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Combustion, gasification and high temperature fuel cell test facilities

The Energy Technology (ET) Chair of the Process & Energy department of the Technical University of Delft (TUD) employs research activities in the following areas:

- Gaseous fuels advanced combustion;
- Fluidized bed gasification of biomass and high temperature gas cleaning using ceramic hot gas filters and upgrading of the gas to hydrogen-rich gas;
- Fuel characterization studies;
- Novel biorefinery concept studies;
- Thermodynamic system evaluations (own code: Cycle-Tempo);
- SOFC studies based on biomass-derived gases.

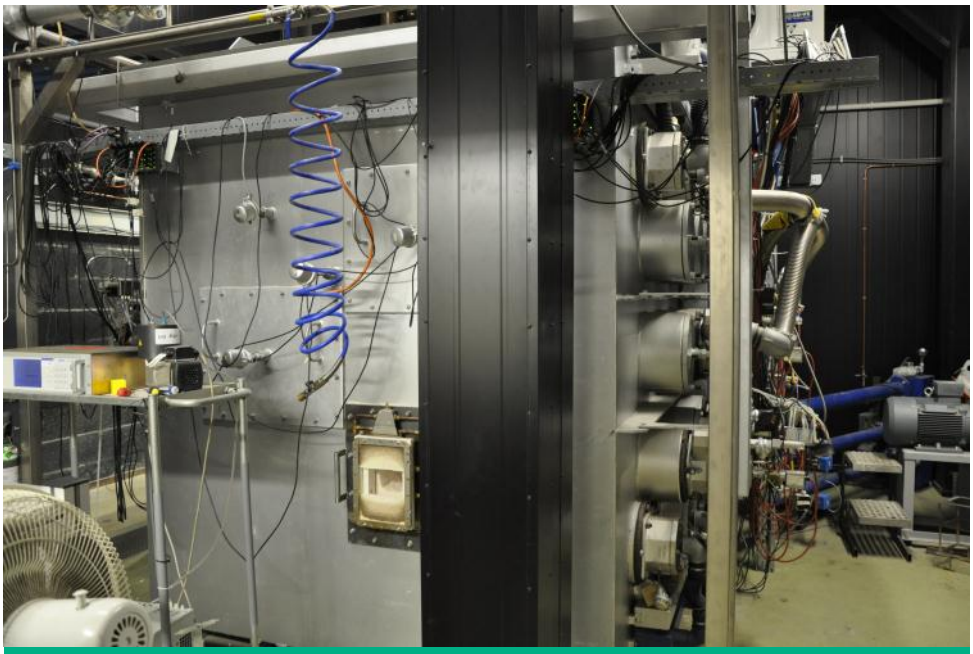

Figure 1: The multi-burner flameless oxidation test furnace.

The ET Chair contributes to the BRISK project via joint research concerning further development of fuel characterization techniques, as well as measurement techniques for gasifiers. Transnational Access is offered on the pilot research units detailed below:

1. Gaseous Multi-fuel Flameless Oxidation Furnace (FLEXFLOX)

This multi-burner flameless oxidation furnace is equipped with up to three pairs of regenerative FLOX^{TM} burners, each with a thermal power of 100 kWth. The REGEMAT CD 200 B type burners were manufactured by WS Wärmeprozesstechnik GmbH. Each burner has four combustion air nozzles, positioned around a central fuel nozzle. The furnace has inner dimensions of 1500mm (length) x 1500mm (width) x 1850mm (height) and is optically accessible.

Insulation consists of three layers of ceramic bricks, 300mm deep in total. During the experiments the furnace temperature is measured at various locations with S-type thermocouples. Also, the temperature of the preheated air is measured in one burner pair. Fuel and combustion air flow rates are measured by orifice plate differential pressure meters. The combustion air flow rate is controlled by a manual valve, allowing variation of the excess air ratio.

