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Badanie degradacji wielofazowych materiałów ogniotrwałych w kontakcie z ciekłym metalem z wykorzystaniem mikrotomografii komputerowej i modelowania numerycznego w geometrii 3D

Investigations of multiphase refractory materials degradation in contact with molten metal using micro-computed tomography and numerical modeling in 3D geometry

dr inż. Jakub Józef Stec

Principal Investigator

Akademia Górniczo-Hutnicza im. Stanisława Staszica w Krakowie

Wydział Inżynierii Materiałowej i Ceramiki

DESCRIPTION FOR GENERAL PUBLIC

Transport in a porous medium is encountered in many diverse fields of science and technology: from agricultural, chemical, petroleum and civil engineering to food and soil sciences. In materials science it is of especially high importance in manufacturing and degradation of the materials. In manufacturing it is important in fabrication of metal and polymer matrix composites, obtained by impregnation of particle or fiber reinforcing material by liquid matrix material. An example of a degradation process, which is limited by transport in materials pores, is a degradation of refractory lining material in contact with molten metal. It is one of the mechanisms of carbon and graphite materials degradation, used as lining material in a blast furnace hearth. One of the promising tool, which can be used to investigate the transport in a porous medium is modeling. It allows investigating the complex processes without expensive experimental research. Such investigations of transport processes in porous media can be used to design more resistant to degradation materials and optimize the manufacturing processes.

The goal of the project is a new attempt to investigation of degradation mechanism of multiphase carbon refractory materials in contact with a molten metal by combination of advanced 3D modeling with X-ray micro-computed tomography (XCT). The model will allow performing simulations of time-dependent two-phase pore-scale flow with moving infiltration front combined with a selective dissolution of micropore carbon material in the liquid metal. For the first time the calculations will be performed in a three-dimensional (3D) geometry representing a real micropore carbon material microstructure, obtained by the XCT. The model will be verified by the infiltration resistance test. Application of the non-destructive investigation technique (XCT) allows investigating the same sample before and after infiltration resistance test and consequently compare measured degradation with the calculated one.

The project is divided into two parts. In the experimental part microstructure, porosity and permeability of micropore carbon materials will be investigated by non-destructive investigations methods such as: helium porosimetry, gas permeability and XCT. Then, samples will be subject to a infiltration resistance test. After the test, samples will be investigated by non-destructive methods once again in order to observe impregnation zone and influence of test on material microstructure, especially pores structure. The wettability of micropore carbon material by the liquid iron with additives, of different carbon, sulfur and silicon content will be also investigated. Data obtained in the experimental part will be subsequently used in modeling.

Based on the XCT investigations the 3D geometries, representing a real material microstructure, will be generated and used in calculations. A molten metal flow will be described by Stoke equations, combined with the Phase Field method, which will allow calculating the movement of infiltration front. Changes in the carbon concentration in metal will be described by the mass balance equation with boundary conditions representing the kinetics of micropore carbon material dissolution. Calculations will be performed using finite element method. The calculated degradation of micropore carbon refractory material will be compared with the results of the infiltration resistance test to verify the model. Investigations will allow defining which parts of the microstructure are most vulnerable to degradation.

The developed model will be used to investigate the influence of the metal composition on the speed of infiltration process, saturation degree and selective dissolution of micropore carbon material. Performed investigations will allow better understanding of degradation of materials used in a blast furnace, which can be used in optimization of the blast furnace technology and in designing of materials more resistant to degradation. Moreover, due to the fact that transport in porous medium is present in many fields of science and technology, the developed model might be adapted to investigations of similar materials and processes.