Renewable Fuels for Fluidized Bed Combustors: Current Status and Future Trends

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Fluidized Bed Combustors have excellent mixing characteristics of the solids, high heat transfer rates and burn efficient with low emissions, together with a perfect acceptability of problematic fuels, and also the flexibility against timely changes in fuel quality. Similarly, the limitations of the fluidized bed technology became known as well.

The demand on thermal utilization of a range of such “problematic” fuels such as biomass and waste increased nowadays the need of collecting and systematic exchanging of knowledge accumulated during the past three decades in the area of operating practice and knowledge of FBCs. A new network has been set up for this reason, where besides basic technical experience also open and solved problems are exchanged in a quantified manner.

State of the art is already the utilization of a fuel mix (mainly wood wastes, bark, sludges, coal) in relatively small (< 50 MW) and large fluidized bed combustors. Future developments are an increased utilization of sewage sludge, small fluidized bed combustors (< 50 MW) with wood as the main fuel and large units (> 100 MW), as well as the utilization of municipal solid waste and gasification.

1. ADVANTAGES AND LIMITATIONS OF FLUIDIZED BED COMBUSTORS

Fluidized Bed Combustors are used for more than 20 years successfully for the thermal utilization of biofuels and waste (wood chips, saw dust, waste from paper industry) as well as for fossil fuels e.g. coals with high ash contents, lignites. The history of this environment friendly and highly economical technology started in 1922 already, but its further development sped up in the mid sixties only, driven by the need for combusting high sulphur coals with low emissions. The major further steps of the history of FBC are the followings.

1922 Winkler patent
1965 First BFB test facility commissioned
… Atmospheric FBC R&D program (USA)
1976 BFB Riversville industrial scale demonstration project
… European CFBC R&D programs
1981 First coal fired commercial CFBC by Alstom (today Foster Wheeler)
1981 First commercial BFB fired by biomass as main fuel, EPI
1982 First Lurgi Lentjes CFB is commissioned
1983 First commercial CFB fired by biomass as main fuel, Foster Wheeler
… Extended R&D activities initiated by companies
… Commercialization of FBC technology
1999 International Energy Agency (IEA) FBC implementing agreement (today 13 members)
2009 First supercritical CFB boiler (Foster Wheeler in Lagisza, Poland; planned start)

The fuels are burned as single fuel or as fuel mixture in a FBC. The fluidized bed consists mainly of bed material (fuel ash and silica sand) and only to a few percentages of the fuel itself. The fluidization is performed with the combustion air. Due to the fluidization of the bed material and the fuel particles the three-dimensional motion of the solids ensures good mixing conditions in horizontal
and vertical directions. This excellent mixing behavior leads to even temperature and fuel distributions within the combustion chamber which is a significant advantage compared to grate furnaces and pulverized fuel combustors. The fluidized bed material acts efficiently as a mobile heat tank and evens changing fuel mixtures and moisture contents.

Due to the fluidization with combustion air a strong coupling between the on-going combustion chemistry and the flow characteristics is given. The fluidized bed has to be operated between the minimum fluidization velocity and the terminal fluidization velocity. If the velocity is high, an increased entrainment of fine particles will arise. This leads to operating conditions which have to be optimized for given particle size distributions. If ashes are generated which melt at low temperatures agglomerates may be formed which may lead to a complete de-fluidization of the fluidized bed combustor.

Generally fluidized bed combustors have high heat transfer rates. Therefore the size of the unit can be kept compact and the heat is used efficiently.

Due to the even temperature distribution and temperature levels (typically 850 °C) no thermal NOx is produced. The NOx formed originates from the fuel nitrogen which has to be considered if fuels with high nitrogen contents are burned.

In-situ desulfurization (SO2 removal) is possible with direct limestone addition into the combustion chamber. Therefore external desulfurization is not necessary.

Besides the bubbling, stationary fluidized bed combustors (FBCs) circulating fluidized bed combustors (CFBCs) are used usually in the thermal power range higher than 100 MWth. These CFBCs operate at higher gas velocities and show excellent heat and mass transport characteristics. Due to fluidization limitations the particle size distribution in CFBCs is smaller (typically below 15 mm) and narrower compared to FBCs (typically up to 40 mm).

2. STATE OF THE ART

2.1. THE FUEL MIX

In Table 1 an overview of the fluidized bed combustors in Austria and their main characteristics is shown. In Austria fluidized bed combustors are mainly used for decentralized heat and power generation. The aim is the thermal utilization of waste from industrial processes, e.g. from the pulp and paper industry. The fuels vary in a wide range and are usually used as fuel mixture. Typical fuels are bark, wood waste, saw dust, coals with low calorific values and recently plastics, municipal solid waste and sewage sludge. The thermal power range is typically between 14 to 133 MWth (combustion) and 8 to 10 MWth (gasification). Circulating fluidized bed combustors are usually used in the higher thermal power range and are able to operate in a very wide range (Figure 1).
Fig. 1. Overview of the operating ranges of stationary fluidized bed combustors (FBCs), circulating fluidized bed combustors (CFBCs) and grate furnaces [1]. Lower Heating Value of the fuel versus thermal power.

