Enhanced catalytic fast pyrolysis of biomass for maximum production of high-quality biofuels

Acronym: EnCat

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- Kungliga Tekniska Högskolan (SE)
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- Institute for Chemical Processing of Coal (PL)
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Project Duration: 01.02.2017 - 01.02.2020

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Introduction

In the present EnCat project, researchers from Austria, Poland, Sweden and The Netherlands teamed up to develop a new process to convert woody biomass into biofuels for heat, power and fuels. Avoiding combustion of fossil fuels reduces the impact on climate change.

The EnCat project idea is schematically given in Figure 1. The biomass will be pyrolysed in a reactor making use of deoxygenation catalysts. Simultaneously, CO2 will be captured with sorbents and via the water-gas-shift reaction in-situ hydrogen will be produced. After cleaning, the oil vapours will be mildly hydrogenated to produce a high quality bio-oil. The high-quality oil will be used for combustion tests in both a diesel engine and a gas turbine for combined power and heat generation.

Results

A biomass leaching process has been developed and optimised for herbaceous biomass feedstocks towards reasonable leaching efficiencies in an economically feasible process. With the process design derived from EnCat the feedstock basis for the production of high-quality bio-oil shall in future be significantly broadened also allowing for the utilisation of low-cost agricultural fuels with disadvantageously high contents of alkaline metals and alkaline earth metals. An experimental study of catalytic pyrolysis of lignocellulose biomass was carried out in a bench-scale fixed bed reactor. Catalytic pyrolysis of lignocellulose biomass using a catalyst mixture H-ZSM-5/Al-MCM-41 ratio of 7:1 at a temperature of 500°C was the best compromise to obtain the highest organic fraction of liquid (5.66 wt-%), the highest yield of non-condensable gases (13.36 wt-%), and the lowest yield of coke (2.22 wt-%). A High Heating Value (HHV) of 34.15 MJ/kg was achieved with a carbon content of 74.90%, a hydrogen content of 8.00%, and an oxygen content of 15.00%. Catalytic pyrolysis of leached lignocellulose biomass resulted in 5.40 wt-% of organic fraction with an HHV of 39.33 MJ/kg and 98.76% of favourable compounds. For the in-situ production of H2, a sorption enhanced catalytic pyrolysis process was added.

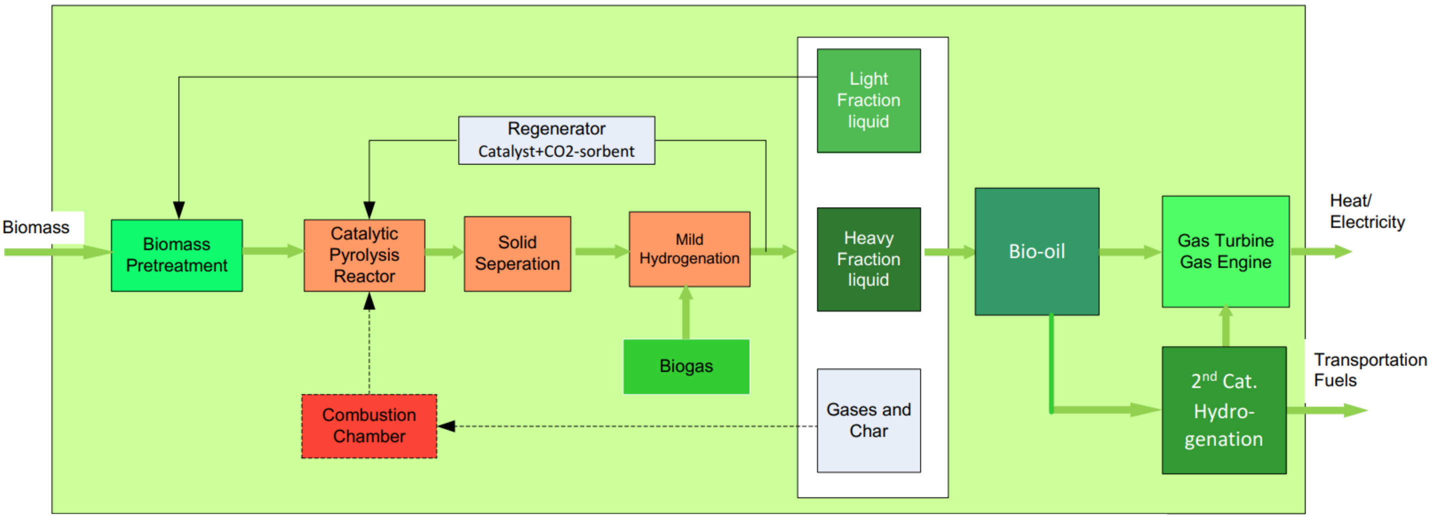

Figure 1: The concept of Enhanced Catalytic fast pyrolysis for the production of biofuels

Here the effect of a deoxygenation catalyst and CO_2 sorbent on pyroysis of biomass was investigated. Dolomite and Hydrotalcite were selected due to indications from the literature on its effect on deoxygenation and also CO_2 Sorption. Dolomite proved to be effective material for CO_2 sorbent as it shifted the water gas shift (WGS) equilibrium towards H_2 Production. Average H_2 Volume fraction=2,83 Vol% (45,1 % on N_2 free basis) was achieved in addition to mildly deoxygenated bio-oil with a HHV of 26.52 MJ/Kg when compared to 18.1 MJ/kg for thermal pyrolysis. On the other hand, Hydrotalcite showed moderate deoxygenation capabilities as it resulted in generation of hydrocarbons and less oxygenated phenols and ketones. However, the shift of Water gas shift reaction was limited. This result showed that the bio-oil can be further processed downstream to achieve high quality bio-fuel. It also opens up possibilities for the usage of In-situ hydrogen for downstream hydrodeoxygenation. Pyrolytic oils stability study have been carried out, with special attention put to transport and storage properties of the fuel at temperatures reflecting environmental conditions in winter and summer season. A detailed analysis of the physicochemical properties of pyrolysis oils allowed for the development of guidelines for storage, transport and use of pyrolysis liquids. The formation of pyrolysis oils stable emulsions with other fuels (Diesel and RME) in presence of non-ionic surfactants as well as selected alcohols (ethanol and butanol) was investigated.

