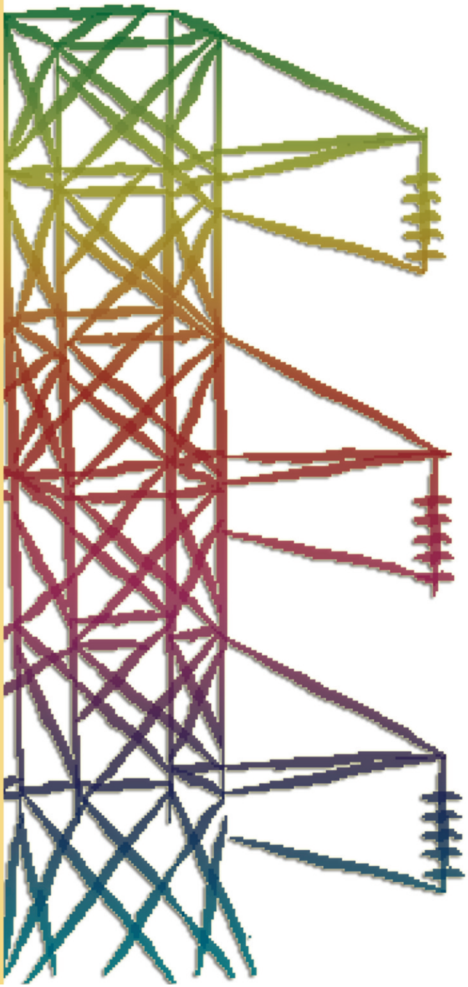
Ente per le Nuove tecnologie,
l'Energia e l'Ambiente

Ministero dello Sviluppo Economico

RICERCA SISTEMA ELETTRICO

Flameless Technology for Particulate Emissions Suppression

M. Malavasi, C. Allouis, A. D'Anna



Report RSE/2009/108

Ente per le Nuove tecnologie,
l'Energia e l'Ambiente

Ministero dello Sviluppo Economico

RICERCA SISTEMA ELETTRICO

Flameless Technology for Particulate Emissions Suppression

M. Malavasi, C. Allouis, A. D'Anna

Report RSE/2009/108

FLAMELESS TECHNOLOGY FOR PARTICULATE EMISSIONS SUPPRESSION

M. Malavasi (ITEA S.p.A. – Gioia Del Colle)

C. Allouis (Istituto di Ricerche sulla Combustione del C.N.R. – Napoli)

A. D'Anna (Dipartimento di Ingegneria Chimica dell'Università di Napoli Federico II)

Aprile 2009

Report Ricerca Sistema Elettrico
Accordo di Programma Ministero dello Sviluppo Economico - ENEA
Area: Produzione e fonti energetiche
Tema: Tecnologie innovative per migliorare i rendimenti di conversione delle centrali a polverino di carbone - Sviluppo di un sistema di combustione di tipo "flameless" per impianti di produzione di elettricità con ridottissimi livelli di emissione di inquinanti e CO_2
Responsabile Tema: Stefano Giammartini, ENEA

Flameless Technology for Particulate Emissions Suppression

M. Malavasi[1], C. Allouis[2], A. D'Anna[3]

1. ITEA S.p.a.,Gioia del Colle - ITALY
2. Istituto di Ricerche sulla Combustione - C.N.R., Napoli - ITALY
3. Dipartimento di Ingegneria Chimica - Università Federico II, Napoli - ITALY

1. Introduction

Proper technologies for energy production must be developed to avoid CO_2 concentration increase in the atmosphere, while reducing emission. Flameless oxy-combustion technology provides frontier emission performances, with the most advanced Rankine+Joule Bryton high yield thermodynamic cycle. The process ISOTHERM PWR® is an innovative high temperature, pressurized oxy-combustion process recently developed. A 5 MWth demonstration unit, settled at Gioia del Colle (BA) scores more than 5000 hr of tests on different fuels, i.e. solid, non vaporizable liquid, vaporizable liquid, gas, and wastes. The specific objective of this paper is to investigate Isotherm airborn emissions fueled by different fuels. The attention has been focused on the size distribution function of the particles formed during the combustion process and emitted when burning different fuels (heavy oils, wastes and coal).

