Context

Nowadays, biomass boilers are an alternative energy source because their diverse fuels sources and dispatchability allows remarkable profits with a reduced environmental and social impact so that these facilities are in vigorous growth and either biomass boiler design and for those performing their characterization and optimization are highly demanded. On the other hand, Spain is the biggest olive oil producer in the world, and this industry generates diverse oil residues (mainly called "ôruliço"), which, in use in biomass boilers to its valorization through the steam production for electricity generation (power ranges from 2 MWe to 25 MWe) is highly extended. In Spain, olive residues fired biomass plants generate more than 126 MWe with a biomass consumption of more than 800 tons per year.

Due to the fuel characteristics, these boilers must stop for maintenance operations (cleaning of fouling deposits on tube banks or biomass auto-ignition on the grate), reducing the dispatchability. This uses to be avoided by means of conservative design values in heat exchanging surfaces and boiler geometry according to flying ashes composition, grate operation, internal flow distribution, exchanged heat and foreseeable fuel nature variation.

FD model allows to perform overall behavior models for a specific fuel as it determines the fuel design, but for olive waste boilers, modelization is poorly developed despite the aroused interest.

PhD research: Modeling fly ash particles deposition on olive waste fired boiler

Introduction:

This work aims to find an useful, accurate and reliable tool for boiler design engineers who need to predict fouling problems in biomass firing troublesome biomasses. Deposition (sticking and fouling) and corrosion are one of the major problems in the design and operation of a combustion system. The particular matter forms during solid fuel combustion known as flying ash particles (FAPs) may be deposited on furnace walls and heat-exchanger tubes, which will reduce the heat transfer and could give rise to corrosion problems.

Biomass-fired furnaces, in particular those burning a high Cl and alkali content (Na/K) in fuel (e.g. olive waste fired furnaces), are often reported to suffer from severe deposition and corrosion problems, compared to conventional coal-fired boilers (Figure a)

Physical modeling:

The model will be based on a Turbulent, Eulerian-Lagrangian model of the flow with one-way coupling. Deposition and fouling should be a standalone choice, independent from the existing pulverized coal firing model on Code_Saturne selection. Once the particle reaches the near wall boundary layer (y+>100), the model initiates a stochastic transport that predicts if the particle enters (injection), remains certain residence time/fusion or changes trajectory and leaves the nearest layer (y+<100). Up to this point, the model (Guingo-Minier) is used. Afterwards, a new set of programs in C++ and fortran is implemented with the deposition criteria [1]. In such a way that the code of the existing CFDF is not altered. The sequence of iteration on each wall is shown in Figure b.

Besides the impact proportion of the high range of particle size (2-250 μm) and low range particles (0,2-10 μm), a new particle class of 0,5 μm for deflagration aerosols particles of KCl (alkali salt condensation) will be implemented in the model, condensation of low melting point salts (KCl and sulphates) is the major source of fouling on the clean surfaces of tubes. Sulphur condensation and submicron FAPs by diffusion and thermophoresis are the initial mechanisms of fouling as it creates the first layer of fouling (see white layer in figure c) over which further FAPs will be deposited. A User Subroutine is used for calculating the critical viscosity, C [1], as a function of the chemical composition of FAPs [2]. The critical temperature Tc, is also determined and will be the limit below which the probability of adherence will be max=1. This will always determine that a FAP particle (velocity v, diameter d) will be deposited and not rebounded off the wall.

Probability of salt condensation deposition will depend on the particle temperature and tube surface temperature (Figure d). Tube surface temperature will increase as the layer of deposit grows up. In each iteration after deposition of a particle, a new thickness of the cell boundary face will be calculated, so in such a way that boundary face temperature will be updated under the running of the model.

Experimental validation:

Models will be tested with data acquisition at site, in existing power station boilers of Gestamp Renewables (8-15 MWe) burning olive oil waste. Deposition probes with (air/water) controlled metal temperature will be used (Figure e).

Status:

The deposition model is being programmed in the Code_Saturne Lagrangian model with a brand-new Lagrangian model 'phylog' based on the aforementioned mechanisms and coded within the Code_Saturne kernel so that different functions and subroutines are being modified and/or updated according to the scheme shown in figure f. Up to now the new compilations of the modified code show promising results (figure f).

PhD research: Experimental and computational analysis of olive residues biomass-fired grate

Objectives:

Developing and validation (in existing power station boilers of Gestamp Renewables) of a feasible olive residue combustion model of industrial grates and its routines for Code_Saturne. This allows to optimize the grate design and to determine optimum stages according to the olive waste nature and particularities. This combustion model will also allow a boiler performance prediction considering the combustion products and particles so that the dispatchability can be maximized.

Background:

CFD packages does not directly support several specific and required models for the grate models so user-defined routines must be defined. The existent models [3] are related with the degree of approximation to the processes in the fuel layer as several products leave the fuel bed and enter into the freeboard together with an energy supply. None of the background approaches include an integration with a spreader-type feeding system (see figure g) and only some of them are capable of predicting behavior thus defining the model approach as it is following explained.

Methodology:

The work will be focused on the numerical modeling of the grate combustion as a stand-alone packed bed numerical model with interactions with both combustion and lagrangian particle transport modules in the freeboard. Two zones will be considered (see figure h): Olive-waste grate model (OWG). Physical/chemical reactions related with the olive-waste fuel and its composition defined and modeled providing gas-phase reactions and flying ashes particles compositions. Some of the OWG model details are shown in figure i. Olive-waste grate model (OWG). Physical/chemical reactions related with the olive-waste fuel and its composition defined and modeled providing gas-phase reactions and flying ashes particles compositions. Some of the OWG model details are shown in figure i. Olive-waste grate model (OWG). Physical/chemical reactions related with the olive-waste fuel and its composition defined and modeled providing gas-phase reactions and flying ashes particles compositions. Some of the OWG model details are shown in figure i.

OWG model output is treated as part of the freeboard inlet conditions, CFD modeling of gas mixing and heterogeneous/homogeneous combustion/particle transport is performed so that a radiative/biomass mass flux onto grate is obtained. Freeboard results are used recursively in steps 1 and 2 until no significant changes between outgoing radiative heat flux from CFD model and incoming from the furnace CFD model are observed. Status: In development.

References