Biomass combustion on a reciprocating grate: coupled CFD-XDEM modelling

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ABSTRACT

The eXtended Discrete Element Method (XDEM) [1] is applied to investigate biomass combustion in a 16 MW super-heater. The system belongs to Enel Green Power, a world leader in the development and management of renewable energy sources, and it is placed in the Larderello geothermal area in Tuscany, Italy. The plant is an example of novel integration between two renewable energy sources: geothermal and biomass energy. The geothermal fluid, after being extracted from the wells, is heated up from about 150°C to 370°C in the super-heater, thus increasing the efficiency of the geothermal cycle and the net electricity generation by of about 5 MW. The super-heater is fed with a mixture of two different biomasses (local virgin forest wood-chips and low-quality agricultural residues) through a reciprocating grate.

The granular behaviour of the biomass particles on the moving grate is described through XDEM that is coupled to Computational Fluid Dynamics (CFD) to consider the interaction with the surrounding gas phase. The peculiar feature of XDEM is that it encompasses chemical and thermodynamic particle properties (temperature profile, species distribution, porosity, diffusivity, charge density profile, etc.) in addition to kinematic (position, velocity and orientation) ones, thus allowing the inclusion of phenomena such as evaporation, pyrolysis and char oxidation. The CFD model is handled with OpenFOAM®-Extend and solves mass, momentum, species transport, energy and turbulence equations in the gaseous phase. Hence, the CFD solution provides boundary conditions to the particles within the XDEM treatment, whereas particles constitute sources/sinks of mass, momentum, chemical species and energy in the gas phase CFD equations.

A 2D model of the biomass bed and combustion chamber was developed using about 2000 particles representative of each biomass class. The results highlighted the unsteady behaviour of the biomass combustion on the reciprocating grate and showed the presence of gas streaks coming out from the bed.

The approach is very useful as it provides a full characterisation of both gaseous and particle phases without the need of any a priori hypothesis on biomass conversion. Hence it may be used to estimate the amount of unburnt biomass and thus to plan different strategies to optimize the combustion process, thus increasing the net efficiency of the plant.

REFERENCES

[1] B. Peters, "The extended discrete element method (XDEM) for multi-physics applications", *Scholarly J. Eng. Res.*, **2**, 1-20 (2013)