2. Experimental

Experiments have been performed on the 5 MWth pilot plant at Gioia del Colle. Baseline studies were performed using diesel and heavy (BTZ) oils. The emissions study has been conducted in terms of particulate size distributions using a 8 stages inertial *Andersen* impactor, Different particle-size measuring techniques including atomic force microscopy, spectroscopic characterization of the material collected in water samples and SEM analysis of material deposited on filters.
The results have been compared to those obtained in a 6 MWth pilot boiler plant of Ansaldo. Moreover, measurements of PM_{10} and $PM_{2.5}$ have been also performed by using different fuels and wastes. Sketch of the Isotherm process is presented in figure 1. The sampling system has been located at the stack and after the Quencher (Fig.1).

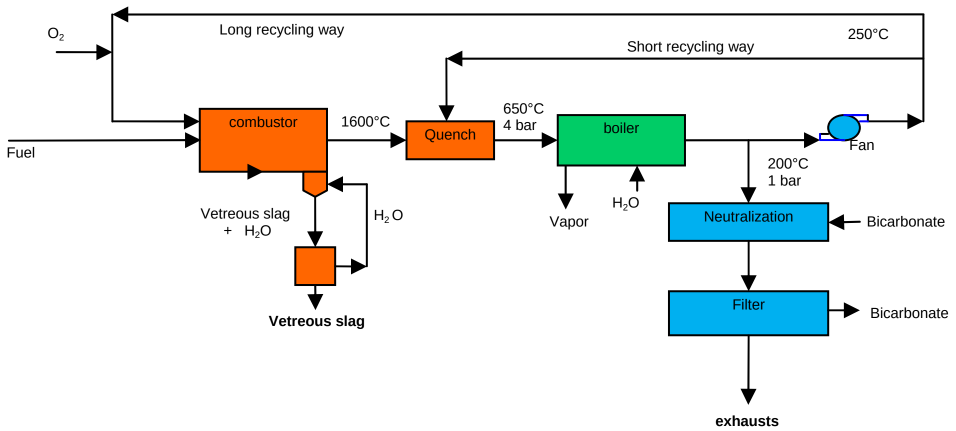


Figure 1: sketch of the Isotherm process.

3. Results and discussion

The base line study has been performed at normal operative condition of Isotherm. The results are compared with those obtained at the stack of a 6 MWth power plant of Ansaldo [1]. Size distribution function are reported in figure 2. It is possible to observe that the size distribution plots are different for Isotherm compared with those of a traditional power plant. In traditional plant the distribution function is bimodal, while Isotherm process produces “flat” particles distribution down to 3 μm. For smaller particle sizes, SEM investigations has allowed to identify different particle types for both systems. Isotherm process forms small particles and condensed matter, while material sampled in the case of traditional plant is made of carbonaceous particles like cenosphere and plerosphere [1]. This indicates that during isotherm process carbon is completely depleted.

