COST Action: CM1404

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STSM type: Regular (from Italy to Switzerland)

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STSM Title: Organization meeting for the activity on the production of biofuels through torrefaction and pyrolysis

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Background/ Purpose of the STSM

The mission will be focused on the planning of the future experimental activity on biomass torrefaction and pyrolysis. The work relates to a research program aimed at studying the torrefaction/pyrolysis as eco-sustainable process for the combined production of a solid residue (classifiable as a bio-char) and gaseous-liquid fractions, embedded in the gas carrier flow, to be directly burned in a MILD combustion burner (hence in highly diluted and pre-heated conditions) for energy recovery.

The activity is first motivated by the need of a more fundamental understanding of the process and products dependence on the operating conditions and on the original composition of the feedstock. On the other hand the study wants to address the need of optimize the whole process (biomass thermal treatment and combustion of the products) with respect to energy balance sustainability and environmental impact. In order to define the optimal conditions in which a pilot scale reactor (available at the hosting institute) should be operated with respect to both the energy sustainability and the desired products yield and characteristics, it is necessary to build a database that allows to correlate the characteristics of the process products to the real thermal conditions experienced by the feedstock and to its chemical composition. To this aim an experimental campaign is needed on a lab scale reactor (available at the institute of the visiting researcher) in which it is possible to effectively control the thermal conditions of the processed biomass as well as investigate the torrefaction/pyrolysis of the single biomass components and how their behavior is affected by the presence of metals.

The last aspect is of particular interest when the biomass to be processed comes from marginal lands contaminated by illegal dumping of urban waste and wrong management of industrial waste. In this case biomass could be potentially contaminated by heavy metals and a proper tuning of the torrefaction/pyrolysis conditions is needed in order to:

- concentrate heavy metals in the char, thus reducing the volume and weight of contaminated matter;
- produce a gaseous/liquid product containing no or limited amounts of heavy metals that can be used for direct energy production or as source for fuel production.

Trough STSM, the visit of the pilot scale torrefactor/pyrolyzer available at the hosting institute will be performed with the aim define a detailed plan of the future experimental activity on the lab scale reactor available at Istituto di Ricerche sulla Combustione in Naples.

Description of the work carried out during the STSM

The first 2 days of the STSM were dedicated to the visit of the laboratory at the host institution. In particular the attention was focused on two lab scale reactors devoted to the torrefaction/pyrolysis tests and to a pilot scale torrefactor. The first reactor consists in a macro thermogarvimetric balance in which it is possible to carry out TG analyses in the desired atmosphere by using as set point alternatively the sample temperature or the sample weight loss. The second reactor is a torrefactor/pyrolyser in which the biomass, fed in form of powder or pellet, is processed at the desired temperature and heating rate under a self-generated atmosphere. The second reactor can be equipped with a condensation unit for the collection of the liquid evolving from the process, whereas the uncondensable gases can be sampled for subsequent analysis. The laboratory is equipped with analytical instruments for the characterization of the biomass and of the pyrolysis products, namely char, gas and liquid, such as CHNSO analyser, ICP/MS, IR spectrometer, gaschromatograph coupled with mass spectrometer.

The pilot scale torrefactor consists in two consecutive screw reactors where biomass is dried and then torrefied in a self generated atmosphere thanks to the heat recovered from the flue gas exiting from a FLOX combustor fed with the gases and vapours evolving from the torrefaction unit.

In the two next days a discussion with the prof. J-B Michel and his co-worker M. McCormick followed aiming at planning the experimental campaign that will be carried out at HEIG-VD by a PhD student coming from the Institute of the visiting researcher (IRC – CNR).

Description of the main results obtained

On the basis of the information acquired during the visit to the experimental systems and the following discussion, the activity that will be conducted by the PhD student has been planned.

Three sets of experimental tests have ben planned and it has been decided to use as a feedstock a biomass grown on a soil contaminated with cadmium, lead, copper and zinc in order to explore the possibility to obtain both a liquid fuel and a solid biomaterial from waste biomasses:

- The aim of the first set is to understand how the heating rate and the pyrolysis atmosphere affects products yield, char porosity and heavy metals behaviour. At IRC we have already tested contaminated poplar using steam as pyrolysing agent at 5°C/min up to different final temperatures ranging from 380 to 600 °C. At HEIG-VD laboratory the PhD student will investigate in the macro TG reactor the same biomass pyrolysed at 5°C/min in the same temperature range under nitrogen atmosphere. Than the same tests will be replicated setting a different heating rate similar to the one established in the small scale torrefactor with the aim of comparing the effect of the different heating rate and pyrolysis atmosphere.

- In the second set of experiments contaminated poplar will be used as feedstock in in the lab scale torrefactor with the aim to follow the evolution of the porosity of the solid residue from pyrolysis, the distribution of the contaminants in the solid and in the liquid phase and the composition of the liquid phase in the temperature range 380 to 600 °C. At the end of this study two temperatures will be identified: th first one is the maximum temperature at which the contaminants are still retained in the char residue, the second one is the optimal temperature needed for obtaining a char with good porosity characteristics. Than a two steps pyrolysis process will be conducted consisting in a first step at low final temperature aimed at recovering a clean condensable product useful as source of fuel and a second step aimed to the production of a char residue with high porosity.

The characterization of chars obtained from the experiments will be performed in part in HEIG-VD laboratory, heavy metals analysis and scanning electron microscopy (if necessary), in part in Naples, porosimetric analysis. Condensable products from the first pyrolysis step

can be analysed in HEIG-VD laboratory by GC/FID. We already have the proper chromatographic column for this kind of analyses and the proper analytic method.

Contribution of STSM to the Action's aim

The content of the visit directly addresses the CM1404 action aims. The planned activity is very important for the definition of the optimal operating conditions of real integrated plant for the production and combustion of bio-based energy carriers. The data produced by the lab scale pyrolyzer will be of great interest for the definition of model mixtures representing real pyrolysis bio-fuel to be used for the development of extend experimental databases over unconventional conditions typical of innovative combustion processes such as MILD combustion.

Future collaboration with host institution

The collaboration between the IRC-CNR in Naples and the group of prof. Michel at HEIG-VD will go on with the activity that will be conducted by the PhD student from IRC-CNR at HEIG-VD on biomass pyrolysis. Other possibilities of future collaboration have been explored. In particular, a possible collaboration has been identified in the framework of a previous experience of both the work groups at HEIG-VD and IRC-CNR on the use of char from biomass thermochemical treatments in the anaerobic digestion of organic wastes with the aim of enhancing the production of biogas. In this case it would be possible to organize students exchange (master degree students).

Confirmation of the Host Institution of the successful execution of the STSM

See attached letter