EFFICIENT UTILISATION OF INDUSTRIAL RESIDUES AND WASTE WITH HIGH BIOMASS CONTENT USING BIOMASS GASIFICATION

Wilk, V. 1, Hofbauer, H. 2

1Bioenergy2020+ GmbH, Wienerstraße 49, 7540 Güssing, Austria
Phone: +43 1 58801 17313, veronika.wilk@bioenergy2020.com
2Institute of Chemical Engineering, Vienna University of Technology, Getreidemarkt 9/166, 1060 Vienna, Austria

ABSTRACT: More and more waste is generated every year, which has to be treated or disposed. Thermal treatment of residues and waste is an important issue with increasing demand. At the moment incineration is the state-of-the-art thermal treatment technology. In addition to that gasification processes are being developed and show encouraging potentials. In this work two pathways of thermal waste treatment, incineration and gasification, are compared. For this purpose literature on both technologies has been reviewed and the state-of-art technology for waste incineration and gasification is presented. The comparison highlights the strengths and weaknesses of both technologies and identifies future potentials.

Keywords: study, waste, fluidised bed

1 INDUSTRIAL WASTE

In industrial processes raw materials are transformed into products. As the conversion is not complete, there are always undesired products (residues), which can be recycled or have to be disposed. [1] The generation of waste in industrial processes is illustrated in Figure 1.

Figure 1: Generation of industrial residues

In wood and wood processing industry residues are generated in the form of splints, wood shavings, sanding dust and bark. As a rule, material-sensitive recycling of wood residues creates more added value than energetic recovery. Splints, wood shavings and sanding dust are used for the production of chipboards. Wood shavings are also employed as raw material for the pulp and paper production. Bark is converted into mulch, but also may be incinerated. Since there is a demand for process heat for drying processes in the wood processing industry, wood residues are also used as energy carriers. [2]

In pulp and paper production process residues are recovered thermally. Usually black liquor, the residue of cellulose production, is combusted in special furnaces to supply heat for the drying process on the paper machine. Other residues, such as fibre sludge, are also incinerated. [2]

Waste generated in plastic processing plants is mostly homogeneous and unpolluted. That is why it can be returned to the production process or reconditioned. Thermoplastics can be recycled in a material-sensitive way to produce new formed parts or regrind. That is not possible for other types of polymers, such as thermosetting plastic or elastomers, because the polymer structure is destroyed by heat. However, their monomers can be recovered by hydrogenation, pyrolysis or gasification. These processes are also suitable for mixed and contaminated plastic wastes. Reclamation of thermoplastics cannot be repeated infinitely without change in composition, because the recycling process slightly alters the molecular structure. At the end of the recovery cascade there is usually energetic recovery. [3]

2 STATE-OF-THE-ART OF THERMAL TREATMENT OF RESIDUES AND WASTE

The objectives of thermal waste treatment are destruction of organic compounds, concentration and lock out of inorganic compounds and destruction and immobilisation of harmful pollutants. In addition to that, reduction of deposition volume and recovery of the thermal or chemical energy of the waste are achieved. [4]

2.1 Incineration

The state-of-the-art thermal waste treatment technology is incineration. It is the most highly developed method. Figure 2 shows a process flow sheet of a waste incineration plant. Typical reactors are grate incinerators or fluidised bed incinerators. Rotary kiln are neglected here, as they are usually used for incineration of hazardous wastes. This work focuses more general on industrial residues.

The energy content of the waste is released in the form of hot flue gas, which passes the heat to the water-steam cycle in the boiler. Electricity and district heat are produced.

The process flow sheet also contains typical gas cleaning steps, which can be considered as state-of-the-art technology. Particles are separated in ESP or fabric filters. In the acid scrubber gaseous pollutants, such as halogens and heavy metals, are absorbed in water. SO2 is precipitated in the alkaline scrubber by the reaction with lime, where gypsum is formed. Activated carbon filters (AC) are multifunctional separators for heavy metals, dioxins, furans and all pollutants that have passed the scrubbers. Fine dust is also precipitated there. The last cleaning device is NOx removal. NOx is reduced on a catalyst and nitrogen is formed. The clean gas is exhausted via the stack.
2.2 Gasification of residues

Several pyrolysis and gasification processes for thermal waste treatment have been developed in the past. Some processes have been designed for municipal solid waste as feedstock. They were multi-stage processes with gasification at very high temperatures, for example the Thermoselect process. Those processes failed because of technical problems and for economic reasons.

