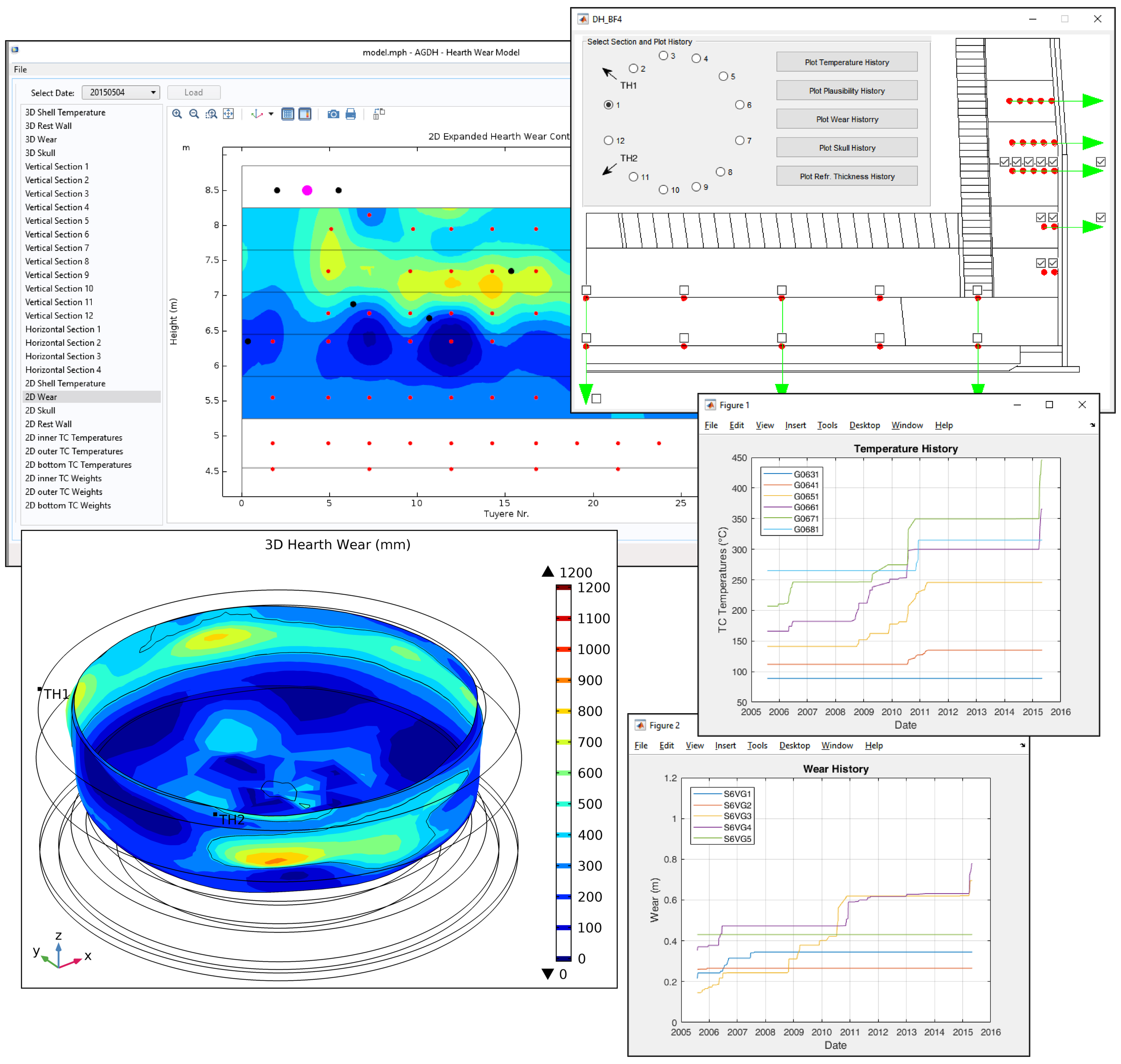

Figure 1. Snapshots of the COMSOL application

COMPUTATIONAL METHODS: Blast furnaces are equipped with many thermocouples in the hearth refractory because the temperatures increase with wear. The inverse geometry problem is finding the best fitting wear profile to observed temperatures [2, 3]. The 3d hearth wear is parameterized using the Kriging interpolation [4] and optimal parameters are computed by using Levenberg-Marquardt algorithm [5]. This problem is mathematically equivalent to the following equations:

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

where $\mathbf{T}^{obs}$ is the vector of the daily average thermocouple measurements, $\mathbf{T}(\mathbf{p})$ is the simulated temperature for the set of geometry parameters $\mathbf{p}=(p_1,\ldots,p_n)$, and $\mathbf{p}^*$ is the optimal parameters. The developed model is solved using COMSOL Server™ with MATLAB® on a daily basis. Also a COMSOL® application has been programmed as a user interface to visualize the results. Some scenes from the user interface are shown in Figures 1.

RESULTS: As COMSOL Multiphysics® has plenty of post processing options. A variety of 2d and 3d visualisation options are implemented in the application interface as seen in Figure 1 and 2. The operators carefully evaluate all these visual results before making critical operational decisions.