Tab. 1. Industrial fluidized bed combustors in Austria [2]

<table>
<thead>
<tr>
<th>location</th>
<th>year</th>
<th>type</th>
<th>capacity</th>
<th>fuels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gratkorn</td>
<td>1981</td>
<td>CFBC</td>
<td>25 MW</td>
<td>Bark, sludge, biogas, natural gas</td>
</tr>
<tr>
<td>Gratkorn</td>
<td>1986</td>
<td>CFBC</td>
<td>133 MW</td>
<td>Coal, sludge, biogas, natural gas</td>
</tr>
<tr>
<td>Bruck a.d. Mur</td>
<td>1984</td>
<td>BFBC</td>
<td>15 MW</td>
<td>Bark, coal, sludge, biogas, natural gas</td>
</tr>
<tr>
<td>Zeltweg*)</td>
<td>1998</td>
<td>CFBC</td>
<td>10 MW</td>
<td>Wood</td>
</tr>
<tr>
<td>Niklasdorf</td>
<td>2004</td>
<td>BFBC</td>
<td>40 MW</td>
<td>MSW, industrial waste, wooden residue, sewage sludge</td>
</tr>
<tr>
<td>Lenzing</td>
<td>1987</td>
<td>CFBC</td>
<td>108 MW</td>
<td>Bark, coal, sludge, wood residue, oil</td>
</tr>
<tr>
<td>Lenzing</td>
<td>1998</td>
<td>CFBC</td>
<td>110 MW</td>
<td>Plastics, waste, sludge, wood residue</td>
</tr>
<tr>
<td>Ebensee</td>
<td>1987</td>
<td>CFBC</td>
<td>43 MW</td>
<td>Coal, wood waste</td>
</tr>
<tr>
<td>Steyrermuehl</td>
<td>1994</td>
<td>CFBC</td>
<td>48 MW</td>
<td>Bark, wood, wood residues, sludge</td>
</tr>
<tr>
<td>Timelkam</td>
<td>2006</td>
<td>FBC</td>
<td>49 MW</td>
<td>Wood, wood residues, bark, sawdust</td>
</tr>
<tr>
<td>Hallein</td>
<td>2006</td>
<td>BFBC</td>
<td>30 MW</td>
<td>Wood chips</td>
</tr>
<tr>
<td>St. Gertraud im Lavanttal</td>
<td>1984</td>
<td>CFBC</td>
<td>61 MW</td>
<td>Bark, coal, sewage sludge, heavy oil</td>
</tr>
<tr>
<td>St. Veit a.d. Glan</td>
<td>1990</td>
<td>FICFBC</td>
<td>33 MW</td>
<td>Bark, sludge, sawdust, wooden residue, plastics</td>
</tr>
<tr>
<td>Arnoldstein</td>
<td>2000</td>
<td>FBC</td>
<td>8 MW</td>
<td>oils, emulsions, wooden residue, sludges, plastics</td>
</tr>
<tr>
<td>Pitten</td>
<td>1984</td>
<td>BFBC</td>
<td>65 MW</td>
<td>Coal, biogas, sewage sludge</td>
</tr>
<tr>
<td>Bad Vöslau</td>
<td>2003</td>
<td>BFBC</td>
<td>1 MW</td>
<td>Sewage sludge</td>
</tr>
<tr>
<td>Vienna</td>
<td>1992</td>
<td>FBC</td>
<td>3 x 25 MW</td>
<td>Sewage sludge</td>
</tr>
<tr>
<td>Vienna</td>
<td>2003</td>
<td>RFBC</td>
<td>40 MW</td>
<td>Municipal Solid waste, sewage sludge</td>
</tr>
</tbody>
</table>
### 2.2. FUEL PREPARATION AND TRANSPORT

A very important topic for transport and feeding of the fuels is their particle size distribution and density. Problems may arise if the fuel is too large in one of its lengths. Bridging in the feeding lines is possible. Figure 2 shows a complex fuel preparation system.

