STSM Scientific Report

1. Purpose of the STSM

The main purpose of the previous STSM was to analyze policyclic aromatic hydrocarbons (PAH) in the flue gas of a domestic fired-pellet boiler and a drop tube furnace (DTF) fed with various biomass fuels. The analysis and quantification of the PAH have been performed in the Aragón Institute for Engineering (Zaragoza, Spain) and Instituto Superior Técnico (Lisbon, Portugal), it combines Soxhlet extraction and gas chromatograph-mass spectrometer (GC-MS).

The analyses were delayed with respect to the experiments and they required tuning until the relative concentrations were found. The first analysis results obtained showed the necessity to improve the sampling system, adding a second quartz tube with XAD-2 resin in order to collect all the PAH in the case of the DTF. In addition, some more types of biomass were used during this period in order to extend the conclusions, such as: platano, kiwi, olive and some repetitions with the previous ones (wheat straw, rice husk, furniture residues, pine and cork).

2. Description of the work carried out during the STSM

2.1 Introduction

Biomass is becoming more relevant as an energy carrier due to its high diversity and availability. In the last years, most of the efforts have been put into woody biomass as fuel; however, due to economic and environmental constrains only a part of the available forest biomass can be used. In this context, in addition to forest biomass, it is critical to use also agricultural residues for energy purposes. The extreme variability of the biomass feedstock demands for an extensive investigation on the impact of its composition in their combustion behavior, especially in their gaseous products. Combustion of biomass is associated with emission of particulate matter (PM) and soot, which have adverse health effects and have received attention in previous works [1,2]. Specifically, soot is strongly related with policyclic aromatic hydrocarbons (PAH) and these ones are considered their precursors [3]. Some of these substances have been classified by The USA Environmental Protection Agency (EPA), that completed a list with 16 priority compounds, as of greatest concern with regard to potential exposure and adverse health effects on humans. This list is often considered as a reference in environmental sample evaluation.

The use of modern pellet stoves is increasing as well as the pellet consumption, usually wood pellets, which are known to produce more PAH than any other fuel [4]. Previous works focused on this topic but evaluating PAH from biomass fuels other than wood is rare. This is the main purpose of this work. Moreover, since the conditions of combustion (combustion type, moisture content, fuel burning amount, fuel qualitiy) play a significant role in the emissions of biomass [5], the use of a drop tube furnace under well controlled conditions could help to elucidate some light about this problem. To our knowledge, there are no previous studies related to the analysis of PAH from the combustion of biomass in a drop tube furnace.

2.2 Experimental investigation of the gaseous products formed during the combustion of different types of biomass

The tests have been performed in a domestic wood fired-pellet boiler shown in Figure 1, which is described in detail elsewhere [1], with the addition in this case of the PAH sampling system. Flue gas concentrations of O_2, CO_2, hydrocarbons (HC) and NO_x were measured to gather information regarding the combustion conditions.

Figure 1. Picture of the pellet-fired boiler

The experiments carried out in this STSM extension have been made with a new type of biomass pellet (kiwi), doing biomass pellets with a pelletizer available at Instituto Superior Técnico. The experiments with kiwi, pine and cork pellets were repeated in order to check the reproducibility of the method. The tests were made at three different feeding ratios (10,14 and 17 kW).

The combustion in the drop tube furnace (DTF), which is shown in Figure 2 and described deeply in [6], was carried out with the following new biomass fuels: kiwi, platano, olive and some repetitions with the previous ones (wheat straw, rice husk and furniture residues).

Due to the first results of PAH collected in the drop tube furnance for wheat straw, a change was made in the PAH collection system when sampling at 900 ºC, where wheat straw showed that probably not all the PAH were being retained. It was added a second quartz tube after the first one with more XAD-2 resin, in order to collect all the PAH. Basically, the PAH collection system, which is shown in Figure 3, consisted of a quartz microfiber filter connected to the outlet gas stream, and just after it is placed XAD-2 resin packaged in a thin quartz tube (300 mm length, 8 mm internal diameter). This tube was divided in two parts by quartz wool, the first one (3 g of resin) with the purpose of retaining PAH in the gas-phase and the other one (2 g of resin) in order to check that all the PAH where retained in the first part.

