Advanced combustion technology for a bioethanol plant

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Introduction

Alternative fuels currently make up only a small percentage of the market for fuel for the transportation sector, but the EU target is for bioethanol to make up 6 % by 2010. As a result, a number of first generation bioethanol plants are being constructed in the EU in order to keep up with the demand on the market. Production of bioethanol from wheat and other types of biomass is a very energy demanding process. Before the grain can be used for such production, it is processed, and the waste product consists of bran and small amounts of husks and chaff.

Straw Combustion

Babcock & Wilcox Vølund (BWV) have been working on and developing combustion technology for straw for many years, and it is this know-how that forms the basis for the new facility in Belgium. Straw is one of the most corrosive types of biomass, providing corrosion problems not previously encountered with combustion of fossil fuels.

When straw is burned, sulphur dioxide and potassium chloride are emitted in the gas phase, and the presence of these species result in corrosive deposits condensing on vulnerable metallic surfaces such as the superheaters. These deposits contain potassium chloride which, when reacted with sulphur dioxide, generates chlorine species that attack the metal. The alkali salt deposits also cause corrosion of metallic components.

One of the best examples of this technology is the Avedøreværket unit 2, the world's largest and most advanced straw fired CHP plant – see figure 1. Avedøreværket generates electricity for the Sealand electricity grid and heat for one of the largest metropolitan district heating systems in Northern Europe.

The new CHP (Combined Heat and Power) block, Avedøre 2, represents a completely new technology and is the world's largest plant of its kind. The ultra supercritical straw fired boiler plant, featuring a new and advanced straw feeding system, began operation at the end of 2001.

The biomass plant produces 35 MW electricity and 50 MJ/s heat. The steam flow is 144 t/hour at 310 bar and 583 °C. The boiler generates steam for the main steam turbine of the CHP block. The straw fired boiler will account for about 10 % of Avedøre 2's annual fuel consumption, or approximately 150,000 tonnes of straw per year. The boiler is designed for one hundred per cent straw firing and is the world's largest and most effective straw fired boiler with ultra super critical steam parameters.

