Clean and flexible use of new difficult biomass fuels in small medium scale combustion

Acronym: BIOFLEX

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- **Technology and Support Centre of Renewable Raw Materials (D)**
- **Umeå University, Department of Applied Physics and Electronics (S)**
- **Luleå University of Technology, Division of Energy Science (S)**
- **Chalmers University of Technology, Division of Fluid Dynamics (S)**
- **Saxlund (Opcon AB)**
- **AMANDUS KAHL GmbH & Co. KG (D)**
- **Institute of Power Engineering (PL)**
- **BTI – Biuro Techniczno Inżynierskie Jan Gumkowski (PL)**
- **POLYTECHNIK Luft- und Feuerungstechnik GmbH (A)**
- **KWB Kraft und Wärme aus Biomasse GmbH (A)**

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Introduction

In a future decentralised and sustainable European energy supply scenario, small to medium scale biomass combustion plants (< 50 WM) are destined to be important. At present, such plants burn mainly stem wood-based fuels in form of logs, wood chips, pellets and briquettes. A widened fuel base including new challenging biomass fuels would increase the growth potential for this sustainable biomass-based energy segment. To accomplish this, further comprehensive R&D work on primary design concepts on fuels and combustion technology is needed.

Possible new biomass fuels include assortments of forest residues, waste wood, short rotation forestry (SRF – e.g. poplar and willow), herbaceous fuels (e.g. straw) as well as residues from agriculture and industry (shells, kernels, sludges etc.). However, due to their chemical composition, these fuels are challenging in terms of combustion behaviour and emissions. Increased S, Cl and N contents lead to increased gaseous HCl, SOx and NOx emissions. Elevated ash contents with high levels of e.g. K, Si and P may cause problems with slagging, deposit formation and fine particulate emissions, of which especially the latter is growing in relevance with the EU-Ecodesign directive and the Medium Combustion Plant (MCP) directive.

While large-scale combustion plants may utilize relatively expensive secondary measures for emission reduction, it is generally not an economically feasible option for smaller plants. The rather limited knowledge of the problems associated with the new challenging biomass fuels has held back the development of fuel flexible combustion systems in small to medium scale. Therefore, the development of cost efficient and general primary concepts for increased fuel flexibility is urged to boost the innovation, enlarge market potential and deliver clean and efficient technology solutions. The overall objective of the BIOFLEX-project has been to increase the fuel flexibility and the innovation potential for the use of challenging solid biomass fuels, that do not compete with food production, in the small to medium-scale heat and power production sector.

Results

The project has increased the fundamental understanding of ash transformation issues in combustion, by ash transformation research. The application of additives and fuel blending have been investigated in order to make the new feedstock better applicable to small to medium-scale biomass combustion systems. The biomass fuels tested include wheat, wood, sunflower husk, grass and poplar. Measures to significantly decrease the alkali related fine PM emissions and slagging problems have been analysed. Relevant combustion experiments have been complemented by chemical analyses. Appropriate new concepts for fuel blending, additive selection as well as fuel/additive mixing ratios have resulted from the project. Within BIOFLEX a special focus has been given to the concept of using kaolin as additive in small- and medium scale grate-fired biomass systems and specific recommendations on how to estimate appropriate dosages have been presented.

Within the project, ash transformation concepts have been implemented in novel realistic, combustion-related modelling. The ash chemistry has been coupled to combustion processes, to enable predictions of slagging and other ash transformation-related events during combustion. Within the BIOFLEX project, the model has been improved and validated by comparing model results to combustion tests performed, both as single pellets and as fuel beds. The concept could serve as powerful tools in the prediction of the behaviour of the ash components in a fuel bed.

The combustion technologies for small to medium sized grate fired boilers have been further developed by means of primary measures such as: advanced air staging concepts, improved control systems and CFD optimised design of the combustion chamber. The CFD simulations and the models applied have been evaluated by operational data from test runs in two different biomass fired grate boilers. The results proved the accuracy of the models developed. Moreover, they supported the evaluation of the measures applied to further develop the plant technologies towards enhanced fuel flexibility, maintaining low emissions, high efficiencies and high plant availabilities.

In addition, a prototype burner for pulverized straw and sewage sludge has been developed and evaluated by CFD-simulations and combustion experiments. The tests showed highly slagging properties of sewage sludge, for which a key issue is the recovery of phosphorus from the ash. To avoid molten ash, a new prototype burner was designed and consequently tested in a laboratory. The best results were obtained when the burner was operated in “volume mode “, characterized by the absence of a clearly visible flame front. The fly ash thus generated had advantageous properties for the recovery of phosphorus. This work included developing methods to pulverize and store the biomass fuels, involving the construction of a prototype disk grinder. A patent application for a new design of the grinder has been submitted to the Polish Patent Office.

Figure 1. Dosing of kaolin-additive into a mixer with milled fuel prior to palletisation.

Figure 2. The ash chemistry has been coupled to combustion processes, to enable predictions of slagging.

Based on accompanying techno-economic analyses it has also been shown that the resulting furnace concepts and proposed fuel additives are economically affordable and commercially competitive in comparison with conventional wood combustion systems as well as with fossil fuel fired systems. Testing of proposed measures have been conducted has in appropriately adapted testing plants in cooperation with furnace and boiler manufacturers. The progress in BIOFLEX has been significant, solutions and technologies have been developed which make an application of these fuels in small to medium-scale plants possible.

Technologically and economically viable guidelines have been presented for the design of appropriate low emission combustion technologies and for appropriate fuel design by use of additives of new challenging biomass fuels.

Figure 3. On February 28 2019, the final workshop within the project was held in Wels, Austria.

Acknowledgment

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