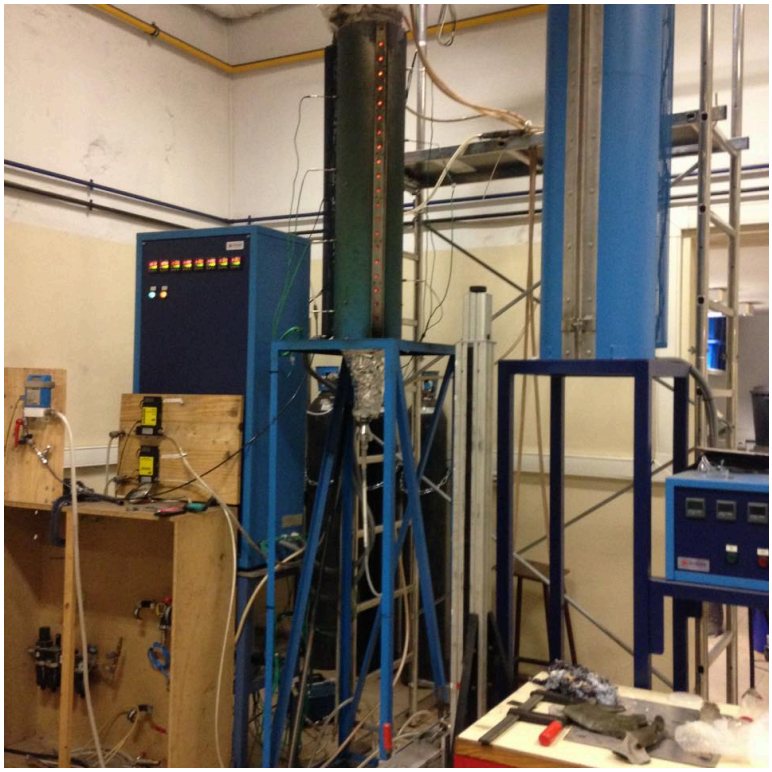

Figure 2. Picture of the drop tube furnance

Measurements were carried out at the same conditions as in the previous STSM, for all biomass fuels for DTF wall temperatures of 900 ºC, 1000 ºC and 1100 ºC. The solid fuels feed rate was set to 23 g/h, the total air flow rate was set to 4 L/min, ensuring a second residence time in the DTF. The PAH collection started after the DTF reached steady-state conditions, with each measurement lasting for about 15 minutes.

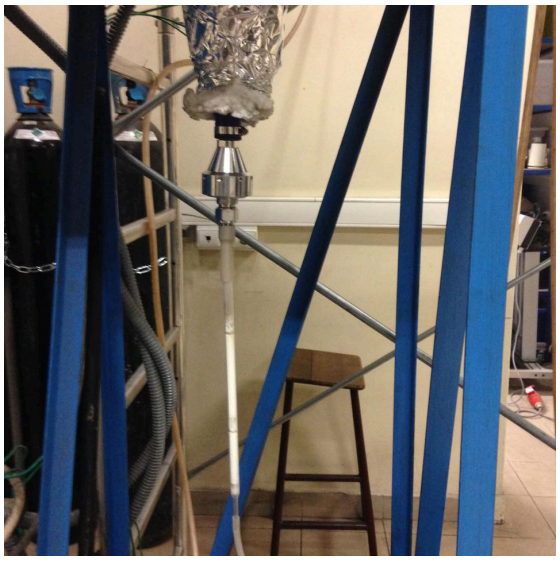

Figure 3. Picture of the collection system: the particle filter and the quartz tube

3. Description of the main results obtained

In the case of the boiler, the results have shown a major concentration of PAH as the feeding ratio was increased for both types of biomass (cork and pine) and a lower concentration of PAH with the commercial pellet (pine), as shown in Figures 4 and 5.

