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Abstract

EnCat - Enhanced catalytic fast pyrolysis of biomass for high-quality biofuels

Thomas Brunner
BIOS BIOENERGIESYSTEME GmbH
Hedwig-Katschinka-Straße 4, A-8020 Graz
E-Mail: brunner@bios-bioenergy.at, www.bios-bioenergy.at

Co-Authors: Ingwald Obernberger, Claudia Benesch (BIOS), Gerrit Brem (University of Twente, UT, NL), Anton Bijl (Alucha Management B.V., NL), Thijs Bouten (OPRA Turbines International BV, NL), Weihong Yang (Kungliga Tekniska Högskolan, KTH, SE), Karin Wilson (RISE IVF, SE), Agata Czardybon (Institute for Chemical Processing of Coal, ICHPW, PL), Sebastian Szuba (HIG Polska Sp., PL)

The EnCat project (03/2017 - 08/2020) aims at the development of a new concept for the production of high-quality bio-oil. Because of a novel biomass pre-treatment step to be developed the concept shall be suitable for both woody biomass and biomass residues from agriculture. The pre-treated biomass shall be pyrolysed in a reactor making use of deoxygenation catalysts. Simultaneously, CO2 shall be captured with sorbents and via the water-gas-shift reaction in-situ hydrogen shall be produced. After cleaning, the oil vapours shall be mildly hydrogenated to produce a high-quality bio-oil. The high-quality oil shall be applicable for combustion in both diesel engines and gas turbines for combined power and heat generation. Parallel to this, the bio-oil shall be further upgraded by a new method of downstream hydrogenation under high pressure for production of high-grade transportation fuels. At the end of the project, a full-scale design concept for the new process shall be available.

Regarding biomass pre-treatment BIOS developed and tested leaching methods with the aim to reduce the levels of alkali and alkaline earth metals (so-called AAEMs - K, Na, Ca and Mg) in the biomass, as these elements promote reactions that degrade the quality of the pyrolysis oil. Test runs have revealed that leaching woody biomass with acids even under moderate temperature conditions (30°C) results in a 75% reduction of AAEMs. The acids may thereby be gained from the light liquid fraction of the pyrolysis oil. When leaching with water, still AAEM removal of about 33% is achieved. For agricultural fuels like miscanthus, which contains significantly higher amounts of AAEMs, reduction rates of around 85% for acid leaching and 60% for leaching with water were found. With such a pre-treatment step, especially agricultural fuels shall be made more suitable for the catalytic pyrolysis process.

Regarding catalytic pyrolysis, tests performed at KTH have shown that H-ZSM-5 and Al-MCM-41 catalysts can improve the quality of the bio-oil. Therefore, the thermal degradation behaviour of lignocellulosic biomass with different catalyst ratios between H-ZSM-5 and Al-MCM-41 was studied. A H-ZSM-5:Al-MCM-41 ratio of 3:1 was found to provide the best results regarding cracking hemicellulose and cellulose compared to other catalyst mixtures that were studied. The same catalyst

ratio also attains the best interaction in terms of a BTX product selectivity. Furthermore, it has been shown that utilisation of pre-treated (leached) biomass is advantageous to reach high devolatilization and reaction rates during pyrolysis. With respect to the concept of sorption enhanced catalytic pyrolysis tests have been carried out at UT with deoxygenation catalysts and CO2 sorbents to reveal the key parameters to optimize the process with respect to quality and yield of the bio-oil. So far, reaction kinetics for two types of biomass both raw and pre-treated have been investigated. The effect of Ilmenite and Dolomite catalyst/sorbent were investigated and it has been found that ilmenite had a minor deoxygenation effect although an increase in hydrogen production was observed.

Regarding bio-oil utilisation, OPRA has been working on the optimisation of its combustion chamber for OP16 series gas turbines. Bio-oil combustion tests at a specific test rig as well as CFD simulations performed by BIOS and UT are therefore applied to gain further insights in the combustion of bio-oil in gas turbines. The existing gas turbine combustion system is currently optimized for (catalytic) pyrolysis oil application at low emissions, high efficiencies and improved load flexibility.

In parallel, at ICHPW studies regarding bio-oil storage and transport properties as well as the miscibility and blend stability of the pyrolytic oil with diesel oil, rapeseed oil and fatty acid methyl esters (RME) are studied. Preliminary combustion tests at a 35 kWel piston engine with a stable bio-oil/butanol mixture (ratio: 80:20) with the addition of 5% 2-ethylhexyl nitrate (Nitrocet) were carried out.

In parallel to these activities, a plant concept for a real-scale EnCat-plant is developed under the leadership of Alucha. Thereby RISE supports with LCAs and BIOS with techno-economic analyses to finally achieve an environmentally and economically sound overall concept.

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More information about the event, photos and presentation slides are available for download: https://nachhaltigwirtschaften.at/en/iea/events/2020/20200124-highlights-bioenergy-research.php