Coal Water Slurry Oxy-combustion CFD Analysis

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ABSTRACT

In the combustor under study, the combination of fuel, generically solid waste, and oxygen makes it possible to reach high temperature of over 2000°C. Fuel, prepared in form of slurry, is introduced by mean of steam used as propellant at very high velocity and recirculated gases enriched with oxygen are partially swirled. This thermal fluid dynamic situation guarantees maximum efficiency and ensures complete destruction of dioxins and furans precursors, PAH and toxic matter introduced with waste, while the pressure provided ensures the supply of oxygen in all work conditions and in every point of reactor. The particular uniformity of the reaction conditions is strengthened by the recirculation of reaction gases which, after being cooled, are recycled with oxygen and re-introduced in the reactor. The thermal content of flue gases is then used for steam production. Since the working condition adopted, a flameless combustion could be present. In flameless oxidation mode, the feeding of oxidising air and fuel gas is performed separately with high injection velocities and this represents an extreme staging of combustion. The high temperature of the recirculated combustion products is used to initiate and maintain this mode of combustion. The flame can then no longer be seen and combustion is, for the most part, distributed throughout the volume of the combustion chamber. The relative homogeneity in temperature and in composition of the combustion chamber is a notable characteristic of the process. As a result of the reduction of temperature peaks in the flame, the mean temperature level of the furnace zone can be increased, reducing NO_x, without leading to local overheating in the vicinity of the burners. The heat transfer to the product can thus be considerably increased. In addition, the noise level induced by the combustion is greatly reduced.

Here we show some results concerning coal combustion and Nitrogen Oxides and Sulphur Oxides production. Fuel used is Sulcis coal, characterized by a high sulphur and ash content. The coal constitutes a non-negligible part used of the produced electricity, a lot of which derives from the combustion of coal slurry. It is clear therefore that the coal constitutes a vital energetic resource to use in judicious way to answer to the future demands. At the same time the environmental normative are becoming urgent more and more, leading to more efficient solutions that succeeds in using poor but economic combustible.

The use of the numerical CFD simulation to study the coal combustion has become an important tool in the design phase, but it becomes necessary to have models that give realistic quantitative results, rather than qualitative forecasts. The use of CFD codes with advanced devolatilization models and volatile and char combustion models can respond to such demand. Some numerical simulations for different working condition have been executed, using coal water slurry as solid fuel, by mean of FLUENT ™ code (V6.3). Combustion has been modelled with the *Eddy dissipation concept model*, while the *DO* model has been adopted for radiative heat transfer. The *k-ε* realizable model has been chosen for turbulence. The pollutants NO_x and SO_x have been evaluated in post-processing. A hybrid computational grid, made of about 500000 tetrahedral and hexahedral cells, has been used.

The operating and boundary conditions are:

Coal flow rate: 254 kg/h with Rosin-Rammler particles distribution (d_{min}=0.01mm

d_{max}=1.18mm); Slurry water content: 47% (mass percentage); Operating pressure: 400 kPa Wall temperature: 1600 K; Recirculating gas mass flow-rate: 1870 kg/h (partially swirled).
If one look at the flow field, one can notices that the swirled component is too weak to affect the fuel jet and disappear completely at very short distance from the nozzle. A portion of the fluid is recalled toward the inlet due to the depression induced by the high-speed fuel jet, especially in the upper part of the reactor. Even if this contributes to temperatures uniformity in the reactor, it is not so strong to be responsible of the mild combustion regime. Before coal starts to burn it is obviously necessary that all the slurry water content evaporates completely. The greater part of the evaporation happens almost immediately and is completed approximately in the first third of the reactor. Coal particles have dimensions ranging from 0.01mm to 1.18mm, so a different thermal behaviour is experimented by them: slower for the bigger and faster for the smaller ones and the volatiles release follows the same trend. The most intense release is located in the first half of the combustion chamber. After the volatiles release is ended, heterogeneous combustion completes coal consumption. The most of the coal burns in the second part of the reactor and a not negligible part is still burning while hits the walls. This means that the conditions adopted, especially referred to diameters distribution, are such to not guarantee a complete conversion (around 70%) of the contained carbon. A very uniform temperatures distribution has been registered, with a peak of 1740 K. Also the radical OH distribution results extremely uniform. These evidences clearly show the existence of a combustion regime such that reactions are extended over a large portion of the reactor with absence of flame front, that is a mild combustion regime.

