A transient thermal problem with non-local radiation arising in steelmaking industry

Patricia Barral Rodiño[1,2], Luis Javier Pérez [1], Peregrina Quintela Estévez[1,2]

[1] Departamento de Matemática Aplicada, Universidade de Santiago de Compostela, Santiago de Compostela, Spain

[2]ITMATI, Campus Vida, Santiago de Compostela, Spain

This work aims to assess the time-dependent thermal response of the Blast Furnace runner or main trough, a refractory concrete structure used in the basic oxygen steelmaking process. It is specifically designed to separate and transport the slag and pig iron produced at the Blast Furnace. During its life, it has to sustain harsh operation conditions, which include extremely high temperatures, reaching 1500ºC. The high degree of wear suffered by the main trough motivates the industrial interest on its assessment and minimization.

The wear suffered by the trough is due to various factors, such as erosion, corrosion and thermal stresses. It is believed to be strongly related to the position of the critical isotherms, which indicate the onset of chemical composition changes in the refractory lining. The casting process is not continuous, as it is done in cycles. Typically, each cast lasts for 90 minutes, followed by short stops. However, depending on the conditions at the casthouse, these stops frequently have a longer duration, reaching up to several days. During these longer stops, the trough has enough time to cool down. Consequently, the temperature field in the trough does not fully reach a steady state and follows patterns that match these cycles. Nonetheless, given the time scales of the temperature variations are very long, in the literature it is usual to assume steady thermal problems (see e.g. [1]). Also, in the previous work [3], a steady thermo-hydrodynamic 3d problem was studied.

Here, we focus on a simplified problem defined on a 2d cross-section of one of the runners that ArcelorMittal Spain operates in Veriña, Asturias. The main objective is to assess the transient thermal behaviour of this section during the two-month campaign life of the runner and to find the position of the critical isotherms. With this purpose, we use time-dependent boundary conditions which emulate the effect of the casting process stops. In addition, we model the non-local radiation at the boundary as an integral equation, which accounts for the effects of thermal radiation emitted by the slag free surface and reflected by the walls of the trough. The spatial discretization and numerical solution of the non-linear problem is done with a finite element method, using the FEniCS library.

The proposed methodology has shown promising results and proved useful in order to predict the transient position of the critical isotherms. The computed temperatures are validated using experimental measures supplied by ArcelorMittal.

Acknowledgements

This work was partially supported by FEDER and Xunta de Galicia funds under the ED431C 2017/60 grant, by the Ministerio de Ciencia, Innovación y Universidades through the Plan Nacional de I+D+i (MTM2015-68275-R) and the grant BES-2016-077228

Keywords: steelmaking, transient heat transfer, non-local radiation

REFERENCES

[1] S. Vázquez-Fernández, A. G.-L. Pieiga, C. Lausín-González, and P. Quintela, "Mathematical modelling and numerical simulation of the heat transfer in a trough of a blast furnace", International Journal of Thermal Sciences, vol. 137, pp. 364-374, 2019.

[2] M. Geerdes, R. Chaigneau, and I. Kurunov, Modern blast furnace ironmaking: An introduction. IOS Press, 2015.

[3] P. Barral, B. Nicolás, L. J. Pérez-Pérez, and P. Quintela, "Numerical simulation of wear-related problems in a blast furnace runner", in Recent Advances in Differential Equations and Applications pp. 229-244, Springer, 2019.