Research Infrastructure in Biorefinery Environment Park - POLITO

The steam explosion process is based on the use of saturated or slightly supersaturated steam at pressure rising up to 32 with the related equilibrium temperature of 137°C. The biomass to be treated gets in contact with vapor for the process defined timing (resulting from the selected severity of the process). After this time, the material is immediately expanded into an atmospheric pressure vessel. The sudden reduction of pressure causes a violent vapor expansion, resulting in the breaking up of the chemical linkages in the treated material. The steam explosion reactor consists of two vessels, one for the pressurization of the biomass (R101) and the other for the following expansion (V101) of the biomass at atmospheric pressure (vessel directly connected to the atmosphere with a funnel). The amount of vapor injected during the process consists of the first volume injected in order to reach the settled pressure inside the reactor volume. In the next phase the pressure is automatically maintained by the software inside the reactor during the process, resulting, stating the not perfect adiabatic condition, in an exchange of temperature with the external ambient and in vapor condensation. Then, by opening the reactor bottom valve, the material expands into the V101 vessel. Expansion occurs under nearly iso-enthalpic conditions, within less than 1 sec. When the collecting vessel is completely de-pressurized, and the internal temperature drops down to safety condition for operators, the control system unlocks the butterfly valve for material recovery.

The chemical hydrolysis process is based on the contact of the biomass with a specific acid or basic solution, at a certain temperature and pressure, allowing to lead to biomass hydrolysation and simple molecules liberation. The chemical hydrolysis reactor has a total volume of 115 litres and can work at the maximum temperature of about 150°C, with 5 bar maximum pressure and it is equipped with a thermostating system suitable for rapid heating and automatic maintenance of the set temperature. Chemical hydrolysis reactor has dosimetric pumps that allow a fine regulation of the operating pH thank to the addition of an acid or basic solution.

The enzymatic hydrolysis reactor is a vertically cylindrical vessel (total volume of 115 l) insulated and equipped with a thermoregulation system that ensures a very precise control of the internal temperature of the reactor. The internal temperature and pH of the reactor can be controlled by a PLC control system. Since enzymatic or biological reactions are usually carried out at moderate temperatures, the thermoregulation system, rather than favoring the heating rate, ensures temperature control. The plant is equipped with an external recirculation closed circuit with a centrifugal pump and two plates heat exchangers, one cooling (water-glycol) and one heating (steam-glycol). The jacket flowing fluid is a water solution-ethylene glycol at 50%. There is a temperature control over the recirculating fluid, in which the split-range system opens the steam valve to the heater or opens the water valve to the coolant. At set temperature, both valves are closed. in respect to the maximum admissible pressure of 1,7 bar, the reactor can operate also under nitrogen or CO_2 environment. The available facility includes also a batch vessel reactor to carry out chemical hydrolysis.

A pilot plant for **hydrogen production** from renewable sources via dark anaerobic fermentation technology has been additionally developed within the lab. It consists of 3 stirred digesters of 5, 35 and 250 litres, suitable to produce both bio-hydrogen and biogas. All the reactors can operate in batch (STR) and in continuous (CSTR) and they are equipped with a pH, temperature, redox potential, biomass flow rate monitoring system to control the key parameters of the process along the fermentation. During fermentation the gas produced is released through a relief valve which opens at a fixed pressure and is connected to a gas collection system. Produced gas composition is continuously evaluated through a micro gas-chromatograph and the produced volume is

measured through an on-line gas counter to control both the quality and the quantity of gas stream. Different typology of biomass can be tested in both plants. An automatic control and alarm system permit a flexible and safe management of the plant.

Steam Explosion pilot plant

Biomass pressurization reactor

- Volume: 22 l (2 kg of biomass/cycle)
- Maximum pressure: 26 bar
- Maximum temperature: 227 °C
- 10 l pre-heating jacket
- Temperature control system
- Pressure control system

Biomass expansion reactor

- Volume: 300 l
- Maximum pressure: 1 bar
- Cooling jacket
- Hermetic butterfly valve for the recovery of the exploded biomass

Chemical hydrolysis pilot plant

115 l reactor
Maximum pressure: 4.5 bar
Maximum temperature: 120 °C
Heating/cooling jacket (low pressure steam)

- Maximum pressure: 3 bar
- Maximum temperature: 134 °C

Acid and basic dosage tanks:

- Maximum pump flow: 62 l/h
- pH regulation

Paddle stirrer (max 650 rpm)
Pneumatic valve for coolant flow regulation
Split range pressure control (with inert gas)

Enzymatic hydrolysis pilot plant

115 l vertical cylindrical vessel
Internal temperature regulation system
PLC control system for pH control
Maximum pressure: 1.7 bar
External recirculation closed circuit:

- Centrifugal pump
- Cooling heat exchanger (water-glycol)
- Heating heat exchanger (steam-glycol)

Bio-hydrogen / biogas production pilot plant

3 stirred digesters (5, 35 and 250 l, respectively)
Batch or continuous (CSTR) reaction operation
System monitoring:

- pH control
- temperature control
- redox potential control
- biomass flow rate

Micro gas-chromatograph (μ-GC) for gas analysis
Online gas counter for volume flow evaluation
Inert gas to enable anaerobic condition
Relief valve for produced gas purge and collection
Automatic control and alarm system