Evaluation of the High Temperature Conversion of Plastic Particles after Injection into Blast Furnace Raceway Using CFD Simulations

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Introduction

The blast furnace is representing the most important technology for producing liquid iron. To reduce the amount of blast furnace coke, alternative reduction agents like oil, coal dust, tar, coke oven gas and also recycling plastic particles are injected into the blast furnace through the tuyere lances placed in radial direction. The reduction agents injected generate heat and the reducing species like CO and H_2. This helps to reduce the demand for high quality coke and operating costs. In this work the injection and conversion of plastic particles at the high raceway temperatures is evaluated using Computational Fluid Dynamics (CFD). Different operating conditions can be calculated to obtain conversion and heat production characteristics in the raceway in order to optimize the substitution process.

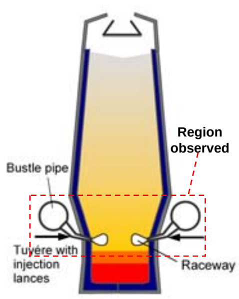

Fig. 1: Scheme of the blast furnace

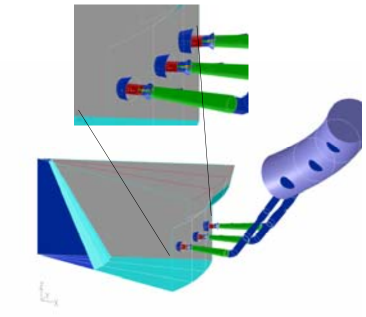

Fig. 2: Geometry section modeled in CFD, detailled view of tuyére section

Characterization of Particles

Physical and chemical properties of the recycling plastic particles like particle size, shapes and composition have been measured or estimated to provide suitable input data for the CFD model. In order to simulate the high temperature conversion process common thermogravimetric methods were not sufficient since the available maximum heat transfer rate was too low. Therefore laser ablation experiments were carried out using a pulsed Nd:YAG laser: A plastic pellet equipped with a temperature probe was treated with a series of 5ms laser pulses. Using a high speed camera the process was recorded, also the weight loss of the particle was measured.

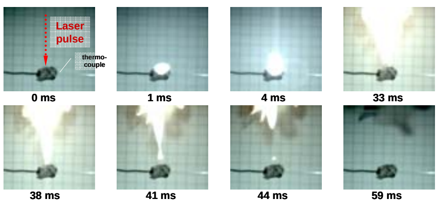

Fig. 3: Laser pulse treatment of plastic particles

CFD-Models

Simulations are carried out using the finite volume code FLUENT, the geometry is constructed using the pre-processor GAMBIT. A blast furnace segment consisting of three tuyeres including the bustle pipe, blast pipe and the appropriate lances for the oil and particle injection was implemented and meshed with finite volumes consisting only of hexahedral elements.

For the description of turbulence the SST k-ω model is applied, radiation is modelled by applying the discrete ordinates (DO) approach. The gas density is described using the ideal gas equation, radiation properties are implemented through a modified "weighted sum of grey gases" (WSGG) approach. This also includes a treatment of the coke bed.

The raceway is modelled as a cavity in a porous coke bed, the shape is determined according to the local gas velocity. A lagrangian discrete particle model (DPM) is used for the shrinking plastic particles. Gas phase combustion is also included (global reactions with 8 species – including especially H_2 and CO, turbulence interaction is handled using Magnussen's EDC model).

Results

The full model provides the possibility to study the influence of the operation parameters on the raceway shape, temperature and species distribution, as well as the velocity field. As shown in figure 4 the shape of the raceway depends not only on the operation conditions but also on a suitable set of parameters describing the coke bed.

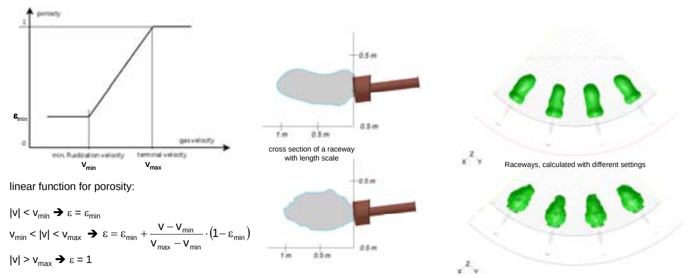

Fig. 4: Basic implementation of the raceway model and resulting raceway lengths and shapes (using a simplified blast furnace geometry)

The maximum hot blast velocity occurs in the tuyére section and the raceway zone. On entering the porous coke bed the gas jet rapidly decreases in velocity. The absolute pressure in the simulated region ranges from the bustle pipe feed pressure of 5.1 bar to approx. 4.6 bar at the exit of the geometry. The main pressure drop occurs in the tuyére and the raceway boundary.

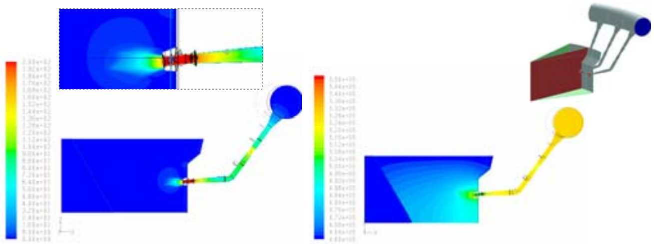

Fig. 5: Left – absolute velocity [m/s] (including tuyere detail), right – absolute pressure field [Pa] on the symmetry-plane (location indicated on the right)

Important for the operation of the blast furnace is also the question of the plastic particle burnout time and the location of particle impacts on the coke bed (raceway boundary). Furthermore it is interesting to know the thermal conditions of the raceway boundary.

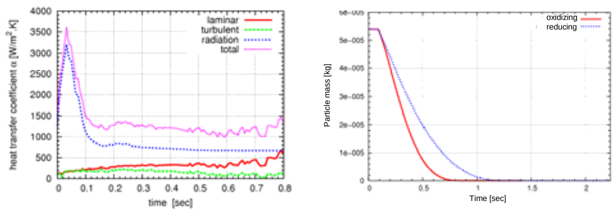

Fig. 6: Left - Particle heat transfer rate, right - particle mass loss over flight time

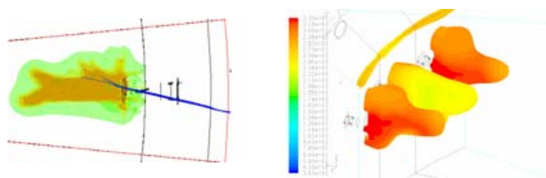

Fig. 7: Left – injected particles hardly deflected – impacting on small region, right – temperature distribution on raceway boundary [K]

Further work

In order to find the optimum particle injection rate different cases will be compared. Especially important will also be the species distribution and the pressure drop of raceways with different reduction agent feed.

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Austrian-Croatian-Hungarian Combustion Meeting (ACH2008); October 3, 2008, Sopron, Hungaria