Lowering Costs by Improving Efficiencies in Biomass Fueled Boilers: New Materials and Coatings to Reduce Corrosion

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Dear Readers,

every 4 months a newsletter will be shared with all stakeholders and scientific community that are involved and or interested in the field of bioenergy, including plant developers, plant operators, and technology suppliers, as well as governmental bodies. Furthermore, members from the general public who are interested in one or more of the topics related to BELENUS, such as bioenergy and materials engineering, will also gain from our quaternary newsletters.

These newsletters will cover project progress, special topics, news, relevant impacts and information and where to meet us in person at important events. In this first edition of the newsletter, you will learn about BELENUS in general and the project members.

The best is yet to come! Enjoy reading!

Francisco Javier Pérez Trujillo
Coordinator of BELENUS
Universidad Complutense de Madrid

Gustavo García Martín & Luis Alberto Bahillo Ruiz,
Editors
Universidad Complutense de Madrid & Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas

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Special Topic: Influence of biomass composition on corrosion processes

Partners involved

VAL, France
INTA, Spain
TEandM, Portugal
SMT, Sweden
UCM, Spain
UNIPER, United Kingdom
CIEMAT, Spain
CHAL, Sweden
RWE, Germany
VTT, Finland
EIFER, Germany
TUM, Germany

Importance of topic

Biomass is one of the most attractive renewable and sustainable energy source and alternative to fossil fuels because it is abundant, clean, and carbon neutral. Biomass can be used directly as solid fuel or can be converted to another form of energy such as biofuels. Biomass can be a suitable fuel for district heating in regions with abundant biomass availability since it can be stored and used to generate energy on demand. The potential to reduce greenhouse gas emissions, increased energy security and development of local economy are some benefits associated with utilizing biomass in district heating systems.

Development of technologies for multiple-fuel firing option made biomass as cheap and effective fuel. However, large amount of impurities in various biomass and waste results in the formation of corrosive deposits and gases which give rise to boiler operation problems. Corrosion in biomass boilers is largely due to the important potassium and chlorine content and low sulphur content in the biomass fuels. Compared to fossil fuels, the content of water vapour, alkali chlorides and hydrogen chloride is higher in biomass and waste-fired plants. Such species are highly corrosive towards superheaters, resulting in lower electrical efficiency and higher maintenance costs. On the other hand, the major ash forming elements (Al, Si) and the composition of the gas phase (O_2, N_2, H_2O, etc.) have significant influence on the behaviour of chlorine and alkali metals and corrosion formation in heating units.

Biomass feedstock is increasingly diverse. In the EU, biomass is divided into 3 categories depending on its source: (i) agriculture, (ii) forestry, and (iii) waste, followed by biomass categories and types with general and specific definitions. In addition, the composition of biomass depends on the specific vegetable species, country or regional area. In order to represent a broad variety of corrosive biomass feedstock for CHP boilers representing the 3 categories, 3 types have been selected within BELENUS project.

Current state of the art

Biomass composition plays a pivotal role in the combustion process. Biomass has a wide range of variety in physical properties, which significantly change the process rates and detailed phenomena. Biomass fuels often contain contaminants such as potassium, chlorine, sulphur and sodium that deposit on superheater tubes that have been exposed to combustion exhaust gases. Some of these deposits have low melting points and can, in their molten state, lead to accelerated corrosion of superheater tubes.

The ash composition is a major concern in biomass combustion. The high presence of alkali metals in biomass may cause slagging, fouling and ash agglomeration. The primary sources of these problems are: the reaction of alkali with silica to form alkali silicates that melt or soften at low temperatures (can be lower than 700 ºC, depending on the composition), and the reaction of alkali with sulphur to form alkali sulphates on heat transfer surfaces. Investigating the elemental composition of ash is important in order to identify possible operational problems in the actual application.

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Biomass fuels such as cereal straw are rich in alkali metals (K and Na) which are mainly present as simple salts and organic compounds and chlorine. These species are promptly released to the gas phase during combustion, forming HCl and KCl. High amounts of KCl in the combustion gases are frequently associated with enhanced deposit formation. This, in turn, will lead to corrosion of super heater tubes in biomass-fired boilers. Sulphur is also involved in the corrosion-related phenomena. Superheaters corrosion is an important obstacle to the development of biomass as a competitive widespread source for ‘‘green energy’’.