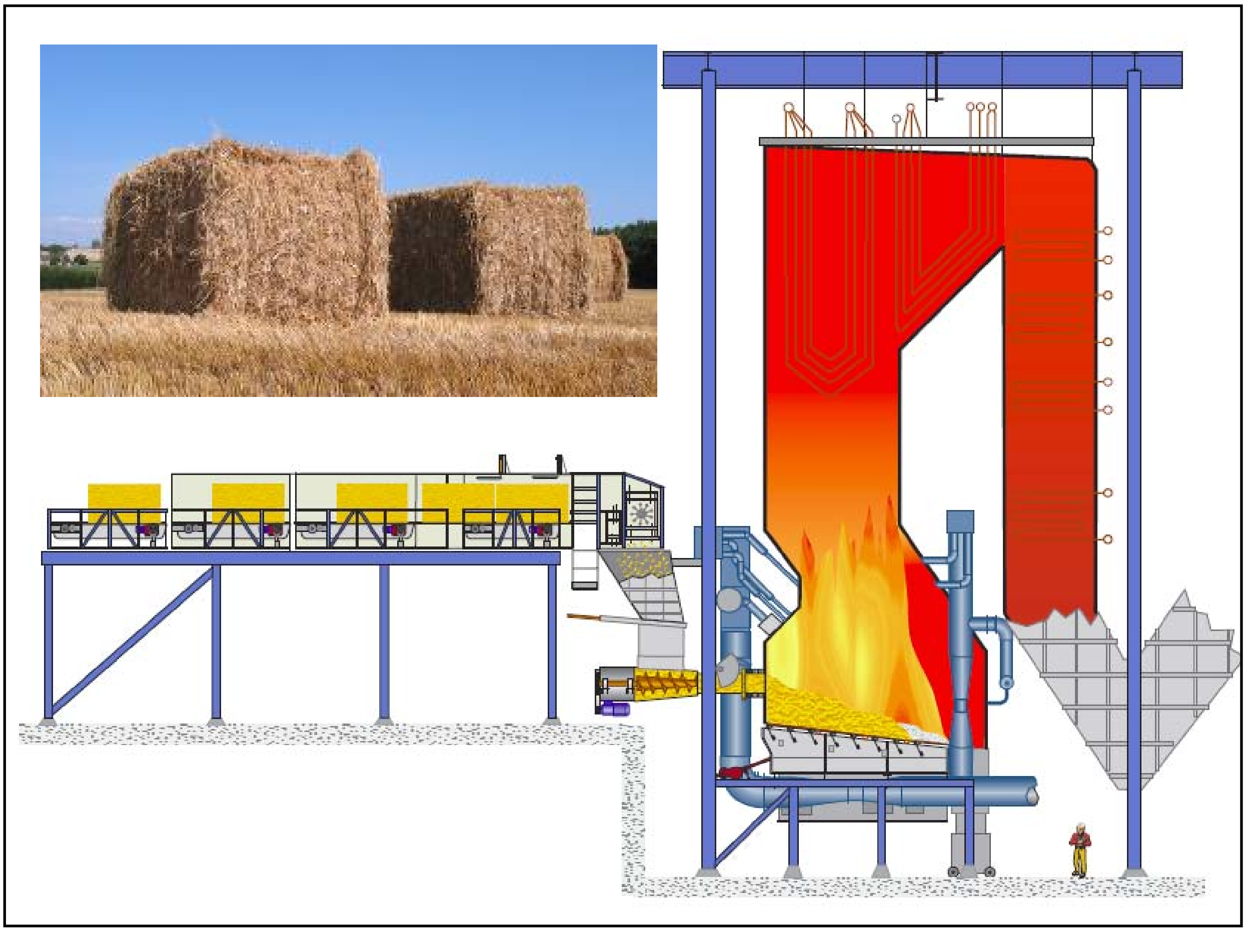

Figure 1. Fuel pre-treatment system and boiler for the 105 MW_{th} ultra super critical unit.

The advanced combustion system consists of two straw feeder systems which include:

- Conveyor system from straw storage to boiler house
- Fire damper for prevention of back fire
- Control system for straw supply
- Newly developed straw shredder which reduces the straw density from 100 kg/m^3 to 30 kg/ m^3
- Double screw feeders built into the water cooled feeding ducts mounted on the boiler front
- Water cooled vibrating grate.

The straw is fed into the furnace by screw feeders onto a small water cooled fixed grate where the straw is exposed to very high thermal radiation and undergoes a rapid pyrolysis process where up to 80 % of the energy content is released. The remaining fixed char from the pyrolysis process will bum out onto the water cooled vibrating grate. The pyrolysis gases are mixed with secondary air, and CFD (Computer Fluid Dynamic) calculations have been used in order to design the best possible nozzle arrangement, resulting in complete burnout.

A bag filter system removes more than 99 % of the particulates from the flue gas leaving the boiler. Slag and ash is carried to containers by a submerged slag conveyor system.

Bran Combustion

Through the latest 30 years Vølund has built up a wide experience with different types of biofuels. Even though bran is not one of these, the 100 t/h bran fired steam boiler contract for Biowanze is based on Vølund's general knowledge about biomass and straw in particulates.

One of the key components is the water cooled vibrating grate which is characterized by the following:

- Ideal for burning most types of biomass, RDF and other solid recovery fuels
- Suitable for a wide range of boilers within 10-170 MW
- Possibility of burning fuels with high moisture contents
- Efficient water cooling results in less wear and ensures long operating life
- High availability, low maintenance costs and low consumption of spare parts
- High flexibility due to multiple water cooling options
- The air flow through the grate can be optimized according to the combustion conditions as there is no need for air cooling.

The grate consists of two or four panel walls mounted on leaf springs. These panels are activated in pairs, in counter phase, by a vibrating unit. This is a simple construction with no internal moving parts which ensures smooth operation and long life – see figure 2.

Primary combustion air is injected through holes drilled in the fins of the grate panel. The pattern of these holes can be custom-designed to meet the demands for primary air as determined by the specific fuel. This, combined with the independency of air flow for cooling needs, gives the optimal conditions for air flow adjustment. A high preheating temperature of primary combustion air and, in special cases, mounting of cast iron plates enable fuels with high contents of moisture to be burned.