However, selected residues have been successfully integrated in biomass gasification processes. The gasifiers in Lathi (Finland) and in the cement factory Rüdersdorf (Germany) use several kinds of residues in addition to biomass.

2.3 Gasification of biomass

The development of biomass gasification has been more successful than waste gasification and it has been studied in detail during the last decades. In Guessing (Austria) a dual fluidised bed steam gasifier is operated successfully on the scale of a demonstration plant.

In Figure 3 the principle of this process is illustrated. Feedstock is gasified with steam in a stationary fluidised bed, which is connected to a fast fluidised bed combustion zone. There the unreacted char is oxidised with air. Heat is released and is transported to the gasification zone by the bed material. Because of the spatial division of gasification and combustion producer gas and flue gas streams are also separated. The producer gas has a high calorific value and it contains virtually no nitrogen due to steam gasification.

3 DUAL FLUIDISED BED GASIFIER FOR RESIDUES AND WASTE

In Guessing woodchips are used as feedstock. It is intended to enlarge the range of feedstock to increase the flexibility of the process. In the following a gasification process for residues and waste is presented, which is based on the Guessing gasifier. Figure 4 presents the flow sheet of this process.

4 COMPARISON

Two ways of thermal treatment, incineration and gasification, are compared in order to determine the advantages and disadvantages of each method.

4.1 Fuel pre-treatment

Fuel pre-treatment mainly depends on the thermal conversion system. For incineration processes grate or fluidised bed incinerators are used. Incineration using a grate incinerator is more tolerant in respect to particle size requirements than a fluidised bed. The most flexible system in this respect is a rotary kiln. For gasification processes fluidised bed reactors are ideally suited. They are basically the same reactors as used for incineration. Thus, no real difference is expected as far as fuel pre-treatment is concerned. The main restrictions for
fluidised beds relate to fuel particle size (< 100 mm) and ash melting.

4.2 Thermal conversion
There is a wide difference between incineration and gasification concerning thermal conversion. In case of incineration complete oxidation and total release of energy take place in the combustion chamber. There the whole amount of flue gas is generated. It is cooled in the boiler and it is cleaned afterwards.

In case of gasification only partial oxidation and reforming occur in the gasifier and producer gas is obtained. The producer gas – the amount is much smaller than the amount of flue gas in case of incineration – is cooled and cleaned. Finally, the clean producer gas is burned in a gas steam boiler, where most of the heat is released (about 70% of the total energy content). Thus, the volume of producer gas that has to be cleaned is about 5 times smaller than the volume of flue gas.

The complexity of the gas cleaning system in case of incineration and gasification is comparable. On the one hand, an additional solvent scrubber is necessary to remove tars in gasification systems. On the other hand, NOx removal is avoided as NH3 already has been washed out of the producer gas.

The advantage of smaller gas volumes seems to lose validity when producer gas is combusted with air, which is part of each process. But there is also a difference in excess air ratio. The excess air ratio in grate incinerators is 1.5–2.0, because air stabilises the combustion and the excess is required to ensure complete combustion. Gaseous fuels can be mixed thoroughly with air and thus less air is necessary. Typical values for the excess air ratio for combustion of gaseous fuels in power plants are in the range of 1.05 to 1.1. [10] This leads to lower amounts of flue gas and therefore lower losses and higher efficiencies.

In this study it is assumed that producer gas cleaning in gasifiers is performed with similar systems as it is done currently for flue gas in incinerators. They have to be adapted to the pollutants present in the gasification process. Most of the pollutants are not present in the oxidised form as it is the case in the flue gas of waste incinerators. Tests on producer gas cleaning with acid and alkaline scrubbers show encouraging results. Nevertheless, the performance is not proven yet and has to be investigated in further scientific and demonstration work.

4.4 Electrical efficiency
The net electrical efficiency of a waste incineration plant amounts to approximately 20% because of the rather moderate steam parameters of 60 bar and 420°C. The steam temperature is limited by chlorine-induced corrosion. [11]

Gasification offers a possibility to avoid chlorine-induced corrosion in the boiler. If chlorine is removed from the producer gas, for example by means of lime injection and filters, the gas can be combusted in boilers operating at higher steam temperatures. The electrical efficiency reaches 28% if the steam parameters are raised to 250 bar and 500°C, which corresponds to an increase of 40–50% in comparison to conventional waste incineration.

