One Gasification Technology For Different Feedstock

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INTRODUCTION

ECN has a long history in gasification. Back in the 80's and 90's, ECN focused on pressurized entrained flow gasification and fixed bed gasification (downdraft) for coal. In the early 90's biomass and waste became more prominent at ECN and a circulating fluidized bed gasifier as well as a bubbling fluidized bed gasifier were constructed. In 2004, the development program for an indirect gasifier started, called MILENA [1].

All these R&D programs had their own drivers. The MILENA development is based on the learning's from the CFB gasification process. A CFB is fuel flexible, but does not have the 100% fuel conversion, has problems with agglomeration due to char accumulation and the gas produced is of a low calorific value. The MILENA development is the solution for these issues and provides new routes for the producer gas utilization, such as chemicals and fuels production.

This paper will outline the flexibility of MILENA and will focus on one aspect in particular, namely different feedstock application.

TECHNOLOGY

The R&D focus of ECN can be captured by the overall description: "Creating value from biomass". The value of biomass is broad, e.g. electricity or chemicals production. It is attractive because of its sustainability and the reduction of CO_2.

For the Dutch situation natural gas is a very important energy carrier and used in many different applications, from cooking, to house hold heating, electricity production and industry. This has been one of the drivers for developing the route to Green Gas. Green Gas is a substitute for natural gas obtained by gasification of e.g. wood and upgrading the gas to natural gas quality.

MILENA is a technology that combines the positive parts from two fuel conversion methods (pyrolysis and combustion). Combustion is an effective way of converting 100% of fuel into energy. However, the increase in temperature results in an efficiency penalty and a low value energy product (electricity and heat). Pyrolysis is an effective way of producing high value energy products; it is also done at a lower temperature which is good for the efficiency. However, it is limited in conversion. If the two are combined the result is gasification. Where part of the fuel is combusted and the larger part is pyrolysed resulting in valuable energy products. However, if this is done in one vessel (as in a BFB or CFB) the fuel conversion will not reach 100% and the gas is diluted with nitrogen, resulting in a lower calorific value gas. The solution to this is indirect gasification, where heat is produced separately from the combustion process. Figure 1 shows the schematic lay-out of the indirect gasifier MILENA.

Fuel (wood, coal or waste) is fed to a riser reactor, which is fluidized with steam (or air). Through a different hole in this riser reactor the hot bed material from the combustor flows into the riser reactor, which converts the fuel into gas and char. This extra gas creates the lift needed for the fuel and bed material to be entrained to the settling chamber. The settling chamber provides necessary time for the solids to settle and the gas to flow out. The bed material and char fall down into the combustor reactor. In here the char is completely combusted, resulting in a white

ash and 100% fuel conversion.

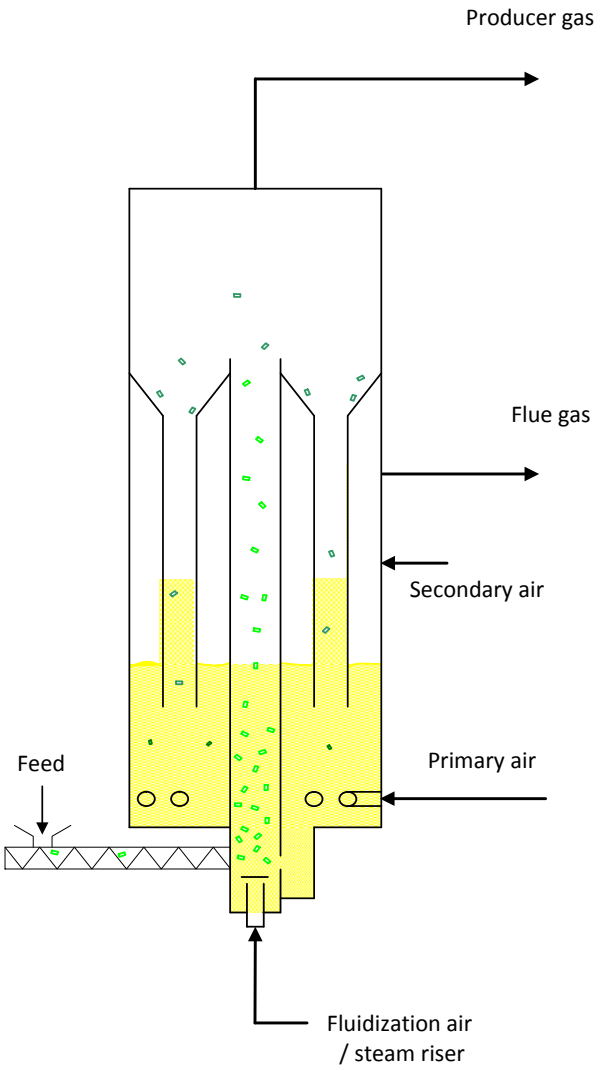

Figure 1: Schematic overview of the MILENA

Over the course of many years the variety of fuels that were tested increased from clean wood to lignite, RDF, grass, straw and eventually even high ash coal. The main conclusion from these experiments is that the MILENA gasification technology is capable of gasifying many different fuels. It also became clear that there is no such thing as one optimal setting for all fuels.