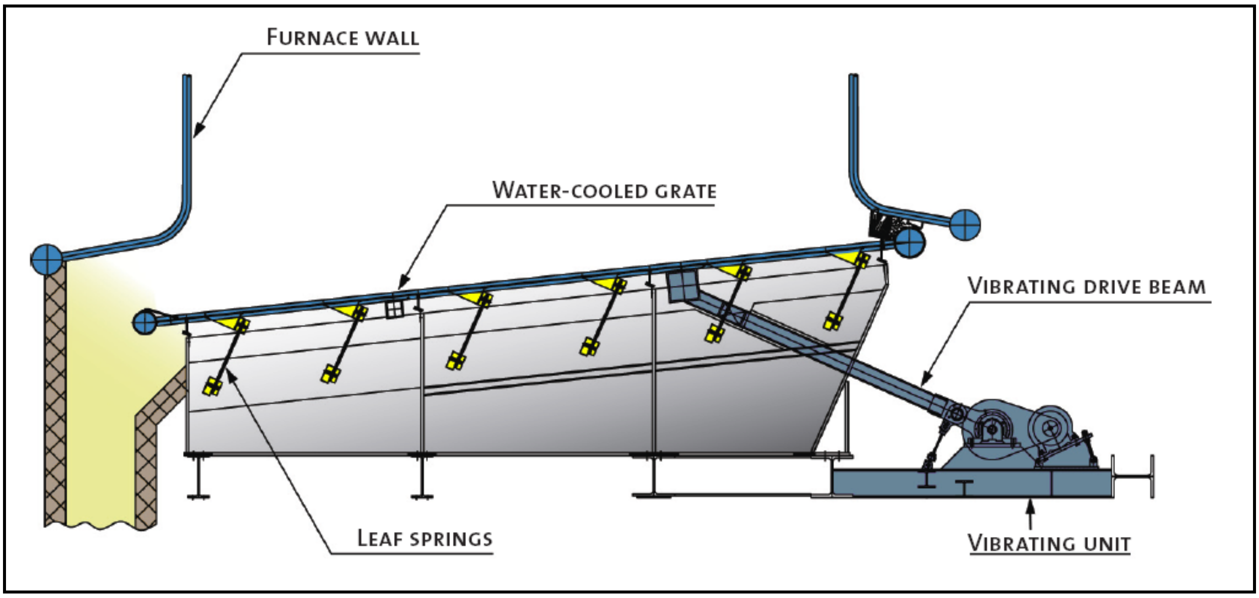

Figure 2. Babcock & Wilcox Vølund's water cooled combustion grate.

Moreover, straw has a chemical composition causing significant deposit formation during combustion and post-combustion which results in acute slagging and fouling of the plant. This can lead to reduced heat transfer, blockage within the plant and increased downtime for the removal of deposits.

Babcock & Wilcox Vølund's technology has been developed for burning biomass on a water cooled vibrating grate. The fuel forms an ash product that has a low melting point, and it requires a very specific boiler technology in order to produce steam without major operating problems. The overall layout of the new plant is shown in figure 3.

The combustion process will convert the waste products into energy, which is recycled for ethanol production. The facility will be capable of burning 20 t/hour. This ensures optimum use of the grain, and the ethanol plant covers a large percentage of its energy consumption – almost 80 % of the energy consumption of the plant – including 20 MW electricity.

Once the plant is in full production by the end of 2008, it will produce 758,000 litres of alcohol per day.