For this reason, typical boiler components and SH tubes operating in biomass fired power plants experience high corrosion rates mainly induced by the high amount of chlorine present in the fuel (gas) and/or the present of alkali and heavy metals in condensed deposits. Therefore, the lifetime of these components is significantly reduced limiting the operating temperature and thus the efficiency of the biomass plant, as well as significantly increasing the maintenance costs. In many cases, these aggressive conditions imply the use of Ni base alloys. Increasing the lifetime of materials by using advanced highly corrosion resistant coating/materials systems will facilitate operation at higher temperatures with the significant efficiency improvement without reducing lifetime and therefore the enhancement of the efficiency and the consequent cost reduction will further contribute to energy use of a great variety of biomass.

The BELENUS approach

Biofuels are not homogenous and differ strongly in their fuel composition. Since one of the objectives of the BELENUS project is to relate the corrosion in function of the biomass composition, three biomasses of very different composition have been chosen to study the effect of flue gas and particles generated at the combustion process about highly corrosion resistant coating systems. The three biomasses selected to be studied within BELENUS project are Eucalyptus chips, wheat straw and industrial wood waste, and their composition is shown in *Table 1*.

Table 1: Composition of biomasses studied.

Parameter	Eucalyptus chips	Wheat straw	Industrial waste wood
Moisture, %	17.9	8.3	4.4
Ash, %	0.7	4.9	2.6
Carbon, %	40.4	41.8	48.5
Hydrogen, %	4.8	6.4	6.1
Nitrogen, %	< 0.1	0.56	1.76
Sulphur, %	0.01	0.11	0.05
Chlorine, %	0.04	0.18	0.08
Ca, mg/kg	2430	4500	3300
K, mg/kg	549	8200	730
Mg, mg/kg	252	1100	490
Si, mg/kg	621	17000	2100

Inorganic species in biomass have been studied extensively because of their significant influence on slagging, fouling, corrosion as well as pollutant formation. The single most important species is potassium. For biomasses and bio-waste, different ratios in the fuel can give a good forecast to predict their corrosion risk, like 2S/Cl, K/(Al+Si), Si/(Ca+Mg) or K/(S+Si) ratios. Some of these ratios are based on the sulphating process between alkali salts and released sulphur, which appears as SO_2 or SO_3. The calculated fuel indices [mol/mol] for three biomasses are listed in *Table 2*.

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Table 2: Studied indices for three biomasses

	2S/Cl	Si/K	Si/(Ca+Mg)
Eucalyptus	0.5	1.1	0.23
Wheat Straw	0,38	2.1	3
Industrial wood waste	1,24	2.9	0.55

The 2S/Cl-ratio predicts corrosion risk. Only minor corrosion risks have to be expected for 2S/Cl ratios > 4 whereas high corrosion risks prevail for 2S/Cl ratios < 1. In our case, for two of the three selected fuels, eucalyptus and wheat straw there is a high risk of corrosion.

Si/K (molar) ratio can predict K release. A high molar Si/K ratio leads to a preferred formation of potassium silicates, which are bound in the bottom ash. Therefore, potassium release is reduced, aerosol formation may decrease while SOx and HCl emissions may increase. For very high Si/K ratios, a high amount of potassium in the bottom ash prevails. However, for low Si/K ratios (<2.5), no clear conclusion can be made.

Si/(Ca+Mg) ratio can provide primary information on ash melting problems in ash systems dominated by Si, Ca, Mg and K. As the molar ratio of Si/(Ca+Mg) increases, the ash sintering temperature decreases, being this decrease more remarkable when the Si/(Ca+Mg) index exceeds the value of 1.

Modelling of the combustion process based on thermodynamic equilibrium calculations is another technique that can provide information on the influence of fuel composition on corrosion processes. Real combustion conditions and atmosphere composition obtained from experimental tests made at the 10 kWth pilot plant are introduced as input data in the equilibrium reactor. Gases and ash composition from the outcoming streams are then determined for the different biomass fuels.

Three different 3 coatings (FeAl, NiAl, SiCrAl), have been selected to evaluate the fuel effect on coupons corrosion. The alloy composition are thus introduced in the equilibrium reactor to determine Fe, Ni, Al, Si and Cr interactions with ash components from the diverse biomasses. Most significant corrosive species formed are determined for varied temperature ranges.

Results show that wheat straw mainly affect to aluminium materials oxidation (≈90%), while for eucalyptus biomass more important corrosion is exerted over Fe materials. In waste wood case, similar affection is caused for both Fe and Al materials and these reactions have been seen to be highly influenced by combustion temperature. Other chemical reactions have been observed with K, Ca and Mg fuels components for most fuels and also with chlorine. Results obtained have thus revealed that fuel composition strongly affects the chemical attack towards coatings. In this sense, coatings efficiency may vary with the biomass employed in the process.

