Tar-free gasification on a large scale

For several years, scientists at the Technical University of Denmark have been known for being able to create small-scale gasification facilities that can produce pure and tar-free gas. Now, the concept has been developed further, which means that the technology can be used for very large facilities as well.

By Jens Dall Bentzen

At the Department of Mechanical Engineering at the Technical University of Denmark, scientists have worked for a number of years on the development of a gasification technology where biomass is transformed into combustible gas through a process that is divided into several steps.

The process is documented on a smaller scale in the Viking gasifier, which is set up at the Technical University of Denmark. The facility has shown very positive results with regard to producing a combustible gas that is suitable for powering gas engines because of a low content of tar substances and particles. By connecting the engine to an electric generator, you get a small CHP station that is characterised by a high electrical efficiency and a low environmental impact.

In the Viking gasifier, the process is divided into two main steps: pyrolysis and coke gasification. During the first step, the biomass is led into a pyrolysis reactor, where the water evaporates and the biomass is transformed into coke and tarry gas. The next step is a reactor where the tar substances are decomposed and the coke is transformed into gas. Finally, the gas is cooled down using a heat exchanger and the soot particles are collected in a regular bag filter.

Also for large facilities

The Viking gasifier has represented a break-through within gasification technology, but the system has its limitations. It can be difficult to scale up the concept, in part because heat-up of the pyrolysis reactor takes place through exhaust gas from a gas engine.

Therefore, scientists at the Technical University of Denmark have worked together with the consulting company COWI on developing the multi-staged process further in order to make it possible to build very large facilities. The new concept has been given the name LT-BIG, which stands for Low Tar Biomass Integrated Gasification. This is a technology that is easy to scale up, but still includes the technical advantages that make the two-step process better than other gasification principles.

The principle

In the new facility, gasification of the biomass is divided into three chambers instead of just two, which provides a better possibility of controlling the entire process.

Before the biomass is added to the system, it is dried using steam, which means that the facility can be dimensioned to just processing fuel with a specific water content. In the original Viking gasifier, the drying took place in the actual gasification system, which could cause problems, if there where significant variations in the water content of the fuel.

The first step in the new facility is a pyrolysis reactor where the biomass is heated to 450 °C using steam. As there is no oxygen in the reactor, the biomass does not catch fire, but is transformed into tarry gas and coke instead. The latter is led directly to the gasification reactor, where it is transformed into gas by adding air, while the tarry gas is led to the oxygen chamber. Here, enough oxygen is added to decompose the main part of the tar substances, but not enough oxygen to cause the gas to ignite. After this, the gas

This is how the gasifier works

Dry fuel is led into the pyrolysis reactor, where it is heated to approx. 450 °C using steam. As there is no oxygen in the reactor, the biomass does not catch fire, but is transformed into tarry gas and coke instead. The latter is led directly to the gasification reactor, where it is transformed into gas by adding limited amounts of air, while the tarry gas is led to the oxygen chamber. Here, enough oxygen is added to decompose the main part of the tar substances, but not enough oxygen to cause the gas to ignite. After this, the gas as well as the remaining tar residues are led to the gasification reactor, where the tar content is reduced further when the gas is mixed with the coke fraction. Finally, the gas flows up into the floating section, where the last tar residues are decomposed.