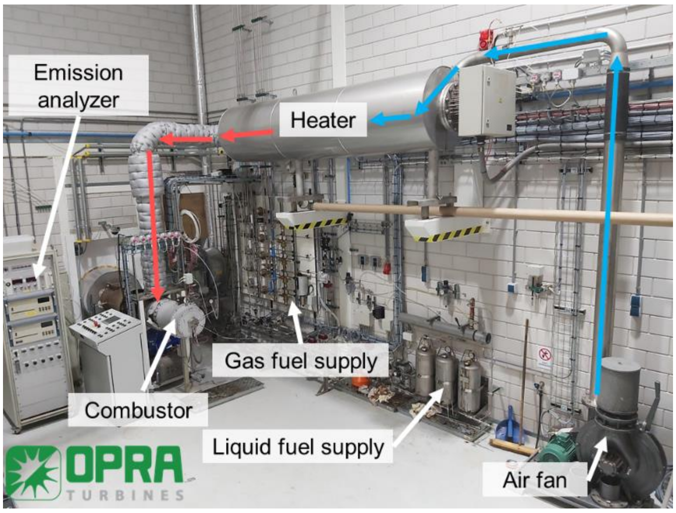

Figure 2: OPRA combustion test cell for gas turbine application

High-pressure catalytic hydrotreating process enables further improvement of pyrolysis oils towards transport fuels. Reducing the oxygen content in oils increases the environmental stability of oils, increases the calorific value and the improved miscibility with other fossil fuels.

Clean and sustainable energy are an important part of the world's energy transition. Available fuel sources should be used effectively for the production of power and heat.

Figure 3: Pyrolysis pilot-plant

By application of small-scale decentralized power generation, fuels can be utilized that are locally available. Gas turbines can hereby provide a flexible solution, which can run efficiently on a wide range of fuels with low emissions. Biomass derived pyrolysis oil combustion in gas turbines is a challenging task due to several reasons. The properties of the fuel are significantly different from conventional liquid fuels. Within the project, the operation of a gas turbine combustor on pyrolysis oil has been improved significantly. Hereby stable operation has been achieved in the 30-100% load range while operating on pyrolysis oil only. These improvements ensure further flexibility and low emission operation for future customers. CFD developments supported the further development of the combustion systems whereby tools have been used for finding optimal conditions and operating windows for pyrolysis oil combustion. A CFD model to describe char burnout, NOx formation and reduction for pyrolysis oil combustion in gas turbines has been further developed and validated. This model can be used in future as a basis to optimise gas turbine combustors towards low emission operation. This is especially needed to comply with the strict emission limit values for NOx according to the European Medium Combustion Plant (MCP) Directive. The economic feasibility of the production of bio-oil via the EnCat process as a crude oil substitute has been shown in the course of techno-economic analyses. The results shall pave the ground for a continuation of the work on this concept and for follow-up activities to develop and implement a first pilot/ demonstration plant based on the EnCat concept. The environmental and social aspects of the production bio-oil via EnCat concept has been assessed using life cycle assessment. The results can be used as a guideline for further improve the EncCat concept in the aspect of environmental performance compare to the conventional fuel oil.

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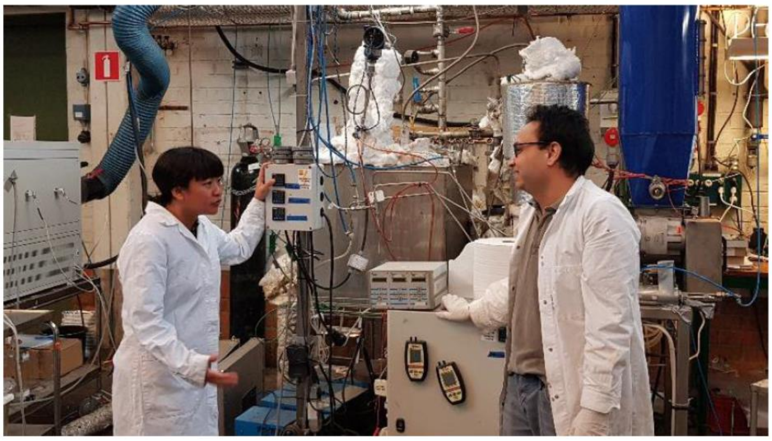

Figure 4: PhD research on catalytic pyrolysis

Acknowledgment

The project was carried out in the core of the ERA-NET Bioenergy programme “10th Joint Call for Research and Development Proposals of the ERA-NET Bioenergy” with financial support provided by: the Austrian Federal Ministry of Climate Action, Environment, Energy, Mobility, Innovation and Technology (BMK); the Netherlands Enterprise Agency (RvO); the Polish National Centre for Research and Development (NCBR) and the Swedish Energy Agency.

The ERA-NET Bioenergy is a network of national ministries and agencies. It contributes to further development of the European research area in bioenergy and strengthening of national research programmes through enhancing international cooperation and coordination. Please check our website to find out the latest developments and for more information contact the secretariat