9. Gasification and Pyrolysis

Gasification of straw is interesting with a view to substitution fossil fuels with biomass at small power plants of an output of 0.2-3 MW electrical power and at power plants of a size of 50-100 MW electrical power. The gas from a small gasifier can be used so as to drive an engine that drives a generator that generates electrical power. The cooling water supplies hot water to a district heating distribution net. At a power station, the gas can be burnt in a high-pressure boiler where the steam drives a turbine/generator.

photo: reto hummelshøj/cowi

The pyrolysis plant at Haslev Kraftvarmeværk (CHP plant). The pyrolysis plant has been coupled to the plant as a demonstration facility and therefore not structurally fitted into the entire design.

From 1988, various experiments on gasification of straw were carried out, e.g., at Kyndbyværket (power plant). The experiments were financed by ELKRAFT Power Company Ltd , Danish Energy Agency, and Ansaldo Vølund A/S. These experiments have revealed certain problems associated with the special properties of straw when used as a fuel. By updraft gasification (the gas rises through the incoming straw), problems were demonstrated within the following areas:

- Feeding of fuel
- Non-homogeneity of layers of fuels with straw compacting in cold zones
- Unburnt straw charcoal blown out of the gasifier

The feeding of fuel resulted in many problems with plugs in the fuel feeding system. A discontinuous feeding of fuel affect the gasification process negatively, since it increases burning through tendencies with a poor gas quality and great variations in the gas composition as the result.

Attempts were made so as to remedy non-homogeneity by means of a stirring system which did not solve the problem, though. Perhaps the stirrer contributed to pyrolysed straw charcoal being pulverised to finely divided powder that is fluidized in hot zones and blown out of the gasifier. In cold zones, the straw compacted in wet lumps more or less impervious to gas. Thereby the heat transfer into the fuel was interrupted so that an evenly distributed glow bed could not be built up.

Experiments on gasification of wood chips made in the same boiler for a shorter period have shown that the granular structure of the wood chips and the formation of a stable wood charcoal make this fuel considerably suitable for gasification purposes.

With the gasifier at Kyndbyværket (power plant) as the prototype, an updraft gasifier has been constructed at Harboøre where wood chips are used as the fuel due to more experience having been gained. The “Kyndby gasifier” was closed down after finishing the experimental programme. It was dismantled in 1997 along with the demolition of Kyndbyværket’s old unit.

At the Technical University of Denmark (DTU), a two-staged gasifier has been developed. During the period from 1994-98, the effort has been concentrated on wood gasification, since it is now easier to upscale wood gasifiers from small to larger test plants. Long-range experiments on gasification of briquette fuel have been carried out.

From 1998, straw gasification has been given priority. The developing work is aiming at two boiler plant types:

1. Small gasifiers of a size of 0.2-3 MW electrical power with a heat production of 0.5-8 MW that can substitute existing boilers at district heating plants where there is no electrical power generation today.
2. Large gasifiers of a size of 50-100 MW electrical power at power plants where the low alkali and chlorine contents of the gas make it possible to burn it in a high-pressure boiler. The concept is called a coupled-gasifier-combustor and has been developed for wood in Finland.

Haslev Pyrolysis Plant

The high chlorine and alkali contents of straw make it unsuitable for direct burning in boilers with high steam data. High steam data are necessary in order to be able to achieve high electrical power efficiency. By pyrolysis, the major part of the chlorine and alkali is retained in the charcoal if the temperature is kept at a maximum of 550°C. Furthermore, particles from the hot gas are separated in a cyclone. Thus, the pyrolysis gas can be used to superheat steam without any major risk of corrosion, erosion, and deposits on the superheater.

In the spring of 1992, it was decided to construct a full-scale demonstration plant designed for pyrolytic gasification of straw in connection with Haslev Kraftvarmeværk (CHP plant). In addition to ELKRAFT Power Company Ltd., the EU “Thermie Programme”, the Danish Energy Agency, Ansaldo Vølund A/S, and COWI Consulting Engineers have supported the project financially.