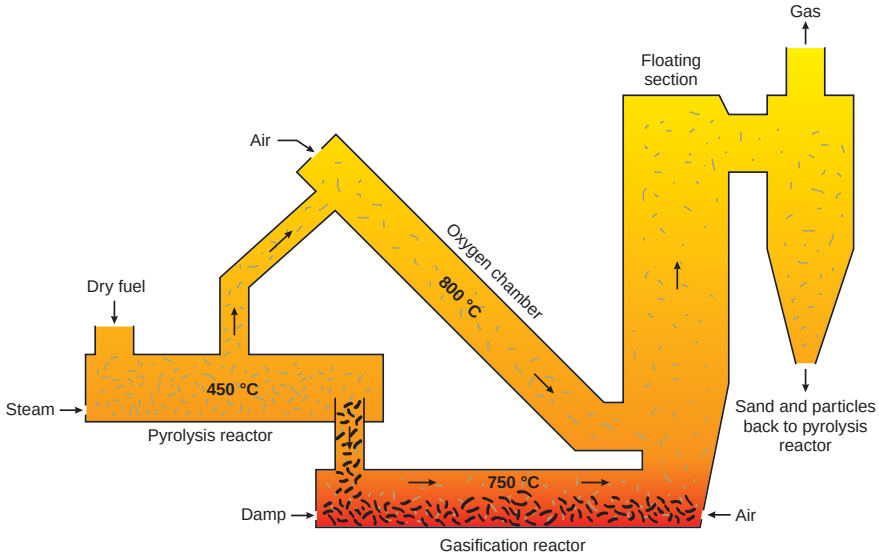

photo: jens dall bentzen/cowi

On the left: The laboratory model of the gasification facility at the Technical University of Denmark. The next phase of the project will be to build a pilot plant at a facility host.

On the right: Testing of the laboratory facility at the Technical University of Denmark. Initially, the gas was burned in a torch. Later, trials will be carried out where the gas is used in an engine that is connected to an electric generator.

photo: jens dall bentzen/cowi

as well as the remaining tar residues are led to the gasification reactor, where the tar content is reduced further when the gas is mixed with the coke fraction.

The gas from the gasification reactor is then purified in a bag filter and possibly an active coal filter, before it is used as fuel in a gas engine that is connected to an electric generator.

The new facility is based on the so-called fluid bed technology, which is familiar from large power plants. The basis of the principle is that a porous material such as sand is brought along around the facility, which makes quick heating of the biomass possible and ensures a correct temperature in the different steps that the facility is divided into.

Laboratory model

The scientists at the Technical University of Denmark have built a 100 kW laboratory model of the new gasification facility and carried out a number of trials that show that the process is stable and that the facility is capable of producing gas with very low tar content.

Simultaneously with the practical trials, a number of model calculations of the efficiency of the various energy systems have been carried out. These calculations show that it is possible to achieve electrical efficiency of up to 40 percent, even with relatively simple facilities. With more advanced facilities, it is possible to achieve an electrical efficiency of about 45 percent.

On the basis of the results from the project, there are now plans to establish a pilot plant at a facility host. Initially, the plan is to use fuel pellets, but it will be possible to carry out trials with different types of fuels.

The project regarding the LT-BIG gasifier has been carried out as a cooperative effort by COWI A/S, the Department of Mechanical Engineering at the Technical University of Denmark and Babcock & Wilcox Vølund. The project has received support from the PSO funds, which are currently being administered by Energinet.dk.

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Gasification - incomplete combustion

When biomass such as wood is heated, it is first transformed into tarry gasses and coke. If you then add oxygen, as is for example the case in a wood-burning stove, the gases as well as the coke are burned. The residual product consists of ash and particles that disappear up through the chimney.

In a gasification facility, you limit the supply of oxygen, which means that the gases are not burned initially, but can be utilised in for example an engine facility. The heating of the biomass usually takes place through burning of a smaller part of the biomass.

At a temperature of about 200 °C, the so-called pyrolysis begins, where the biomass is transformed into tarry gas and a solid residue of carbon (coke). After that, the coke can be transformed into gas by adding limited amounts of air, just as the main part of the tar substances from the pyrolysis can be transformed into gas by adding limited amounts of air.

Gasification facilities have been in use for more than 100 years, so in many ways, it is a well-known technology. During World War II, a lot of cars were equipped with small gasification systems that ran on dried beech blocks the size of tobacco tins. This resulted in relatively pure gas, but it is a type of fuel that is only available in very limited quantities.

The research within gasification facilities aims at constructing facilities that can produce pure gas when using many different types of biomass. Wet wood chips, straw and waste are some of the types of fuel that are available in significant amounts, but they are also fuels that are difficult to gasify.