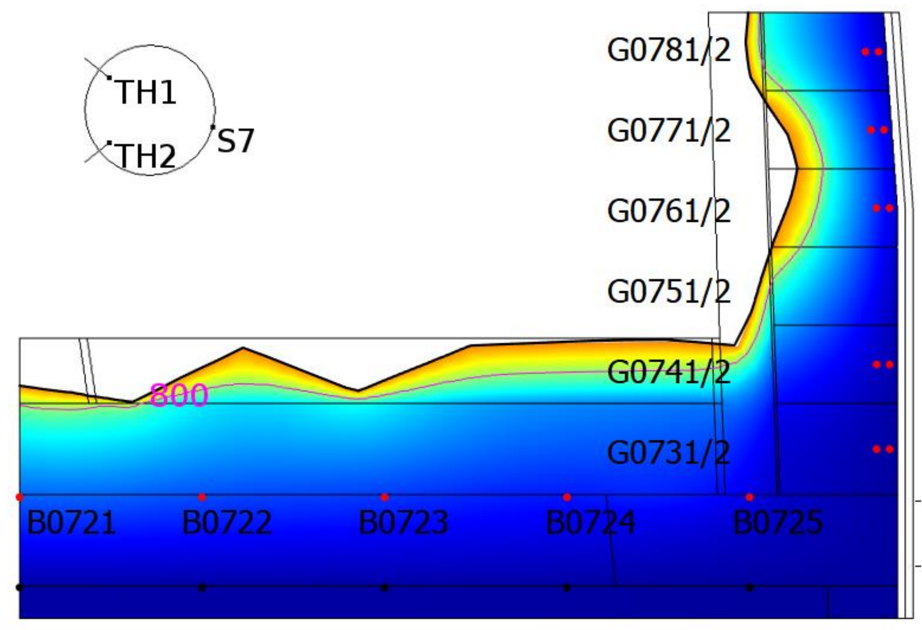

Figure 2. AGDH BF4 hearth state on 20.11.2013

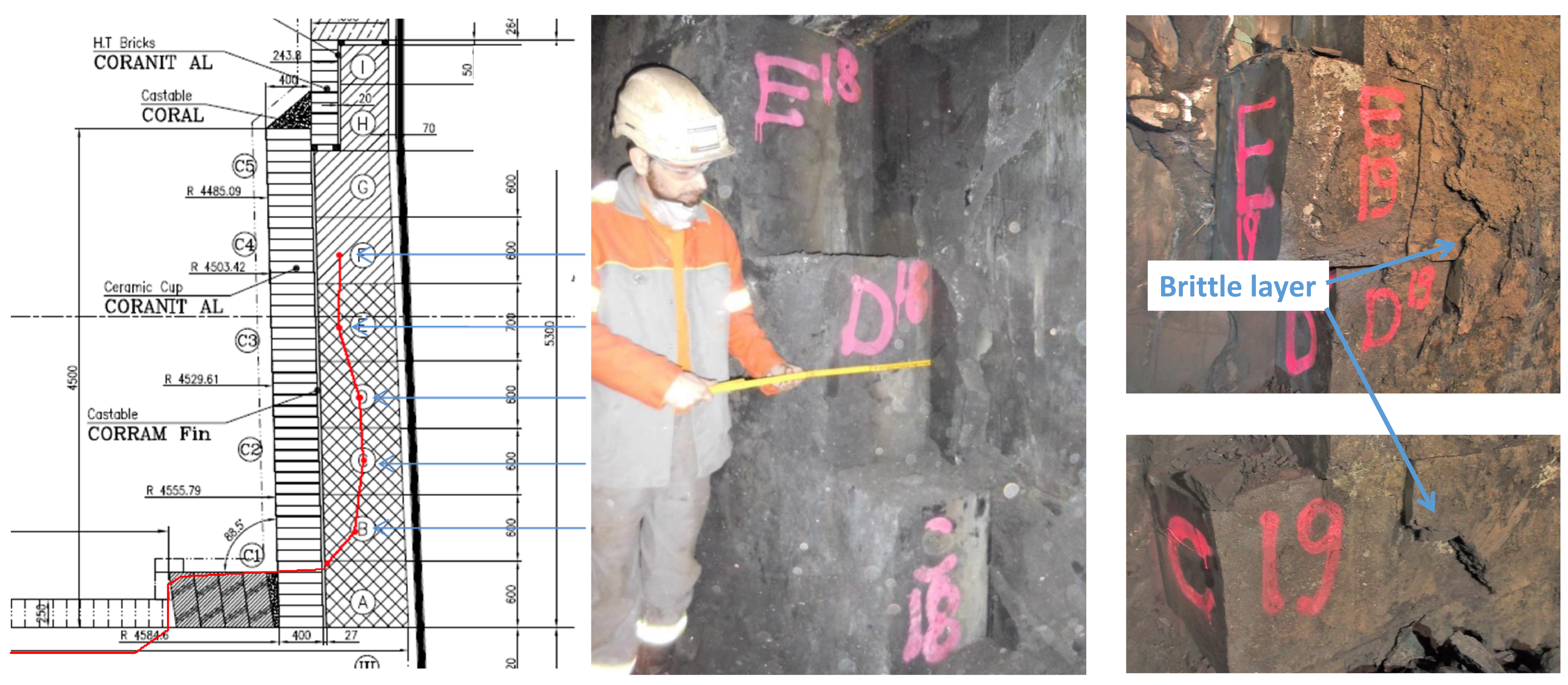

Figure 3. AMEH BF5A hearth excavation measurements

CONCLUSIONS: An inverse 3d heat transfer model has been developed for monitoring the blast furnace hearth lining state using COMSOL Server™ with MATLAB®. The furnace operators can access variety of results via the application user interface. The model was validated and calibrated by relining observations (Figure 3).

The developed model is very flexible, for example other physics can be easily integrated. Currently, the thermal stresses in the lining or fluid flow and drainage in the hearth are being implemented to extend the capabilities.

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