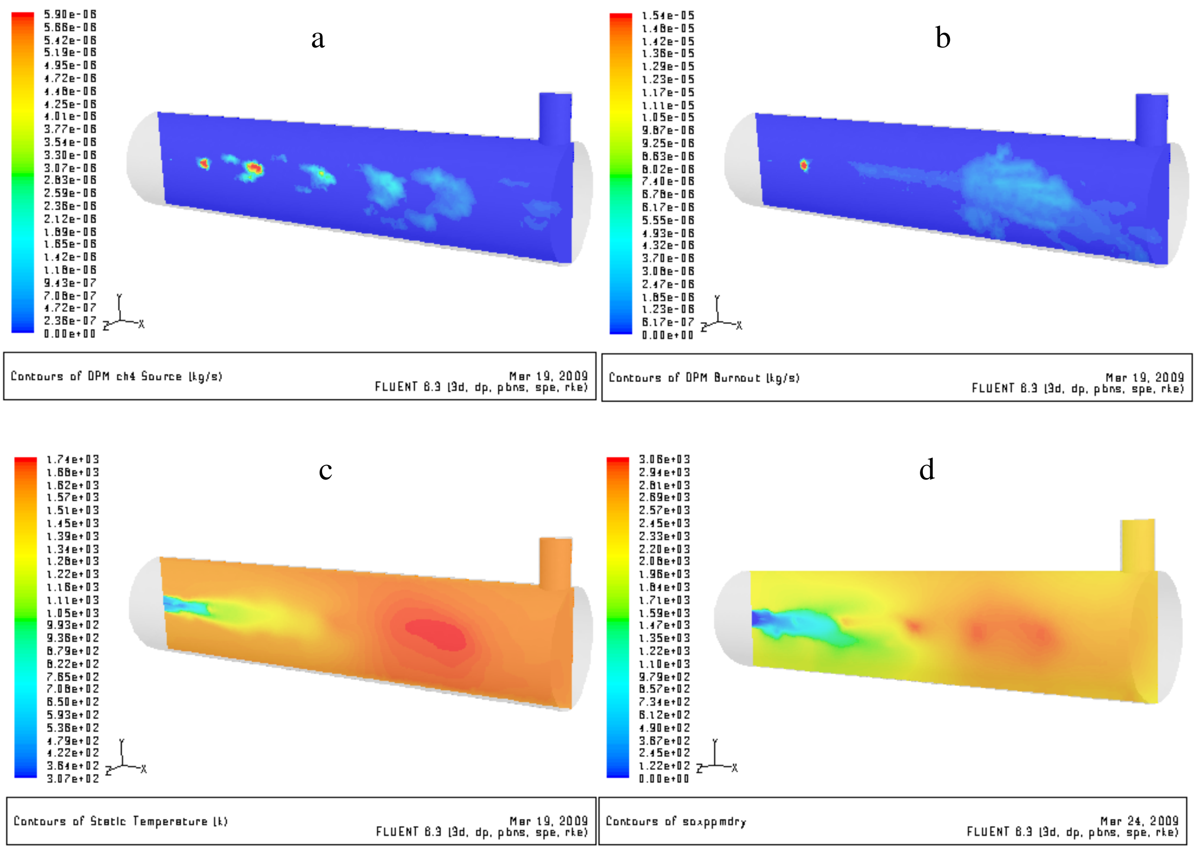

Figure 1*. a) Volatiles release rate; b) Coal surface combustion rate; c) Temperatures; d) SO_x concentration.*

Keywords: Oxy-combustion, coal combustion, numerical simulation.

Proposed Topic: Oxy-combustion