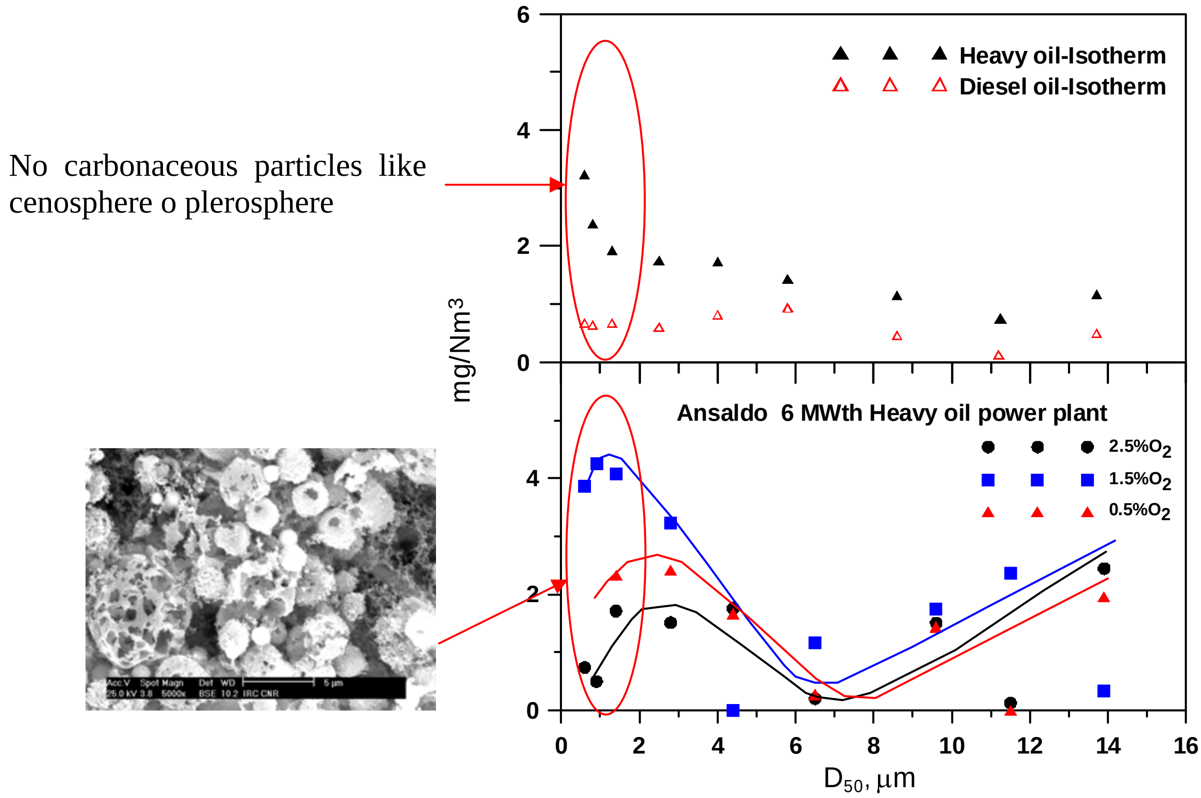


Figure 2: Particulate size distribution for Isotherm and traditional power plant.

Previous measurements evidenced different particle production behaviour. Flameless oxy-combustion produced lower particle sizes and lower emissions in terms of particle concentrations [2]. To confirm this trend further measurements have been performed after the quencher of the Isotherm process by using different fuels: diesel oil, heavy oil, coal slurry and industrial wastes. The results are presented in figure 3. The distribution functions have been divided in different classes, PM_{10}, $PM_{0.4\text{-}10}$ and $PM_{0.4}$. All the results presented here for the Isotherm process are on dry gas basis. It has to be considered that water content in the exhausts is about 55-60%vol, oxygen residue concentration is about 5 %. If emission concentration would be expressed referring to air equivalent, namely in mass flux, the presented concentration should be divided by a factor of 10. Since this topic is delicate and due to the lack of clarity of the Italian Law about emissions, concentration based on air equivalent results will not be presented here.

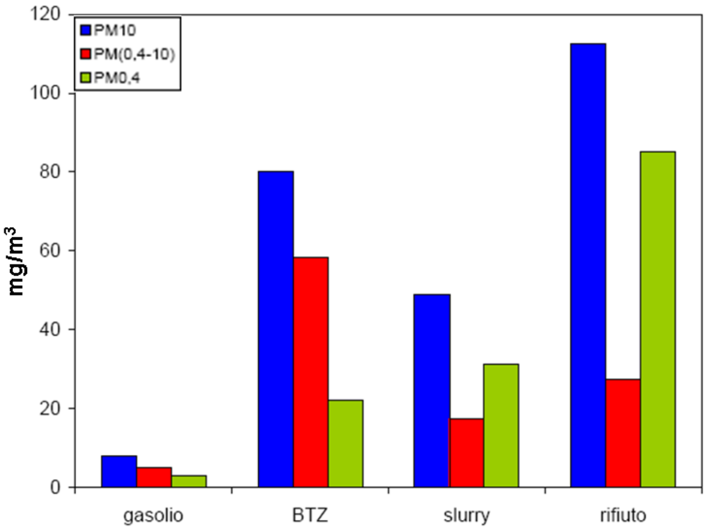


Figure 3: Particulate distributions after the quencher.

From Fig.3 it appears that in the case of heavy oil (BTZ) the main part of emitted particles have sizes ranging between 10 and 0.4 μm, while for the case of coal slurry and wastes (rifiuto) the particle sizes are smaller than 0.4 μm.

Further analysis were performed using Atomic Force Microscopy to characterize nano-sized particles. Results are resumed in Figs. 4-5, where two typical particle size distribution functions are reported.