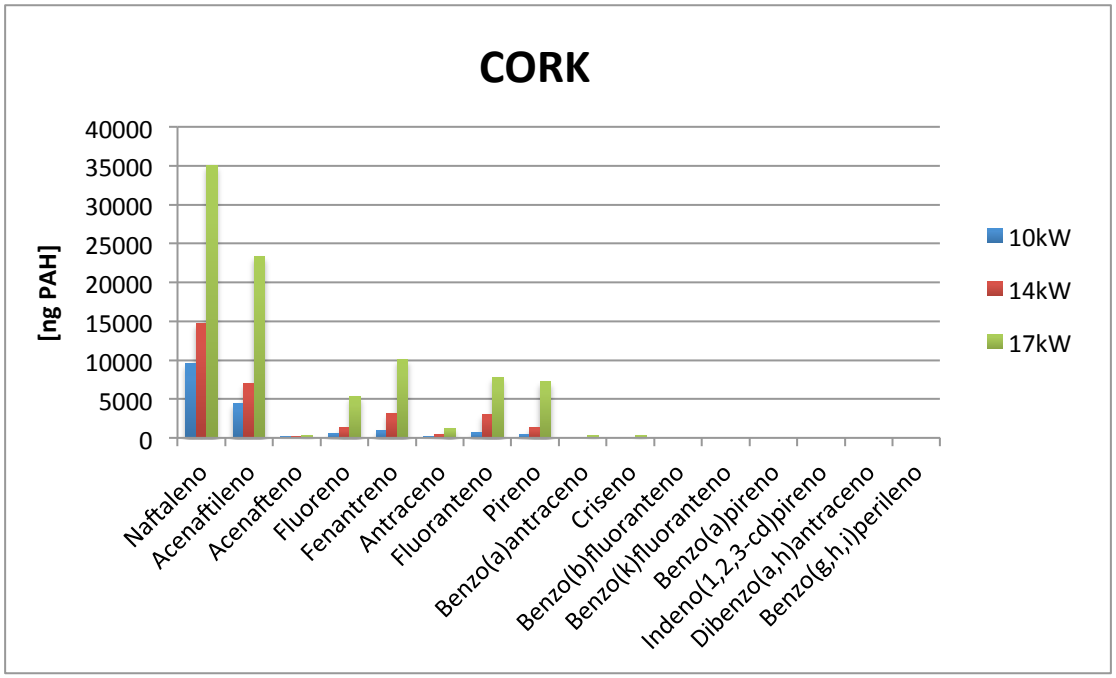

Figure 4. PAH emissions in the pellet-fired boiler feeded with cork, results for 3 different feeding ratios

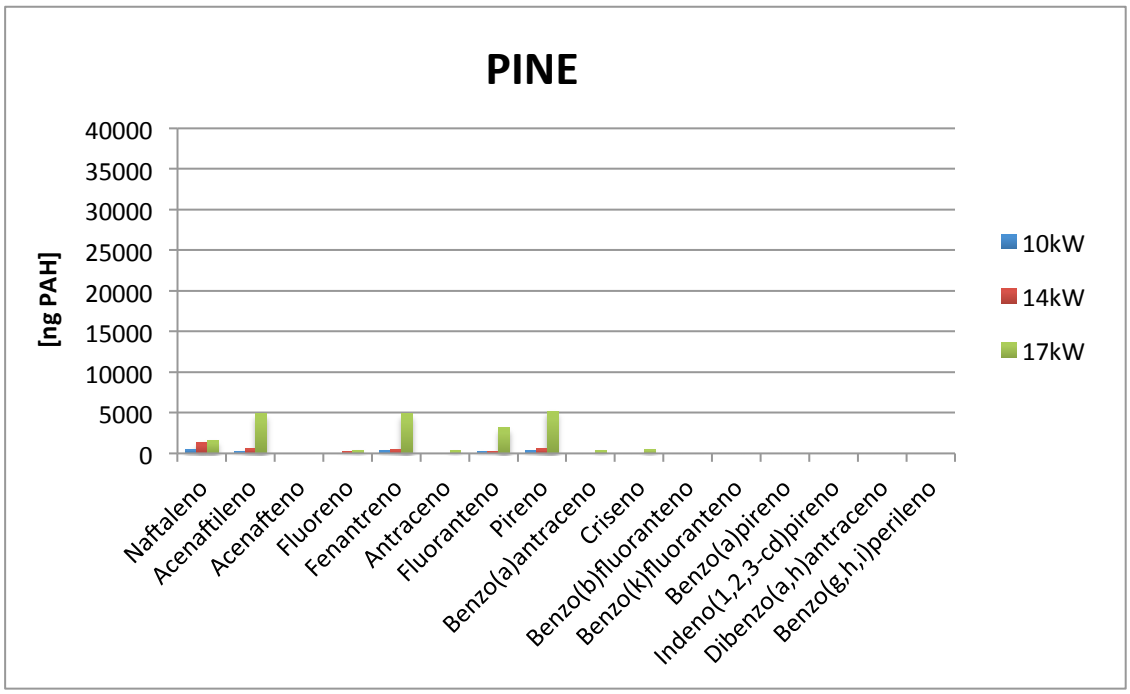

Figure 5. PAH emissions in the pellet-fired boiler feeded with pine, results for 3 different feeding ratio