During regeneration the flue gas passes through ceramic honeycomb heat exchangers inside the burners. The inlet temperature is ~950°C and the outlet temperature is ~150°C, under steady state conditions. The thermal load is simulated by a cooling system consisting of eight single ended concentric tubes, four placed at the bottom of the furnace and four at the top. Air enters the inner tube, turns at the end and flows back through the outer tube.

This design was made to minimize the temperature gradients along the length of the outer tube, thus creating as uniform heat extraction distribution as possible. The furnace is equipped with standard on-line analysers (CO, NO, CO_2, O_2). Along with the measurements

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Figure 2: Circulating Fluidized Bed (CFB) gasifier with integrated hot gas filters.

modelling, activities are on-going using Fluent™ and Numeca software (CFD).

2. Biomass Gasification & Gas Cleanup Unit (BiG-CU)
This integrated test rig for biomass gasification is unique in Europe due to the integration with crucial process components for syngas cleaning. The facility consists of a 100 kWth Circulating Fluidized Bed (CFB) gasifier that is steam/oxygen/air blown, two ceramic filter units (one operating on approximately 450°C – BWF type, the other at substantially higher temperatures to 850°C – Pall type), and in the slipstream a catalytic reformer and a catalytic water gas shift unit.

Thus the whole chain from biomass to hydrogen-rich syngas can be demonstrated. Fuels used so far include: wood (clean and demolition), agricultural residues (straw, Dried Distillers Grains with Solubles (DDGS)), dedicated energy crop species (*Miscanthus*).

The unit is fully instrumented with:

- Advanced PLC control;
- Temperature measurements via arrays of thermocouples;
- Pressure and pressure drop sensors;
- An extensive set of analysis instrumentation, like a high resolution Fourier Transform InfraRed spectrophotometer for quantitative gas analysis;
- Micro-GCs;
- GC for tar and sulphur traces;
- On-line analysers (NDIR, paramagnetic and UV);
- Solids particle size distribution (cascade impactor and microtrac).

Moreover, the section has a Scanning Electron Microscopy (SEM) for particle morphology study. There is a closely integrated laboratory for specific wet chemical analyses e.g. ICP-OES (trace metals), ion-chromatography, HPLC-UV-RFI.

Connected to the gasifier is a small, high temperature catalytic filter. This research unit allows the study of the combination of fly ash capture and catalytic conversion of (model) tars (polyaromatic hydrocarbons) and other gaseous components. It is equipped with a set of mass flow controllers for precise metering of synthetic syngas with addition of model tar components via a saturator. Water is added via an HPLC pump. The gases pass through a preheater to a temperature between 500 and 900°C. The dust cake can also be regenerated.

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Did you know?

Grants for travel and subsistence are available through BRISK for researchers to visit TUD.

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3. Fuel Cell Lab (solid oxide fuel cell test facilities)
The solid oxide fuel cell (SOFC) stack test station is used to test stacks up to 1 kW. Studies concerning stack performance, fuel flexibility and degradation can be done with various fuel mixtures. The cell test station is used to test single cells in order to understand various phenomena like performance, kinetics and influence of parameters like gas composition, temperature of the performance of a particular kind of cell. Current-voltage (I-V) measurements can be made on either of the above two setups and in addition to this, impedance measurements can be performed on the single cell test setup.

Figure 3: SOFC lab facility (stack research).

The impedance test station is used to test either the cathode or the anode of a particular type and impedance analysis can be used to gain mechanistic details, kinetics, diffusion etc. The gas cleaning unit uses gasified biomass of 2 l/min with a lowest gas cleaning temperature of 600^{o}C for 50W SOFCs. A parallel gas flow stream for testing independent sorbents separately in another reactor e.g. tar catalytic reforming, is also possible with the setup.

TUD has another 40 l/min gas cleaning unit with the lowest gas cleaning temperature of 350^{o}C for testing SOFC stacks of 1 kW power level using gasified biomass. In addition, computational facilities include Computational Fluid Dynamics analysis and power plant and thermodynamic analysis using Cycle-Tempo (in house thermodynamic evaluation software).

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