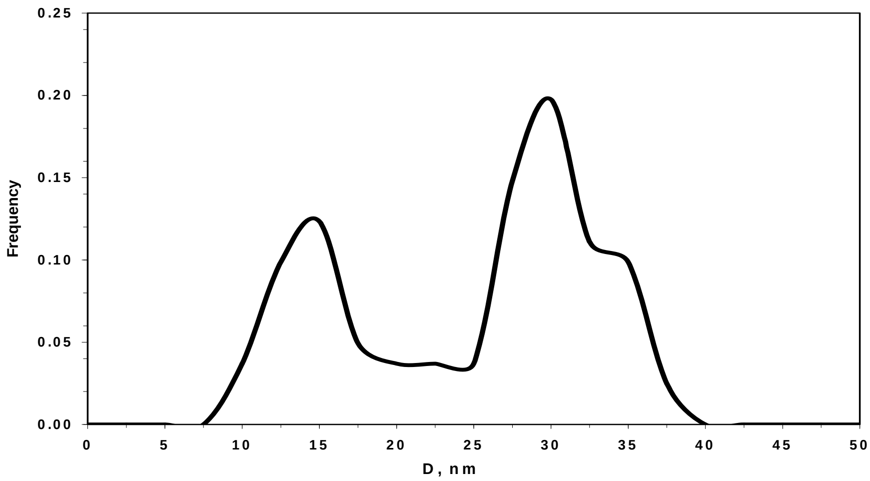


Figure 4: AFM distribution function of sampled material during coal combustion after the quencher.

Size Distribution function of figure 4 has been obtained considering disaggregated particles. In the case of fossil liquid fuels the AFM distribution functions are similar to the one presented in figure 5, roughly mono modal. This tendency was considered as a fingerprint of the process. It is worthwhile to note that coal combustion extended particle sizes up to 40 nm introducing bimodal distribution function.

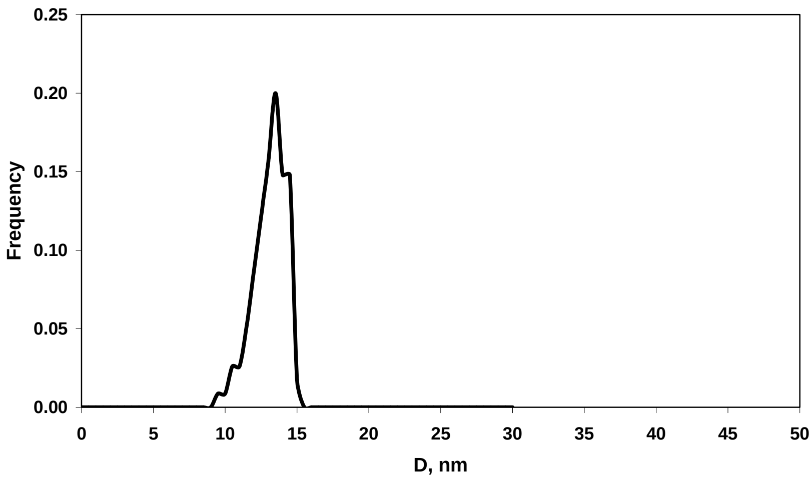


Figure 5: AFM distribution function of sampled material during coal combustion after the boiler.

4. Conclusion

Emissions study have been performed on the 5 MWth pilot plant at Gioia del Colle. Baseline studies have been performed using diesel oil and heavy oil (BTZ). Attention has been focused on the size distribution function of the particles formed during the combustion process and emitted when burning different fuels (heavy oils, wastes and coal). It has been observed that:

- Fossil fuel presented similar distribution function in the "nanosize" range (3-100 nm),
- No presence of plerosphere-like particles for all the fuels,
- Coal combustion presented bimodal distribution function in the range 3-50 nm,
- Isotherm process allows to reduce particle concentration respect to traditional combustion systems

Acknowledgments

The authors gratefully acknowledge the contribution provided by dr Alberto Barone for the AFM measurements.

References

1. C. Allouis, A. L'Insalata, L. Fortunato, A. Saponaro, F. Beretta. *Experimental Thermal and Fluid Science*, 31:420-426, 2007.
2. A. D'Alessio, Report contratto di ricerca – ENEA-Dipartimento di Ingegneria Chimica, 2007