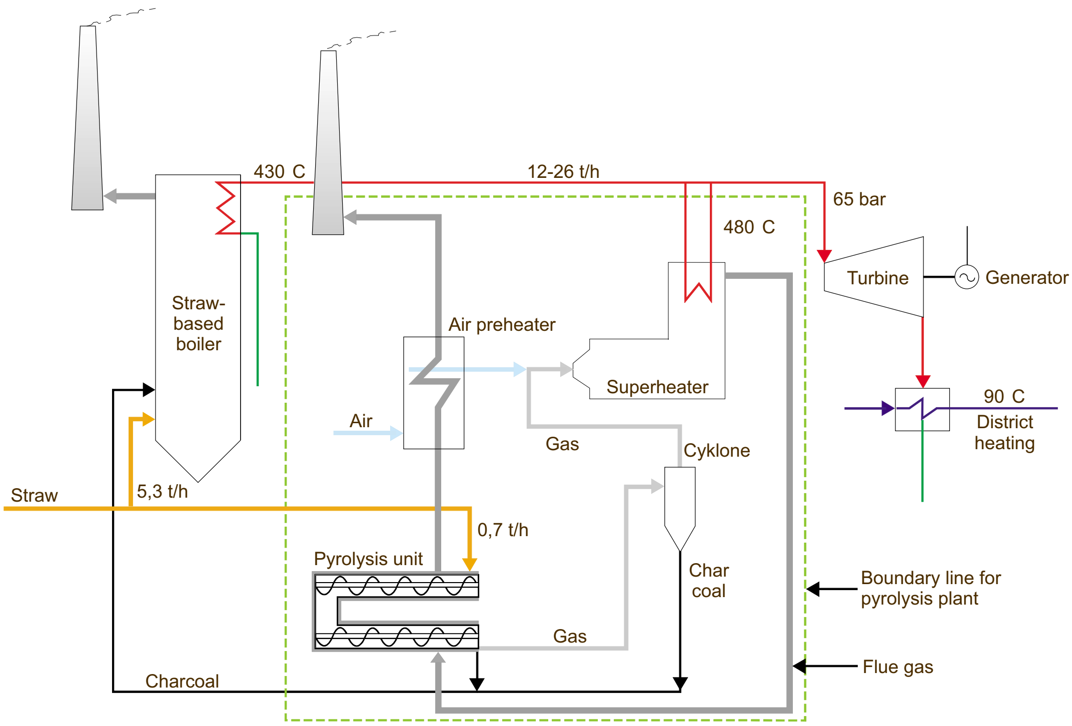

Figure 23: Simplified diagram of the pyrolysis plant at Haslev Kraft-varmeværk (CHP plant).

The overall objective of the project is to demonstrate the function of the main components and the concept as such, since it can improve the efficiency of waste- and biomass-fired CHP plants.

Already in 1987 in ELKRAFT Power Company Ltd.'s brainstorm competition on gasification technology, COWI was awarded the first prize for the above-mentioned concept. The project started up in 1989 with laboratory tests carried out at the Technical University of Denmark (DTU). Then a pilot plant was constructed also at the Technical University of Denmark (DTU) where the plant in 1991 operated for a total of 1,000 hours producing an extremely promising result. This formed the basis for the decision to construct a pyrolysis plant in Haslev.

Test operation at the pyrolysis plant in Haslev commenced in the autumn of 1996, and after approx. 800 hours of operation of which 200 being based on gas produced by pyrolysis, the plant was retrofitted and optimised in several respects.

In the separate superheater, see Figure 23, the gas heats a partial steam flow from approx. 430°C to approx. 480°C, the flue gas then passes to the pyrolysis unit double jacket, thereby transferring energy to the process. The pyrolysis unit is a worm-based pyrolysis unit where the maximum jacket temperature is kept at approx. 600°C. The maximum temperature in the pyrolysis unit can thereby be kept at approx. 550°C. The flue gas is further cooled in an air preheater and then released through the chimney. The charcoal from the pyrolysis process is lead to the straw-based boiler and burns together with the straw. The pyrolysis plant has a capacity of 675 kg straw per hour, equal to an input of approx. 2.7 MW. The pyrolysis gas output is approx. 1 MW. The remaining 1.7 MW is recovered in the charcoal that is utilised in the boiler.

In addition to straw, the pyrolysis unit can be fed dried sludge, and the charcoal can be used as auxiliary firing and thereby replace natural gas and oil. Straw charcoal can also be used in order to regulate variations in the straw quality, thereby keeping a constant boiler load. A partial flow of the charcoal can also be used in the flue gas cleaning system thus reducing the purchase of activated charcoal.

At new plants, the concept may increase the electrical power output by 10-15% at a given heating basis, equal to an improvement of 2-3 percentage point in electrical power efficiency. In Haslev, the interplay between the boiler and the pyrolysis unit is not yet finally optimised, since it is still being a pilot plant with an expected limited life.