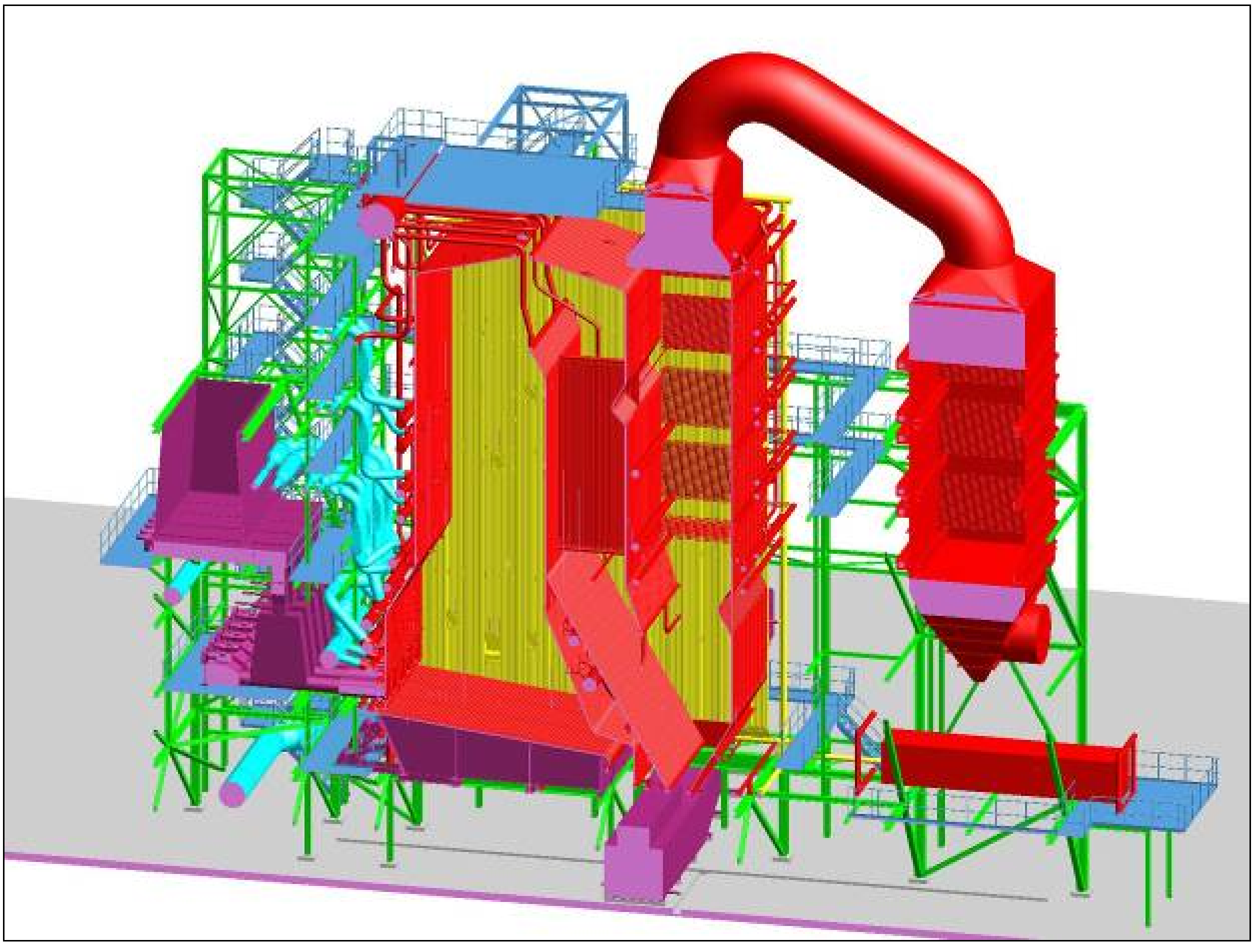
Figure 3. Plant layout for the bran fired boiler at Biowanze, Belgium.

As part of the Biowanze steam boiler design phase it was decided that a full scale test firing should be made on a Vølund water cooled vibration grate. As the combustion equipment of the Vølund boiler at Örebro Kartonbruk AB is quite similar to that of the Biowanze project, an agreement was made with the boiler owner, to carry out a test firing in February 2007. A short duration pre-test at a small installation at Aalborg University added valuable facts as to handling and ignition.

The test firings were meant to answer as many of the below questions as possible, within the natural limits that the different furnace shape and secondary air system allowed. These tests pointed out a number of problems, most of them being well-known to Vølund, especially from wheat straw firing.

- How do the silo and the feeder screws handle the fuel?
- How does the fuel physically act when entering the grate through the screw feeders? Will it pile up down the grate as a row of long hills or will the grate vibrations also even out the layer across the width of the grate?
- How fast and how steady does the fuel ignites when exposed to radiation from the gas phase combustion in the furnace?
- How do the different stages of the primary combustion at the grate take place and what can be learned as to hole sizes and configuration?
- How much primary air must be added to the grate in the three different zones in order to support the ignition, the flame combustion and the char burnout?
- How should the grate vibrate to obtain the best possible fuel distribution and char burn-out?
- How will this influence the carry over of fuel and fly ash?
- The amount of emission before and after the flue gas filter?
- How good is the burnout of bottom ash and fly ash?

All the information from the test firing has been evaluated and compiled for use in the detailed engineering design. The plant will be ready for operation in 2008.

The future

In the future, there will be a demand for such systems, as there are around 50 projects involving the establishment of bioethanol plants at various stages in the EU aiming to meet the EU Commission’s target. In general, we are seeing an increasing interest in energy production based on biomass. This is due to an increasing interest in trading CO_2 certificates for electricity produced from biomass and a desire to reduce the dependence on imported oil.