Where ECN is still developing the route to Green Gas based on wood gasification, it is nowadays also looking into alternative routes, such as:

- Co-firing via indirect gasification
- Waste gasification
- High ash coal gasification

These routes open various new possibilities of utilizing high efficient indirect gasification for the production of electricity or chemicals.

FLEXIBILITY

The flexibility of the MILENA gasification technology is based on the decoupling of gasification and combustion. This flexibility of the decoupling can be seen in several fields.

1. Possible to gasify a large range of fuels, where fuel shape, agglomeration tendencies or produced gas are not determining the operation.
2. Gasification temperature can be chosen freely.
3. MILENA can be operated in different modes.
4. The applications after MILENA can be boilers, engines, turbines, SNG or liquid fuels production.
5. Large scale and/or pressurized operation are possible.

The flexibility will be explained via 3 routes. One is a Waste-to-Energy route (flexible in fuel), another is in Application flexibility (indirect co-firing) and the last is in different operating modus (gasifying high ash coal).

The gasification temperature is not directly related to the combustion of fuel, but by the circulation of hot bed material to the riser. If the circulation of bed material is increased the gasification temperature will approach combustion temperature. Via active cooling and/or reducing the amount of hot bed material circulation the gasification temperature can be significantly reduced as well. MILENA has been operated between 630 – 930°C. No further example is described in this paper

The scale of the MILENA is foreseen to 500 MW_{th} plants at atmospheric pressure. However it is also possible to go to several bars overpressure in the MILENA, which only becomes interesting at the very large scale. No

further example is described in this paper.

WASTE TO ENERGY

The MILENA gasification technology is fuel flexible. It has been tested on a variety of fuels, as mentioned before. It recently also was chosen by ETI for a project in England where the MILENA will be used to produce electricity from waste [2]. Royal Dahlman is one of three companies chosen for the design of an integrated system that would be commercial at between 5 MW_e and 20 MW_{el}. For this purpose Royal Dahlman will use the ECN's propriety MILENA technology and OLGA technology. The system they will develop is on a 7 MW_e scale and will have a net electrical efficiency of at least 25%.

In 2013 tests will be done at ECN in the 800 kW_{th} MILENA pilot gasifier. It will be operated on waste to test the gasifier and gas cleaning. This way data will be generated for the design of the 7 MW_e plant. The integrated design can be a stepping stone to even larger and more efficient plants.

INDIRECT CO-FIRING

The concept of indirect co-firing is that by gasifying a low quality fuel the gas can directly be utilized in a coal fired boiler, without increasing the ash load to the boiler. The concept can be compared to the Amer gasifier in the Netherlands, where a circulating fluidized bed gasifier is producing gas that is fired in a coal fired power plant. However, using an indirect gasifier will provide some major advantageous compared to direct gasification.

- More than 95% of the ash components do not end up in the boiler.
- The fuel gas is of a medium calorific value.
- The fuel has a 100% carbon conversion.

Indirect co-firing also has advantages compared to direct co-firing, where typically clean pellets are fed to the pulverized coal boiler. In this case all impurities in the pellets will end-up in the boiler. However, an even bigger down-side to this option is that the clean pellets are very expensive. It has been shown in [3] that most revenue generated with direct co-firing is lost to purchasing this fuel. A simple lay-out of operating an indirect gasifier with a PF boiler is shown in Figure 2. This figure shows how the ash load to the boiler can be decimated via indirect gasification. The fuels used can therefore be of low quality (RDF, MSW, high ash coal)

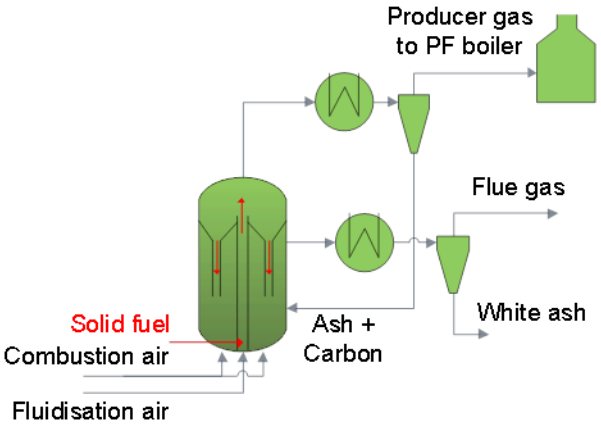

Figure 2: Schematic line-up of indirect gasification for co-firing application

HIGH ASH COAL GASIFICATION

In 2008 test were done with lignite in the MILENA gasifier [3]. Lignite has a substantial amount of volatiles, which makes it possible to gasify in the MILENA. In 2012 work started on gasifying other coals and high ash coal was tested in MILENA. For the first experiments the standard mode of MILENA (see Figure 1) showed that gasification was possible, but that the conversion was a little too low. The high ash coal used contains small amounts of volatiles (compared to waste and biomass) and therefor did not produce a lot of gas. The gas was of medium calorific value and the ash coming from the flue gas was white. Complete combustion was achieved. More residence time was needed to increase the gas yield. The MILENA as such was not capable of doing that.