Furthermore, producer gas cannot only be used in a steam boiler but also in IGCC processes. In a combined cycle producer gas is combusted in a gas turbine and the sensible heat of the exhaust gas is further used in a heat recovery steam generator. Thus, higher electrical efficiencies than in any incineration process can be reached. In Figure 5 there is an overview on the electrical efficiency of the different processes.

4.5 Product range and overall efficiency
In waste incineration plants only power and/or heat are generated. About 80% of overall efficiency is attainable in cogeneration waste incineration plants. A precondition for heat use is heat demand. Thus, the plant has to be located close to a district heating system or an industrial site.

Due to gas production in gasification plants the product range can be extended considerably. By means of chemical synthesis producer gas can be converted to products such as methanol, ammonia, liquid fuels (Fischer-Tropsch synthesis), synthetic natural gas (SNG),... For synthesis steam gasification is mandatory since no nitrogen should be present in the producer gas. The technical and economic feasibility of polygeneration strongly depends on the gas cleaning system, because there are severe requirements for producer gas purity. In a polygeneration plant the overall efficiency increases markedly, as not only the energy content of the waste is recovered, but there is also chemical recycling. In addition to that, the possibility to use chemicals, liquid fuels and gas produced in polygeneration plants does not depend on the location of the plant. They can be transported more easily.

4.6 Residues and ashes
Regardless of the process, whether it is waste gasification or incineration, waste should be treated, so that only a small amount of residues that are not harmful anymore remains. In the dual fluidised bed gasifier only
one waste stream is generated: ash in the combustion section. The residue of the gasification reactor, char, is transported to the combustion section by the bed material. After combustion only inorganic compounds, ash, remain. It is reasonable to assume that the composition and properties of this ash are similar to ash of waste incineration plants. Waste incineration can be dumped at a landfill site. There are stringent national and European laws for waste incineration plants. It has to be proven that waste gasification processes are able to meet those requirements too.

5 CHALLENGES

The comparison shows that gasification is a reasonable pathway of thermal treatment for selected residues and waste. However, it has to be determined, whether all pollutants are really present in the producer gas and not in the flue gas stream.

The performance of the scrubbers that are usually used in waste incineration plants is another uncertainty. It has to be investigated that they are suitable for producer gas cleaning.

Another crucial question is the choice of material for the gasifier and the producer gas cleaning devices. In the producer gas there are compounds that promote corrosion.

6 GASIFICATION TESTS

It is intended to conduct gasification tests at the 100 kW pilot plant at Vienna University of Technology. This pilot plant was the prototype of the Guessing gasifier, it is also a dual fluidised bed system.

In the past several feedstock already have been tested, among others lignite, sewage sludge and clover. Basically, all kinds of feedstock containing solid carbon could be gasified. However, the ash melting behaviour is an important restriction for the operation of a fluidised bed. If the ash melting point of a feedstock is too low, there is liquid ash at operation temperatures of the gasifier, which renders fluidisation impossible.

Feedstock of interest for the gasification tests are waste wood, packaging material, plastics, rubber waste and biologically pre-processed waste. Detailed feedstock characterisation prior to gasification is necessary to determine pollutants that are present in the material. During gasification producer gas composition and properties are measured. An interesting aspect is also the distribution of pollutants in the producer gas and the flue gas stream. This data will be the basis for the design of the gas cleaning equipment.

7 CONCLUSION

The comparison shows that gasification has several interesting advantages over incineration. There is less gas volume to be cleaned. Chlorine-induced corrosion in the boiler can be avoided due to gas cleaning. That leads to a remarkable increase in electrical efficiency. Due to enlargement of the range of feedstock the flexibility of the whole process is increased.

Waste gasification processes already have been developed in the past, but the plants were shut down because of economic reasons and/or technical problems. However, important research has been done in the field of biomass gasification in the last years and thus gasification technology has been improved markedly.

Considering these developments, there is definitely interesting potential for gasification now. The design of a new gasification process suitable for residues and waste, which is based on the findings in biomass gasification, will be the scope of future research work.

8 REFERENCES


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