In the case of the drop tube furnance there are results for two different types of biomass, total PAHs show different trends with the temperature between biomasses (Figure 6) and it is needed more results in order to be compared. Analysis are still in process with 6 types of biomass remaining and some repetitions.

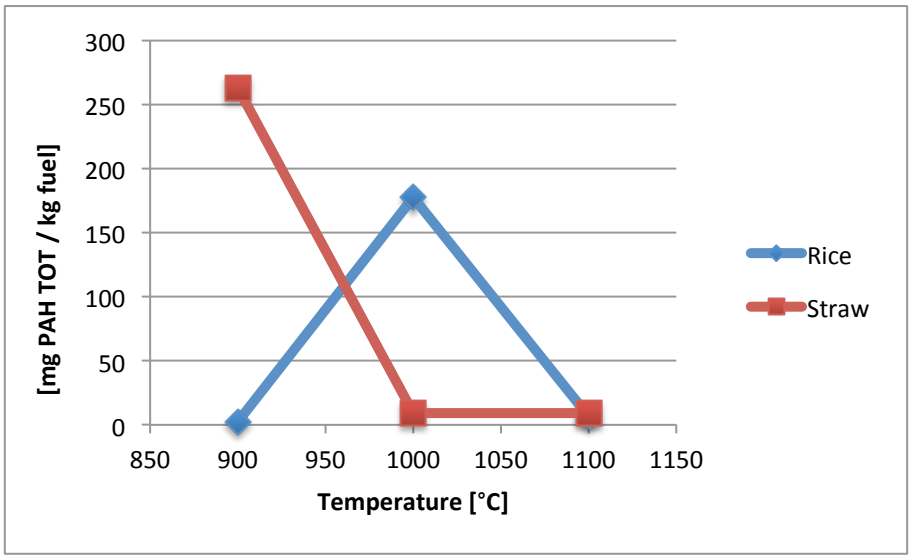

Figure 6: total PAH emissions in the drop tube furnance feeded with rice husk and wheat straw, the results are for 3 different temperatures

4. Future collaboration with host institution

Taking into account the fruitful cooperation established between the two research institutions, the Aragón Institute of Engineering Research and Instituto Superior Técnico will continue to collaborate in the area of the formation and emission of PAH from biomass combustion.

5. Foreseen publications/articles resulting or to result from the STSM

Authors are preparing two manuscripts for submission to international scientific journals, one reporting the experiments undertaken in the domestic pellet-fired boiler and other reporting the experiments in the DTF as follows:

1. Colom, J. M., Fernandes, U., Alzueta, M. A. and Costa, M. (2016). Characterization of polycyclic aromatic hydrocarbons in the flue gas and particulate matter of a domestic biomass-fired boiler. In preparation.

2. Colom, J. M., Fernandes, U., Alzueta, M. A. and Costa, M. (2016). Emissions of polycyclic aromatic hydrocarbons during biomass combustion in a drop tube furnace. In preparation.

In addition, a summary of the results will be presented at the 2nd General Meeting of the COST Action CM1404 that will take place in Lisboa from 14 to 16 of November 2016.

6. Acknowledgements

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7. References

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[2] Fitzpatrick, E.M. et al. “Emission of Oxygenated Species from the Combustion of Pine Wood and Its Relation to Soot Formation.” Process Safety and Environmental Protection 85.5 (2007): 430–440.

[3] Richter, H, and JB Howard. “Formation of Polycyclic Aromatic Hydrocarbons and Their Growth to Soot - a Review of Chemical Reaction Pathways.” Progress in Energy and Combustion Science 26.4-6 (2000): 565–608.

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[6] Wang, Gongliang, Rene Zander, and Mario Costa. “Oxy-Fuel Combustion Characteristics of Pulverized-Coal in a Drop Tube Furnace.” Fuel 115 (2014): 452–460.