A second series of testing in MILENA

focused on increasing the residence time and showed that the gas yield increased with increasing residence time.

For gasifying high ash coal, MILENA is not the only solution. There exist many different technologies that gasify coal nowadays and could perhaps be utilized for high ash coal gasification. In a general view these technologies could be categorized as.

- Entrained flow gasifiers
- Fixed bed gasifiers
- Fluidized bed gasifiers

Entrained flow gasifiers are supplied by large companies, such as: Shell, Siemens and General Electric.

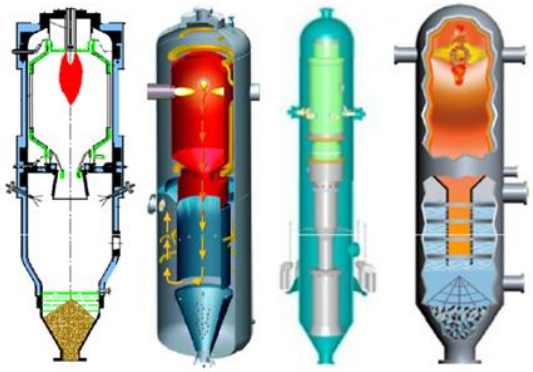

Figure 3: Some EF gasifier examples

An entrained flow gasifier operates at high temperatures (1500°C) needed for (nearly) complete conversion. Due to the temperature the ash in the fuel can melt (sometimes additives are used) and the liquid slag flows down the wall, protecting the refractory. When using high ash coal, the amount of energy needed for melting the ash (and also the extra additives needed) increases, reducing the efficiency. Also milling the fuel to fine particles needed for the gasifier requires much more energy if the ash content is high. Generally an entrained flow gasifier is not the first choice for gasifying high ash coal.

The second technology is the fixed bed gasifiers. Lurgi and Sasol are two commercial suppliers and operate these gasifiers in e.g. South Africa for Fischer Tropsch diesel from coal. Sasol operates 14 Lurgi Mark IV gasifiers in North Dakota (US). The technologies are similar and as an example the Lurgi FBDB^{TM} is looked at. The Fixed Bed Dry Bottom does not operate at extreme temperatures needed for melting the ash. Therefor an increase in ash does not mean the technology will not work. In the following figure presented by Lurgi [4] the operating window is shown. It shows that there is a window of operation for the gasifier based upon moisture and ash content. From this graph it becomes clear that 35 wt. % ash is already being done in these gasifiers. However, going up to >50 wt. % is not considered feasible.

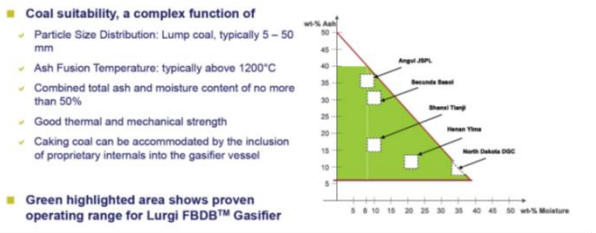

Figure 4: Coals tested in the Lurgi gasifier

A fixed bed gasifier is suitable up to a certain range of fuels containing large amounts of ash. However, the technology itself is limited in scale. For large scale gasification more than one unit is needed.

The third technology option is fluidized bed gasification. Many different variations to this concept exist as well. From bubbling fluidized and circulating fluidized bed gasification to indirect gasification. Comparing these three variations of fluidized bed gasification is not the purpose of this paper; this has been done before [5]. However, the work that has recently been done at ECN shows that the MILENA concept opens the route to gasify high ash coal as well.

The conversion of lignite or high ash coal into a combustible gas can be used to produce electricity (Coal to Energy) or it can be further upgraded to fuels, such as methanol, methane or FT diesel (Coal to Chemicals).

Compared to other gasification technologies MILENA has one or more of these advantages

over the other options.

1. 100% conversion of fuel
2. Medium calorific gas production
3. Broad fuel applicability
4. Operating flexibility
5. Scalable to large plants

CONCLUSIONS

The development of MILENA is expanding. Although developed for one main goal, to produce Green Gas, it has also shown to have unique features making it very suitable for difficult fuels. A unique feature that makes this possible is the freedom of operating with any desired gasification temperature without loss of conversion. This has opened a whole new range of possible applications.

- Biomass to SNG
- Waste to Electricity/Chemicals
- Coal to Electricity/Chemicals

There are many different types of gasifiers, all within their field capable of perform to standard. However, MILENA is capable of performing well in many different areas where other gasifiers have to stick to their specific area.

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