Possible impact

Developing new coatings for superheaters in biomass combustion processes will solve corrosion issues, increasing the operating temperature and therefore increasing efficiency, and reducing maintenance costs.

This fact will allow the energy use of a wider range of biomass, promoting the use of bioenergy to achieve EU's expectations on the electricity demand. Besides, the fuel flexibility of biomass power plants will improve allowing biomass with different chemical properties.

Another important consequence of the energy use of biomass waste is the deforestation reduction.

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Sectorial Breaking News

Date	Headline	Source
27 October 2020	*Renova to develop 75 MW biomass plant in Japan*	Bioenergy Insight
20 October 2020	*US Forest Service offers funding for wood energy projects*	Biomassmagazine
17 September 2020	*European Commission proposes 55% cut in GHGs by 2030*	Biomassmagazine
2 September 2020	*Atlantic Power's Cadillac biomass plant returns to service*	Bioenergy Insight
19 August 2020	*Poland increases production, use of wood pellets*	Biomassmagazine
7 August 2020	*US wood pellet exports top 684,000 tons in June*	Biomassmagazine
30 July 2020	*ENplus: Many European pellet producers impacted by COVID-19*	Biomassmagazine
9 July 2020	*Bioenergy Europe welcomes EU Strategy for Energy System Integration*	Bioenergy Insight

Remarkable Upcoming Events.

1. *ICBCRE 2021: 15. International Conference on Biomass Conversion and Renewable Energy*

The International Research Conference is a federated organization dedicated to bringing together a significant number of diverse scholarly events for presentation within the conference program. Events will run over a span of time during the conference depending on the number and length of the presentations. With its high quality, it provides an exceptional value for students, academics and industry researchers.

ICBCRE 2021: 15. International Conference on Biomass Conversion and Renewable Energy will be celebrated during January 25-26, 2021 in Paris, and aims to bring together leading academic scientists, researchers and research scholars to exchange and share their experiences and research results on all aspects of Biomass Conversion and Renewable Energy. It also provides a premier interdisciplinary platform for researchers, practitioners and educators to present and discuss the most recent innovations, trends, and concerns as well as practical challenges encountered and solutions adopted in the fields of Biomass Conversion and Renewable Energy.

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2. *EUBCE 2021. 29th European Biomass Conference and Exhibition*

EUBCE is the largest biomass conference and exhibition in the world. 29th European Biomass Conference & Exhibition will have place from 26th to 29th April, 2021 in Marseille France.

Each year, EUBCE brings together the greatest minds and latest advancements in biomass, with the aim of accelerating research and market uptake across the globe. During the conference, over 2,000 experts from both academia and industry share and discuss groundbreaking ideas, technologies, applications, and solutions for the sourcing, production, and utility of biomass. The conference programme will address topics from biomass to bioliquids and biofuels for heat and electricity, transport and biobased products. It will cover all aspects of each value chain, from supply and logistics to conversion technologies, from industrial application of research results to impacts on the environment, from market and trade aspects to policy strategies, not least to the role of biomass as a source in integrated energy systems.

The EUBCE is supported by European and international organizations such as the European Commission, UNESCO – United Nations Educational, Scientific and Cultural Organization – Natural Sciences Sector, WCRE – the World Council for Renewable Energy, EUBIA – the European Biomass Industry Association, The Central European Initiative, The Global Bioenergy Partnership and other organisations.

3. *WasteEng 2021*

8th International Conference on Engineering for Waste and biomass Valorisation will take place in Guelph (Canada), on 12th-15th July 2021. The event will bring together senior executives and experts from the biomass trading industry, biomass producers, energy companies, policy makers, consultants, technology innovators and leading market analysts to discuss the latest challenges and developments within the industry. The event will give you an insight into the industry`s latest policy and regulations, recent developments in biomass technologies, biomass planning and logistics management, quality controlling and costs effective ways of transport. WasteEng 2021 will also showcase latest policy and regulations, criteria and certification for sustainable biomass production. The event topics will provide a solid background for the two days discussion on best solutions for sustainable biomass trade in Europe.

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Stay in contact with us. Visit our website

BELENUS website www.belenus-project.eu is available since the early beginning of the project. It is the relevant source to show the scope and objectives of the project up and outstanding results. Find out more interesting information about the project and the impact of the results achieved, including all dissemination activities carried out.

If you have any questions feel free to drop us a line at *contact@belenus-project.eu* and remember you can follow us on *Twitter* & *LinkedIn* .

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