![Fuel preparation Swedish concept](image)

**Fig. 2:** Fuel preparation Swedish concept [5].

In case of power plants fired by coal alone, a very good and commonly used way for characterizing the actual fuel is giving its lower heating value, which considers already its moisture content as well. Notice, that this approach is applicable only in case of fuels of relatively low moisture, typically below 10%. A basic characteristics of most biomass fuels – which constitute an important group of renewable fuels – is however their significant moisture contents, generally above 10–20% or even more. (See Table 2.) The worst cases are regarding this aspect the sludges, especially sewage sludges, where in some cases the extremely high moisture result even negative lower heating values, which do not allow their mono-combustion without effective drying to be carried out generally before transportation.

**Tab. 2.** Typical calorific values and moisture contents of fuels [3], [4].

<table>
<thead>
<tr>
<th>Fuel</th>
<th>calorific value (MJ/kg) dry</th>
<th>moisture (%) as received</th>
</tr>
</thead>
<tbody>
<tr>
<td>beech wood</td>
<td>17 - 19</td>
<td>10 - 30</td>
</tr>
<tr>
<td>spruce wood</td>
<td>19 - 21</td>
<td>10 - 30</td>
</tr>
<tr>
<td>grass</td>
<td>17 - 18</td>
<td>10 - 40</td>
</tr>
<tr>
<td>waste wood</td>
<td>16 - 17</td>
<td>10 - 30</td>
</tr>
<tr>
<td>paper</td>
<td>17 - 18</td>
<td>5 - 30</td>
</tr>
<tr>
<td>bark</td>
<td>15 - 16</td>
<td>10 - 30</td>
</tr>
</tbody>
</table>

BFBC = bubbling fluidized bed combustor  
CFBC = circulating fluidized bed combustor  
FICFBC = fast internal circulating fluidized bed combustor  
CFBG = circulating fluidized bed gasifier  
DFBG = dual fluidized bed gasifier  
RFBC = rotating fluidized bed combustor  
*) not in operation, **) operation starts
Drying is a very important part of fuel preparation in case of most renewable fuels. Figure 3 indicates this process (thick line) on the example of an arboreal energy plant characterized by 43% moisture in its harvesting state. In case of drying biomass fuels on site (in the power plant storage area) besides the positive effect of increasing its heating value, also the loss of total fuel mass should be considered. This is indicated in Figure 3 by the thin line, which is the lower heating value relative to the original fuel mass.

**Fig. 3.** Effect of drying of a biomass fuel (arboreal energy plant)
Thick line: change of lower heating value (relative to the actual fuel mass)
Thin line: change of lower heating value relative to the original fuel mass

### 3. FUTURE DEVELOPMENTS

A future development is the increasing utilization of sewage sludge in fluidized bed combustors. Sewage sludge is co-combusted in large-scale pulverized coal boilers [6] or in CFBCs with coal as the main fuel [7] (Figure 4) or in small-scale units as single fuel or co-combusted with e.g. municipal solid waste (Vienna district heating).

**Fig. 4.** Co-combustion of sewage sludge with lignite and waste in a circulating fluidized bed combustor (CFBC) [7].
Smaller FBCs with wood as fuel are planned and started in Austria, e.g. in Hallein with a thermal power of ca. 30 MW, Heiligenkreuz (45 MW), Timelkam (49 MW) [8] and Vienna.

In Finland the strategy is to use large fluidized bed combustors with peat, wood and biomass as the main fuels. In Alholma the worldwide largest fluidized bed combustor operating on biomass basis can be found (550 MW) [9]. As fuels waste wood, saw dust, bark, peat, coal and oil are used.

A current trend is the increased utilization of municipal solid waste and biomass waste in fluidized bed combustors. Examples can be found in Austria and Germany: Fernwärme Wien (40 MW), Niklasdorf (40 MW), Neumünster (75 MW).

Another trend is the application of fluidized bed reactors for gasification. The Güssing gasifier (8 MW) uses a dual fluidized bed system and operates on biomass. Other gasifiers based on fluidized bed technology are scheduled.

Main reasons for the application of the fluidized bed technology are the efficient utilization of a very wide range of different material flows from process industry (e.g. pulp and paper) and households for heat and power production, the utilization of renewable energy sources, the reduction of landfill waste and the reduction of CO₂. The fluidized bed technology is significantly contributing to CO₂ reduction.

4. SUMMARY

Fluidized bed combustors show excellent mixing and heat transfer conditions. They burn efficiently and with low emissions. Due to the high heat capacity of the fluidized bed a wide range of different fuels with very low calorific values and high moisture contents can be used. Limitations exist due to the particle size distribution of the fuel and fluidization characteristics.

State of the art is the utilization of a wide fuel mix (mainly wood wastes, bark, sludges, coal) in relatively small (< 50 MW) and large fluidized bed combustors. Future developments are an increased utilization of sewage sludge, small fluidized bed combustors (< 50 MW) with wood as the main fuel and large units (> 100 MW), as well as the utilization of municipal solid waste and gasification

References